Pakistan J. Zool., vol. 49(5), pp 1749-1759, 2017. **DOI**: http://dx.doi.org/10.17582/journal.pjz/2017.49.5.1749.1759

Biodiversity and Species Distribution of Coccinellids (Coccinellidae: Coleoptera) in District Sargodha (Punjab), Pakistan

Kanwer Shahzad Ahmed[1], Muhammad Zeeshan Majeed[1,*], Muhammad Ather Rafi[2], Fatima Sellami[3] and Muhammad Afzal[1]

[1]*Department of Entomology, University College of Agriculture, University of Sargodha, Pakistan*
[2]*National Insect Museum, National Agricultural Research Center, Islamabad, Pakistan*
[3]*Cadi Ayyad University, Marrakech, Morocco*

Article Information
Received 08 December 2016
Revised 01 March 2017
Accepted 22 March 2017
Available online 07 September 2017

Authors' Contribution
KSA, MZM and MA conceived and designed the experimental protocols. KSA performed experiments. MA and MAR provided technical assistance in experimentation. KSA and MZM performed statistical analyses and prepared the manuscript. FS revised the manuscript and assisted technically.

Key words
Coccinellid beetles, Coccinellidae, Diversity indices, Male genitalia.

ABSTRACT

Coccinellid beetles (Coccinellidae; Coleoptera) are voracious predators of many insect pests of economic importance. Among 6,000 species of coccinellids described worldwide, only 75 species have been reported from Pakistan so far. Keeping in view the limited work on these important beetles, an extensive faunal survey was conducted in the district Sargodha (32°05'02" N and 72°40'18" E), Pakistan to assess the species richness and distribution of coccinellid beetles in seven selected regions (Bhera, Bhalwal, Kot Momin, Sahiwal, Sargodha, Shahpur and Silanwali). A total of 1,470 coccinellid specimens were collected from all types of vegetation and were identified up to species level by means of external morphology, published descriptions and male genitalia micrometry. Nine species were identified belonging to 9 genera and 4 subfamilies occurring along with 10 trophic associations. Five species viz; *Coccinella septempunctata* (Linnaeus 1758), *Hippodamia variegata* (Goeze 1777), *Menochilus sexmaculatus* (Fabricius 1781), *Micraspis allardi* (Mulsant 1853) and *Propylea dissecta* (Mulsant 1850) belonged to tribe Coccinellini (Latreille 1807) of subfamily Coccinellinae (Latreille 1807). Two species belonged to tribe Chilocorini (Costa 1849) of subfamily Chilocorinae (Mulsant 1846) *i.e. Brumoides suturalis* (Fabricius 1798) and *Exochomus nigripennis* (Erichson 1843). Two species namely *Henosepilachna vigintioctopunctata* (Fabricius 1775) and *Scymnus nubilus* (Mulsant 1850) represented respectively the tribe Epilachnini (Mulsant 1846) of subfamily Epilachninae (Mulsant 1846) and tribe Scymnini (Mulsant 1846) of subfamily Scymninae (Mulsant 1846). Among all the species, *C. septempunctata* was found widely distributed in all localities studied, whereas, Sargodha locality represented highest diversity indices of Shannon-Weiner's (1.65), Margalef's (1.40) and Simpson's (0.75).

INTRODUCTION

Coccinellidae is a well-known, abundant and diversified coleopterans family with about 6000 described species of beetles worldwide (Vandenberg, 2002; Akhavan *et al*., 2013). Its sub-families are Coccinellinae, Chilocorine, Scymninae, Coccidulinae, Ortalinae, Sticholotidinae and Epilachninae (Bouchard *et al*., 2011), which are distributed worldwide and are predacious in nature except Epilachninae which is phytophagous (Vandenberg, 2002).

Predaceous coccinellids play a significant role in agro- and forest ecosystems as the larvae and adults of most of these beetles are predacious on many phytophagous insect pests. These predatory beetles are voracious feeders of soft bodied insects such as whiteflies, aphids, psyllids, jassids, scale insects, mealybugs, mites and feed on eggs and minute larvae of other insects as well (Veeravel and Baskaran, 1997; Hodek and Honek, 2009). Due to their predatory nature, these beetles are considered as beneficial insects and are being employed as efficient biological control agents against different insect pests (Obrycki and Kring, 1998; Hodek and Honek, 2009; Ali and Agrawal, 2014).

Classical examples of successful use of predatory coccinellids include introduction of vedalia beetle, *Rodolia cardinalis*, from Australia to California against cottony-cushion scale, *Icerya purchase*, in 1888 (Harmon *et al*., 2006). Because of their great economic importance, indigenous coccinellid fauna have been widely studied in different parts of world (Soares *et al*., 2003; Thalji *et al*., 2010; Akhavan *et al*., 2013; Biranvand *et al*., 2014; Hesler *et al*., 2014). However, there is lack of information on this

* Corresponding author: zeeshan.majeed@uos.edu.pk
0030-9923/2017/0005-1749 $ 9.00/0

important family in Pakistan, particularly in Sargodha region which is the best citrus groove of the country.

This study was aimed at exploring the coccinellid fauna of this district and to find out species richness and their specific distribution.

MATERIALS AND METHODS

Study area

Study was carried out in the district Sargodha, stretched over an area of 5,864 km² with geographical coordinates as 32°05'02'' N and 72°40'18'' E. Main agricultural crops grown in the area include citrus, wheat, sugarcane and maize, while the dominant wild vegetation includes parthenium (*Parthenium hysterophorus*) and khabal grass *Cynodon dactylon*).

Collection protocol

Collection of coccinellid beetles was carried out by frequent visits of the targeted area in the morning (9:00-12:00 AM) and evening (3:00-6:00 PM) hours. To assess the species distribution of coccinellid fauna, the area was divided into seven regions, namely Bhalwal, Bhera, Kot Momin, Sahiwal, Sargodha Shahpur and Silanwali tehsils. Locations and geographical coordinates of these collection areas are given in Table I. Each locality was sampled biweekly for the coccinellids using aerial sweep nets and by manual picking. Collected specimens were brought to laboratory and were mounted on tip of triangular card clips with field collection and identification tags.

Table I.- Geographic coordinates of the collection sites.

Localities	Latitude (N)	Longitude (E)	Altitude (ft)
Bhera	32°28'59"N	72°54'34"E	610
Bhalwal	32°15'57"N	72°54'03"E	603
Kot Momin	32°11'18"N	73°01'43"E	626
Sahiwal	31°58'23"N	72°19'32"E	544
Sargodha	32°05' 00" N	72°40' 15"E	633
Shahpur	32°16' 03"N	72°28' 24"E	554
Silanwali	31°49'45"N	72°32'21"E	567

Identification of specimens

Collected specimens were identified with the help of available literature and already identified specimens, preserved in the National Insect Museum of National Agriculture Research Center (NARC), Islamabad, Pakistan. It was done on the basis of morphological characteristics and genital characters. All identified specimens are deposited in the Laboratory of the Department of Entomology, University College of Agriculture, University of Sargodha, Sargodha, Pakistan.

Description of specimens

Morphological and taxonomic descriptions of the coccinellid specimens were made on the basis of published literature, visual observation of specimens including micrometry, and by morphology of male genital and other obvious differential traits of the specimens.

For genitalia extraction, the methodology described by Majerus and Kearns (1989) was used. Male genitalia were mounted on an adhesive plastic strip with hydro-soluble glue and were characterized following basic male coccinellid genitalia morphology as proposed by Kovar (1996).

Olympus SZX16 stereomicroscope, mounted with a digital DP2-BSW (CCTV) camera was employed for the microscopic examination, visualization and photography of collected specimens.

Statistical analysis

The data collected was analyzed statistically to calculate the diversity, species richness and evenness. Diversity indices were calculated by using the software Paleontological statistics software package (PAST) (Hammer *et al*., 2001).

RESULTS AND DISCUSSION

A total of 1470 specimens of coccinellid beetles were collected during the collection expeditions of seven selected localities of Sargodha district from September 2013 to April 2014. Nine species of coccinellid beetles belonging to nine different genera under four subfamilies were identified and described in this study. Subfamily Chilocorinae represented two species, Coccinellinae five species and subfamilies Scymninae and Epilachninae represented one species each. Keys to subfamilies and genera are also worked out. Species identified in different tribes and subfamilies of Coccinellidae are as follows:

Genus *Brumoides* Chapin, 1965
Brumoides suturalis Fabricius, 1789

Diagnosis

Adult body length 2.8-3.8 mm, width 2.2-2.4 mm. Body oval shape. Elytra yellowish white with 3 brownish black longitudinal bands, one on each elytron and one on mid dorsal line of elytra (Fig. 1-1a). Pronotum finely pitted, projected on each anterolateral side. Head brown, not concealed. Eyes larger and dark brown. Antennae 8-segmented. Maxillary and labial palpi 4- and 3-segmented, respectively.

Genitalia

Phallobase and parameres symmetrical. Trab; long, wide distally. Penis shape asymmetrical (Fig. 1-1a).

Parameres articulated with phallobase. Sub-apical portion with long hairs. Penis firm, consisting of single sclerite; basal capsule discrete and T-shaped.

Host and distribution

Not a common species in Pakistan and was collected from few of the localities studied but usually it can be found in both natural and agro-ecosystems. It is an active predator of mealybugs and pyrillas (Chakraborty *et al*., 2013), psyllids (Ullah *et al*., 2012), and aphids (Ullah *et al*., 2012) usually found on a wide variety of plants such as *Calotropis gigantean*and *Citrus reticulate* (Singh and Sharma, 2010). Locally, it was collected from Sargodha, Bhera, Sahiwal, Bhulwal, Silanwali, Jhawarain, Bhera and Kot Momin. Globally, it is reported from different Asian countries including Bangladesh (Kumar *et al*., 2000), China (Ren *et al*., 2009), India (Pushpendra and Prakash, 2010) and Taiwan (Guoyue and Wang, 2001).

Genus *Exochomus* Redtenbacher, 1843
Exochomus nigripennis Erichson, 1843

Diagnosis

Body 3.5-4.5 mm and width 2.6-3.5 mm. Body shape oval, somewhat convex; dorsal surface shinning and glabrous. Head black, mouthparts, antennae and legs yellow (Fig. 1-2a). Pronotum yellow, elytron fully black and shinning (Raimundo and van Harten, 2000).

Genitalia

Phallobase and parameres symmetrical. Trab; long, wide distally. Basal piece long. Parameres at base along tips rounded or curved and provided with long hairs on dorsal side and apex (Fig. 1-2b). Penis/siphon shape asymmetrical, long and rod shape. Penis firm, consisting of single sclerite; basal capsule discrete.

Host and distribution

This is not commonly occurring species. It is an active predator of psyllids (Rakhshani and Saeedifar, 2013) and of common pistachio psylla (*Agonoscena pistaciae*) which feeds on pistachio trees, *Pistacia vera* (Mehrnejad, 2010). Locally, it is not widely distributed coccinellid species but is reported from Afghanistan (The Entomological Collection: Lund University, 2012), China (Ren *et al*., 2009), India (Pushpendra and Prakash, 2010), Iran (Zare *et al*., 2013), Indonesia (Muniappan, 2012), Russia (Ren *et al*., 2009) and Spain (The Entomological Collection: Lund University, 2012).

Subfamily Coccinellinae Leach, 1815

Diagnosis

Body size varies from medium to large, dorsally glabrous. Antennae 11-segmented with well-developed club portion, antennal insertion between mandibular bases and eyes. Apical segment of maxillary palpi securiform and implicitly truncate. Pronotum not joining elytral bases completely. Epipleura wide, reaching anterior margins. Elytral punctation simple.

Genus *Hippodamia* Dejean, 1837
Hippodamia variegata Goeze, 1777

Diagnosis

Body length 5.1-6.3 mm and width 3.3 mm. Body shape oval and creamy red colored. Head brown with prominent black eyes. Black and white pattern behind head and black spots on red forewings. Polymorphs with number of elytral spots varying from few to 13 spots, commonly six along with one spot on the mid-dorsal line of junction of elytra near the scutellum (Fig. 1-3a). Elytra yellow to orange with brownish spots, without hairs and smoothly pitted. Pronotum yellow white with brownish black large areas along the posterior margin of pronotum and has four fingered-like thick anterior projections. Antennae about 1.3 mm long and 11-segmented. Labial palpi 3-segmented (Kuznetsov, 1997).

Genitalia

Phallobase: Trab small, highly dense, expanded distally with deeply concaved apex. Basal piece long. Parameres somewhat shorter than median lobe, moderately thick, slightly compressed at base along rounded tips and provided with short hairs on dorsal side and apex (Fig. 1-3b).

Host and distribution

This species feeds on aphids (Ullah *et al*., 2012), psyllids (Ullah *et al*., 2012) and scale insects (Ives *et al*., 1993) attacking wheat *Triticum aestivum* (Mohamed *et al*., 2000), *Brassica compestris* (Grevstad and Klepetka, 1992), *Medicago sativa* (Rebolledo *et al*., 2009) and *Zea mays* (Latigo *et al*., 1993). Locally, this species is found in fodders, agricultural crops, wild vegetation and was collected in this study from Sargodha, Bhera, Silanwali, Sahiwal, Jhawarain, Aziz bhatti town and Kot Momin, while this species is found in all Asian (Pushpendra and Prakash, 2010; Zare *et al*., 2013) and European countries (The Entomological Collection: Lund University, 2012) .

Genus *Coccinella* Linnaeus, 1758
Coccinella septempunctata Linnaeus, 1758

Diagnosis

This species has different polymorphic forms (Fig. 1-4a, b). Body usually round, oval, convex, almost

hemispherical and densely punctate. Body with seven black spots of variable sizes, three on each elytra and one right behind the middle of thorax (Fig. 1-4a). Elytra patchy black without hairs and finely pitted. Head transverse and black with pair of yellow spots on frons near compound eyes. Pronotum black, twice as broad as long and densely pitted. Scutellum brownish black, black and almost equilateral. Antennae 11-segmented.

Genitalia

Phallobase: Trab short and dense. Basal piece lengthy. Median lobe broad at base and brusquely diminishing towards apex. Siphon: siphonal capsule bloated and dense. Parameres comparatively shorter than median lobe, covered with dense long hairs on dorsal side except base. Siphonal tube elongated and the distal end carries dense sac like structure (Fig. 1-4c).

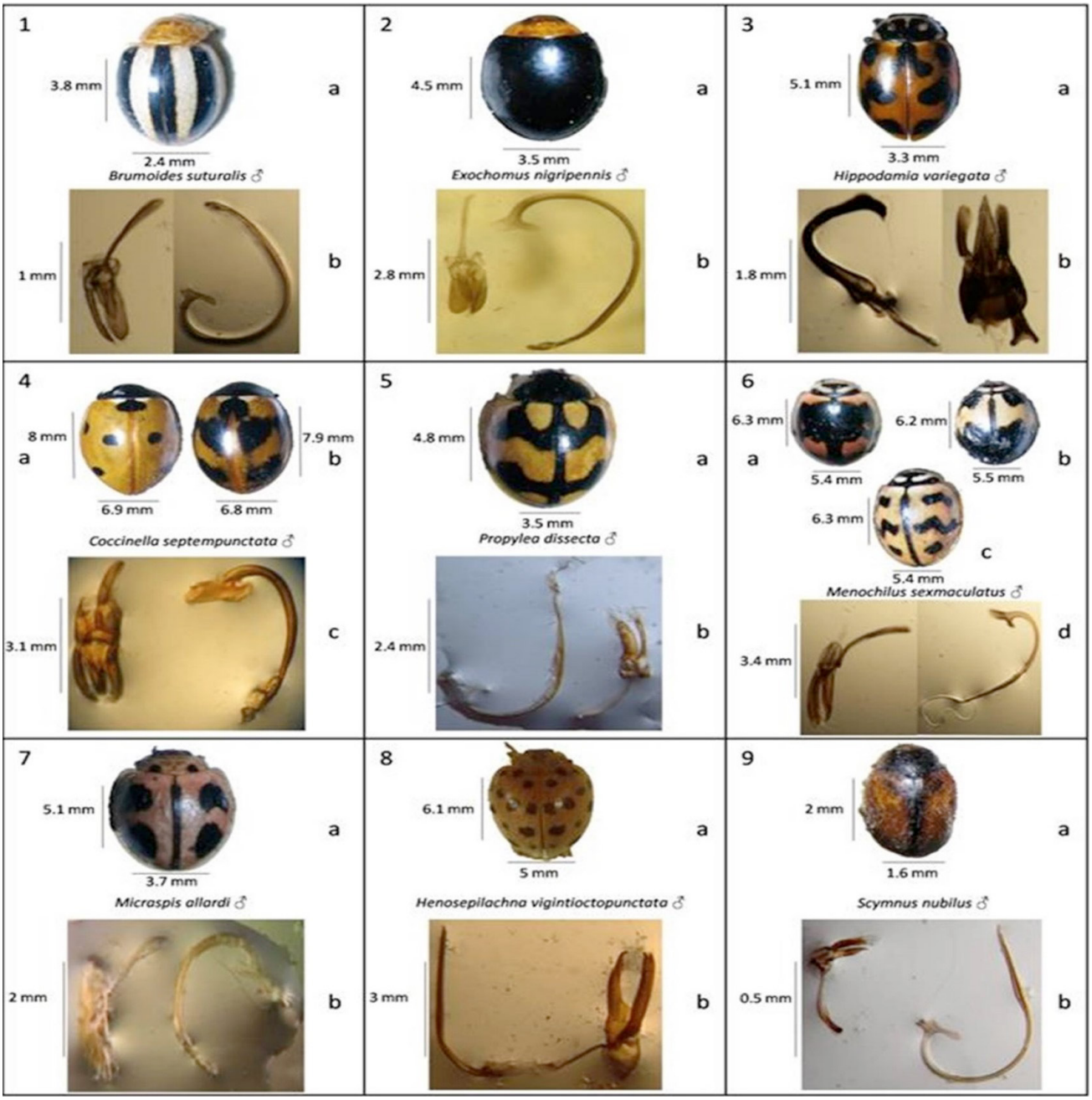

Fig. 1. Coccinellid species collected and identified from different localities of the district Sargodha.

Host and distribution

Different polymorphic forms are present of *C. septempunctata* and can be found in all type of habitats and agro-ecosystems. This species feeds voraciously on aphids (Srivastava, 2003; Zare *et al*., 2013), mealybugs and psyllids (Ullah *et al*., 2012), and scale insects (Zare *et al*., 2013) and is found widely distributed on different crops including wheat, brassica, cabbage, cotton and on fruit trees and wild vegetation. Locally, in this study, it was collected from all locations and globally it is reported from all Asian, European and American countries (Sarwar and Saqib, 2010; The Entomological Collection: Lund University, 2012).

Genus *Propylea* Mulsant, 1846
***Propylea dissecta* Mulsant, 1850**

Diagnosis

Body oval, black on ventral side, somewhat convex. Head brown, pronotum and scutellum black. Antennae short. Eyes very small, finely facetted. Body brownish with network of four black bands, two on each elytron, one on anterior side and one on posterior side. Mid dorsal line of junction of elytra is black in color (Fig. 1-5a).

Genitalia

Phallobase: Trab long and thin. Basal piece oblong. Parameres elongated and longer than median lobe, moderately dense, somewhat expanded at apex and have dense hairs on apical portion. Median lobe equally thick for all of its length except apex with rounded tip (Fig. 1-5b).

Host and distribution

It can found predating on aphids on brassica plants (Omkar and Pervez, 2004; Pervez, 2004). It occurs less commonly in agro-ecosystems. This is the reason that this species was not found in all sampled sites. However, globally it is reported from China (Ren *et al*., 2009), India (Joshi *et al*., 2011), Nepal (Poorani, 2002) and Pakistan (Rafi *et al*., 2005).

Genus *Menochilus* Timberlake, 1943
***Menochilus sexmaculatus* Fabricius, 1781**

Diagnosis

Body broadly oval or almost rounded, glossy and moderately convex. Large color variation mostly light red, orange, pinkish or yellow (Fig. 1-6a, b, c). Head yellowish brown mostly concealed in pronotum. T-shaped median band on anterior of pronotum, linked to a broad black band on posterior margin. Scutellum brownish black. Sixblack markings on elytra including two zig-zag black lines and a posteriorly black spots. Sutural line with a broad black band longitudinally. On each elytron, first patch like inverted V-shaped, second complete W-shaped and the third one somewhat round. A thin longitudinal brownish black stripe lies along the line of junction of elytra (Fig. 1-6a, b, c).

Genitalia

Phallobase: Trab; long and distally wide. Basal piece oblong. Parameres long, dense, cylindrical and slightly bent at base. Sub-apical portion wide with hairs. Median lobe short than parameres, usually dense, outer side straight and inner side convex, somewhat constricted apically. Tip pointed, siphonal capsule asymmetrical, outer arm larger and inner arm smaller. Siphonal tube deeply curved at base then become straight up to 3/4th of its length. Sub-apical portion having long thread like structure (Fig. 1-6d).

Host and distribution

This is an oriental species geographically found more commonly in plain areas, but occasionally in foot hills. There is a great variation among size and color pattern of this species and thus mostly misidentified. The numerous color morphs of this species misidentified among *Chilocorus nigrita* and *M. discolor*. It predates on aphids, psyllids and mites (Ghosh *et al*., 2007; Ullah *et al*., 2012; Saleem *et al*., 2014) associated with brassica and maize crops. Locally, it has been found in great numbers in all selected sites sampled in this study and globally, this species has been found distributed in Afghanistan, Indonesia, USSR and Bangladesh (Muniappan, 2012) and China (Ren *et al*., 2009).

Genus *Micraspis* Dejean, 1836
***Micraspis allardi* Mulsant,1853**

Diagnosis

Adult body length 4.6-5.1 mm and width 3.3-3.7 mm. Body round and deeply convex. Head deeply concealed not visible from dorsal side. Elytra orange-yellow with two black spots on the metathorax on either side near elytral base (Fig. 1-7a).

Genitalia

Parameres and phallobase and penis-guide all symmetrical. Basal capsule is distinct and T-shaped. Apodeme of male sternum narrow and rod-shaped (Fig. 1-7b).

Host and distribution

This is not most commonly occurring species. It

predates on wheat aphids (Abbas *et al*., 2013) and found in different crops including maize, wheat and potato. Locally, it was collected from all sampled sites of district Sargodha and globally, this species has been reported from different Asian countries (Rafi *et al*., 2005; Singh and Sharma, 2010; Weil *et al*., 2011).

Subfamily Epilachninae Mulsant, 1846

Diagnosis

Body medium to large, dorsally convex, pubescent, punctuated with mostly uneven pattern. Antennae 11-segmented. Mandibles wide, smooth at base but finely dented at tip. Maxillary palpi thickly pubescent. Pronotum toughly transverse, oval with deeply excavated anterior margin. Epipleura most developed, horizontal and without grooves for reception of tips of femora. Tarsal claw bifid. Abdomen having six visible sternites. Abdominal or coxal lines present.

Genus *Henosepilachna* Li, 1961

Six visible abdominal sternites of female longitudinally split; in male genitalia, yellowish setae on upper side of median lobe.

Genus *Henosepilachna* Li, 1961
Henosepilachna vigintioctopunctata Fabricius, 1775

Diagnosis

Body size medium to large, elytra reddish brown or pale brown and pubescent. Elytral apex-angled. Elytral spots variable in size from 12-28 but mostly 26 in number (Fig. 1-8a).

Genitalia

Phallobase: Trab short and curved. Basal piece small and long. Parameres with an apical thorn and covered with hairs. Median lobe with basal knife edge beginning at the foot of parameres and a lump beyond the middle, after which it curves up into an apical hook lie structure. Second half with two rows of hairs, hairs shorter than parameres. Siphon slightly curved at base then become straight and ended in a point (Fig. 1-8b).

Host and distribution

This is most common but quite variable and confusing species. Variation occurs among shape, size, color and elytral spots. Previously this species was grouped into four geographical subspecies under its old synonym *sparsa,* but later on, all these subspecies were verified as forms of a single highly variable species. It was reported 1st time under the name *H. sparsa* from solanaceous plants from Pakistan by CIBC (1982) and by the name *H. vigintioctopunctata* by Hashmi (1994).

This species is phytophagous and feeds on *Symphytum tuberosum* (CIBC, 1982), cucurbitaceous vegetables as well as solanaceous plants and many other vegetables. It was collected from all sampled sites of this study and on a global scale; it is distributed in Asia (Chong *et al*., 1991; Dingxu *et al*., 1996; Naz *et al*., 2012), Africa and Europe (The Entomological Collection: Lund University, 2012).

Genus *Scymnus* Kugelann, 1794

Pronotum longitudinally trunctate at middle of the anterior margin. Last segment of maxillary palpi cylindrical.

Genus *Scymnus* Kugelann, 1794
Scymnus nubilis Mulsant, 1850

Diagnosis

Body very small, elongate and slightly convex. Head light to dark brown. Head deeply inserted but clearly visible from dorsal side with large eyes. Pronotum dark-brown, darker in middle with lighter and reddish brown posterior and anterior margins (Fig. 1-9a). Elytra yellowish to reddish brown with a black sutural stripe originated from basal margin and gradually tapered towards apex, adjacent margins narrowly dark brown to black at middle.

Genitalia

Phallobase: Trab; long, dense and curved at middle. Basal piece small and rectangular in shape. Parameres dense, moderately longer than median lobe, somewhat compressed at base, tips rounded with long thin hairs. Median lobe wide with apex pointed and slightly curved (Fig. 1-9b).

Host and distribution

This species is greatly similar to *S. hoffmanni*in under general appearance and coloration but can be differentiated by the male genitalia. It is a vigorous predator of aphids, particularly found on wheat crop and also found on other agro crops such as maize, barley etc. Locally, it was found on few of the sites sampled in this study but globally, it is widely distributed in China (Ren *et al*., 2009), India (Santha *et al*., 1996), Pakistan (Santha *et al*., 1996), and Europe (Ferrari and Burgio, 1994).

Seasonal collection of different coccinellid species from various host plants (Table II) revealed that most of these species were captured from September to April throughout the collection period, particularly *C. septempunctata* and *H. variegata*.

Table II.- Temporal distribution of different coccinellid species on their host plants.

Name of species	Host plant	Collection period
B. suturalis	*Calotropis gigantean*	September
E. nigripennis	*Triticum aestivum*	March
M. sexmaculatus	*Medicago sativa, Trifolium alexandrinum, Zea mays* and other ornamental plants	September
C. septempunctata	*Zea mays*, *Lactuca sativa*, *Triticum aestivum*, *Ziziphus mautitiana, Brassica compestris, Medicago sativa and Trifolium alexandrinum*	September- April
H. variegate	*Triticum aestivum*, *Brassica compestris, Medicago sativa, Trifolium alexandrinum and Zea mays*	September- April
P. dissecta	*Zea mays, Triticum aestivum* and *Brassica compertris*	September- March
M. allardi	*Zea mays, Triticum aestivum* and *Brassica compertris*	September- March
H. Vigintioctopunctata	*Symphytum tuberosum*	March-April
S. nubilus	*Zea mays*	September- November

Table III.- Relative abundance of each species of family Coccinellidae from different localities of the district Sargodha.

Sub-family	Species	Total Abundance of Species	Relative Percentage Abundance
Chilocorinae	*B. suturalis*	30	2.04
	E. nigripennis	1	0.07
Coccinellinae	*M. sexmaculatus*	458	31.16
	C. septempunctata	665	45.24
	H. variegate	50	3.40
	P. dissecta	31	2.11
	M. allardi	36	2.45
Epilachninae	*H. vigintioctopunctata*	166	11.29
Scymninae	*S. nubilus*	33	2.24
Total		**1,470**	**100**

This is due to that fact that these coccinellid species usually shift to alternate crop plants and vegetation in case of unavailability of their preferred host plants. Moreover, as these species are euryphagous, feeding on a variety of hosts, not only on soft bodied insects but also on plants pollens when prey is scarce, therefore, it ultimately gives a positive effect on their population increase by retarded cannibalism (Hodek and Michaud, 2008).

Moreover, *C. septempunctata* had the highest relative abundance (45.24), whereas *E. nigripennis* had the least relative abundance (0.07) (Table III). Among four sub-families of Coccinellidae; sub-family Chilocorinae has maximum (2.04) and minimum (0.07) relative abundance of *B. suturalis* and *E. nigripennis*, respectively.

The collective rank list (Table IV) reveals that both the species *C. septempunctata* and *M. sexmaculatus* were found in all the localities representing about 76% of the total individuals collected during the study. Among the collected genera, *Exochomus* showed narrow range of habitat and was captured only from one place (Sargodha tehsil). Sargodha and Silanwali localities showed maximum species richness (9 and 8 species, respectively), while the localities of Shahpur and Sahiwal with the least (5 species each). *C. septempunctata* was the dominating species in both these localities and *B. suturalis* and *E. nigripennis* were the recessive ones.

Similarly, data regarding similarity indices (Table V) showed maximum similarity index (0.47) between Sargodha and Silanwali and minimum (0.20) between Sahiwal and Shahpur.

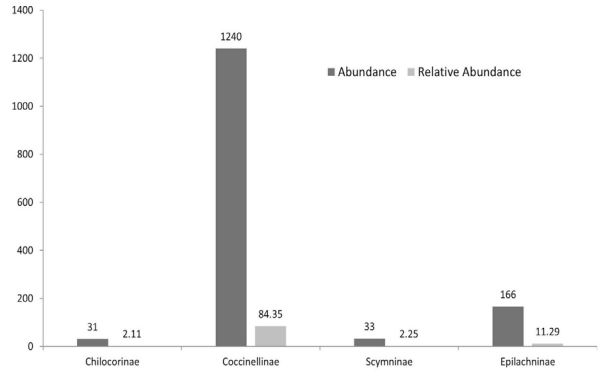

Fig. 2. Relative abundance of different subfamilies of the family Coccinellidae, collected from different localities of the district Sargodha during September 2013 to April 2014.

Diversity indices, used to evaluate species richness and evenness of coccinellid fauna among sites studied (Fig. 2), showed that Sargodha site exhibited the highest values of Shannon-Wiener's (1.65), Margalef's (1.40) and Simpson's (0.65) diversity indices, while tehsils Shahpur and Sahiwal had the minimums.

Table IV.- The collective rank list along with the list of taxa of family Coccinellidae collected from different localities of the district Sargodha.

Name of Taxa	Abundance	Bhera	Bhalwal	Kot Momin	Sahiwal	Sargodha	Shahpur	Silanwali
B. suturalis	30	+	+	+	+	+	-	+
E. nigripennis	01	-	-	-	-	+	-	-
M. sexmaculatus	458	+	+	+	+	+	+	+
C. septempunctata	665	+	+	+	+	+	+	+
H. variegate	50	+	-	+	+	+	-	+
P. dissecta	31	-	+	+	+	+	-	+
M. allardi	36	+	-	+	-	+	+	+
H. Vigintioctopunctata	166	+	+	+	-	+	+	+
S. nubilus	33	-	+	-	-	+	+	+
No. of individuals	1470	201	181	181	159	303	189	256
No. of Species	9	6	6	7	5	9	5	8

Table V.- Similarity indices of coccinellid species collected from different localities of the district Sargodha.

Sampling locality	Bhera	Bhalwal	Kot Momin	Sahiwal	Sargodha	Shahpur	Silanwali
Bhera	1						
Bhalwal	0.33	1					
Kot Momin	0.46	0.38	1				
Sahiwal	0.36	0.36	0.41	1			
Sargodha	0.40	0.40	0.43	0.35	1		
Shahpur	0.36	0.36	0.33	0.20	0.35	1	
Silanwali	0.42	0.42	0.46	0.38	0.47	0.38	1

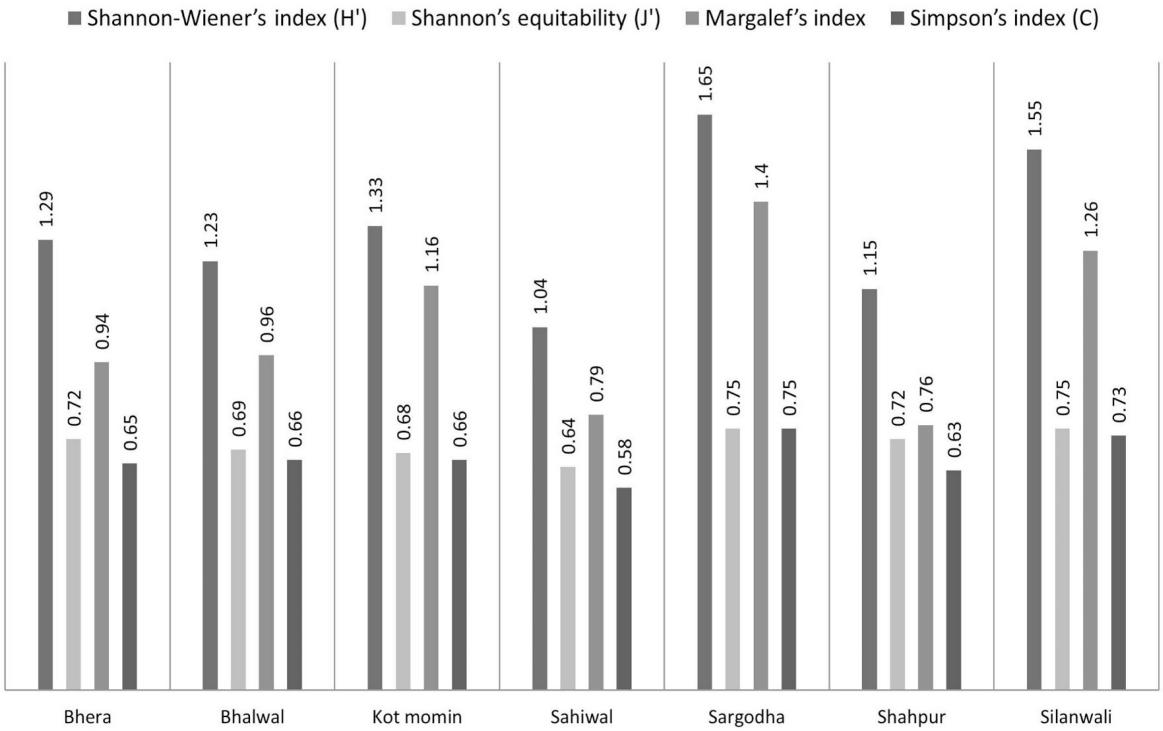

Fig. 3. Calculated values of diversity indices of different coccinellid species from different localities of the district Sargodha.

Collectively, these results indicate that coccinellid beetles were not well scattered in all selected localities of the district Sargodha. However, the species richness of coccinellids among these selected localities of district Sargodha was not so different from each other as demonstrated by a narrow range (0.64–0.75) of Shannon's equitability (J') index (Fig. 3).

CONCLUSION

The present study aimed at exploring and identifying the indigenous coccinellid fauna of the district Sargodha which is the major citrus producing area of the country. A total of nine species were identified belonging to 9 genera and 4 subfamilies occurring along with 10 trophic associations. These findings provide a baseline for perspective researchers in order to study their biology, ecology and predatory potential against different insect pests and will finally lead to the development of a conservation-based biological control strategy for indigenous plant protection programs.

Statement of conflict of interest

Authors have declared no conflict of interest.

REFERENCES

Abbas, M., Kausar, N.S. and Rana, S.A., 2013. Diversity and distribution of ladybird beetles (Coccinellidae) in the cropland of Faisalabad district. *Int. J. Adv. Res.,* **1**: 27-33.

Akhavan, E., Jafari, R., Jafai, R. and Afrogheh, S., 2013. Biodiversity and distribution of predaceous ladybird (Coleoptera: Coccinelliae). *Int. Res. J. appl. Basic Sci.,* **5**: 705-709.

Ali, J.G. and Agrawal, A.A., 2014. Asymmetry of plant-mediated interactions between specialist aphids and caterpillars on two milkweeds. *Funct. Ecol.,* **28**: 1404-1412. https://doi.org/10.1111/1365-2435.12271

Biranvand, A., Jafari, R. and Khormizi, M.Z., 2014. Diversity and distribution of Coccinellidae (Coleoptera) in Lorestan Province, Iran. *Biodiver. J.,* **5**: 3-8.

Bouchard, P., Bousquet, Y., Davies, A.E., Alonso-Zarazaga, M.A., Lawrence, J.F., Lyal, C., Newton, A.F., Reid, C., Schmitt, M., Slipinski, S. and Smith A., 2011. Family-group names in Coleoptera (Insecta). *ZooKeys,* **88**: 1-972. https://doi.org/10.3897/zookeys.88.807

Chakraborty, K., Das, K. and Kar, T.K., 2013. An ecological perspective on marine reserves in prey–predator dynamics. *J. biol. Phys.,* **39**: 749-776. https://doi.org/10.1007/s10867-013-9329-5

Chong, K.K., Cooi, P.A. and Tuck, H.C., 1991. *Crop pests and their management in Malaysia*. Tropical Press Sdn, Kuala Lampur, pp. 242.

CIBC, 1982. *Investigation on natural enemies of* Epilachna *spp. in Pakistan*. Final report. Commonw. Inst. Biol. Contr., Pakistan Station, Rawalpindi, pp. 31.

Dingxu, L., Zhiyong, Z., Tieshuan, L., Xinli, M. and Zhenguo, L., 1996 Studies on the population dynamics and control techniques of the ladybird skinner in Western Henan province. *Chinese Potato J.,* **107**: 147-150.

Ferrari, R. and Burgio, G., 1994. Aphid parasitoids (in Italian). *Informat. Fitopatol.,* **44**: 25-30.

Ghosh, S.K., Laskar, N. and Senapati, S.K., 2007. Seasonal incidence of predator *Menochilus sexmaculatus* (Berliner) on brinjal and harmful effect of insecticides on the predator. *Indian J. agric. Res.,* **41**: 102-102.

Grevstad, F.S. and Klepetka, B.W., 1992. The influence of plant architecture on the foragingefficiencies of a suite of ladybird beetles feeding on aphids. *Oecologia,* **92**: 399-404. https://doi.org/10.1007/BF00317466

Guoyue, Y. and Wang, H. 2001. Two new records of ladybeetles (Coleoptera: Coccinellidae) of Taiwan. *J. Nat. Taiwan Mus.,* **54**: 1-7.

Hammer, O., Harper, D.A.T. and Ryan, P.D., 2001. PAST: Paleontological statistics software package for education and data analysis. *Palaeontol. Elect.,* **4**: 9.

Harmon, J.P., Stephens, E. and Losey, J., 2006. The decline of native coccinellids (Coleoptera: Coccinellidae) in the United States and Canada. In: *Beetle conservation*, Springer, Netherlands, pp, 85-94. ISBN, 978-1-4020-5987-2.

Hashmi, A.H., 1994. *Insect pest management of horticultural and forest crops.* Pak. Agric. Res. Council (PARC) Islamabad, Pakistan, pp. 346.

Hesler, L.S., Losey, J.E., Allee, L.L. and Smyth, R.R., 2014. New records of coccinellidae (Coleoptera) from Wyoming, USA. *Coleopts. Bull.,* **68**: 128-130. https://doi.org/10.1649/0010-065X-68.1.128

Hodek, I. and Honek, A., 2009. Scale insects, mealybugs, whiteflies and psyllids (Hemiptera, Sternorrhyncha) as prey of ladybirds. *Biol. Contr.,* **51**: 232-243. https://doi.org/10.1016/j.biocontrol.2009.05.018

Hodek, I. and Michaud, J.P., 2008. Why is *Coccinella septempunctata* so successful? *Eur. J. Ent.,* **10**: 1-12. https://doi.org/10.14411/eje.2008.001

Ives, A.R., Kareiva, P. and Perry, R., 1993. Response of a predator to variation in prey density at three hierarchical scales lady beetles feeding on aphids. *Ecology,* **74**: 1929-1938. https://doi.org/10.2307/1940836

Joshi, P.C., Khamashon, L. and Kaushal, B.R., 2011. New additions of coccinellid beetles (Coleoptera: Coccinellidae) to the already reported species from Uttarakhand, India. *Nat. Sci.,* **6**: 26-30.

Kovar, I., 1996. Morphology and anatomy. In: *Ecology of Coccinellidae*. Springer Netherlands, pp. 1-18. https://doi.org/10.1007/978-94-017-1349-8_1

Kumar, M.V.S., Bandyoapadhyay, U.K. and Saratchandra, B., 2000. *Brumoides suturalis*, a potential biological control agent of *Maconellicoccus hirsustus* in Mulberry. *Proc. Fifth Nat. Conf. Adv. Zool. Res. Assoc.*, 27–29 November 2000, Chennai, Tamilnadu, India.

Kuznetsov, V.N., 1997. *Lady beetles of the Russian Far East*. Memoir No. 1, Center for Systematic Entomology, pp. 248.

Latigo, M.W.O., Baliddawa, C.W. and Ampofo, J.K.O., 1993. Factors influencing the incidence of the black bean aphid, *Aphis fabae* Scop on common beans intercropped with maize. *Afr. Crop Sci. J.,* **1**: 49-58.

Majerus, M. and Kearns, P.K., 1989. *Lady birds.* University of Cambridge. Richmond Publishing Co. Ltd., England, pp. 1-101.

Mehrnejad, M.R., 2010. Potential biological control agents of the common pistachio psylla, *Agonoscena pistaciae*, a review. *Entomofauna,* **31**: 249-272.

Mohamed, A.H., Lester, P.J. and Holtzer, T.O., 2000. Abundance and effects of predators and parasitoids on the Russian wheat aphid (Homoptera: Aphididae) under organic farming conditions in Colorado. *Environ. Ent.,* **29**: 360-368. https://doi.org/10.1093/ee/29.2.360

Muniappan, R., 2012. *Arthropod pests of horticultural crops in tropical Asia.* CABI Publishing, UK. https://doi.org/10.1079/9781845939519.0000

Naz, F., Inyatullah, M., Rafi, M. A., Ashfaque, M. and Ali, A., 2012. *Henosepilachna vigintioctopunctata* (Fab.) (Epilachninae; Coccinellidae); its taxonomy, distribution and host plants in Pakistan. *Sarhad J. Agric.,* **28**: 421-427.

Obrycki, J.J. and Kring, T.J., 1998. Predaceous Coccinellidae in biological control. *Annu. Rev. Ent.,* **43**: 295-321. https://doi.org/10.1146/annurev.ento.43.1.295

Omkar, and Pervez, A., 2004. Functional and numerical responses of *Propylea dissecta* (Col., Coccinellidae). *J. appl. Ent.,* **128**: 140-146.

Pervez, A., 2004. Prey-dependent life attributes of an aphidophagous ladybird beetle, *Propylea dissecta* (Coleoptera: Coccinellidae). *Biocont. Sci. Technol.,* **14**: 385-396. https://doi.org/10.1080/09583150410001682313

Poorani, J., 2002. Anannotated checklist of the Coccinellidae (Coleoptera) (excluding Epilachninae) of the Indian subregion. *Orient. Insects*, **36**: 307-383. https://doi.org/10.1080/00305316.2002.10417335

Pushpendra, K.S. and Prakash, C.J., 2010. New records of coccinellid beetles (Coccinellidae: Coleoptera) from district Dehradun (Uttarakhand), India. *N.Y. Sci. J.,* **3**: 112-120.

Rafi, M.A., Irshad, M. and Inaytullah, M., 2005. *Predatory ladybird beetles of Pakistan.* Roohani Art Press, Islamabad, Pakistan, pp. 105.

Raimundo, A.A. and van Harten, A., 2000. An annotated checklist of the Coccinellidae (Insecta: Coleoptera) of Yemen. *Faun. Arab,* **18**: 211-244.

Rakhshani, E. and Saeedifar, A., 2013. Seasonal fluctuations, spatial distribution and natural enemies of Asian citrus psyllid *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae) in Iran. *Entomol. Sci.,* **16**: 17-25. https://doi.org/10.1111/j.1479-8298.2012.00531.x

Rebolledo, R., Sheriff, J., Parra, L. and Aguilera, A., 2009. Life, seasonal cycles, and population fluctuation of *Hippodamia variegata* (Goeze) (Coleoptera: Coccinellidae), in the central plain of La Araucanía Region, Chile. *Chilean J. agric. Res.,* **69**: 292-298. https://doi.org/10.4067/S0718-58392009000200020

Ren, S., Wang, X., Pang, H., Peng, Z. and Zeng, T., 2009. *Colored pictorial hand book of beetles in China.* Science Press, Beijing, pp. 336.

Saleem, M., Hussain, D. and Abbas, M., 2014. Predation efficacy of *Menochilus sexmaculatus* (Fabricus) (Coleoptera: Coccinellidae) against *M. rosae* (Linneaus) under laboratory conditions. *J. agric. Res.,* **3**: 125-129.

Santha, K.M.V., Chakraborty, N., Prasad, B.C. and Gupta, S.K., 1996. Feeding efficiency of Scymnus nubilus Mulsant, A native predator on pink mealy bug, Maconellicoccus hirsutus (Green). In: *Integrated pest management and sustainable agriculture: an entomological approach* (ed. S.C. Goel), Uttar Pradesh Zoological Society, Muzaffarnagar, India, pp. 224.

Sarwar, M. and Saqib, S.M., 2010. Rearing of predatory seven spotted ladybird beetle *Coccinella septempunctata* L. (Coleoptera: Coccinellidae)

on natural and artificial diets under laboratory conditions. *Pakistan J. Zool.*, **43**: 47-51.

Singh, S. and Sharma, D.R., 2010. Coccinellid predators beetles of insect pests of citrus in the Indian Punjab. *Crop Improv.,* **37**: 207-207.

Soares, A.O., Coderre, D. and Schanderl, H., 2003. Effect of temperature and intraspecific allometry on predation by two phenotypes of *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae). *Environ. Ent.,* **32**: 939-944. https://doi.org/10.1603/0046-225X-32.5.939

Srivastava, S., 2003. Influence of six aphid prey species on development and reproduction of a ladybird beetle, *Coccinella septempunctata*. *BioControl,* **48**: 379-393. https://doi.org/10.1023/A:1024762822955

Thalji, R., Stojanovic, D. and Nestorovic, S., 2010. Preliminary research on the ladybirds community (Coleoptera: Coccinellidae) of the National Park Derdap. *Acta Ent. Serb.,* **15**: 75-80.

The Entomological Collection, 2012. Museum of Zoology, Lund University. Available from: www.biomus.lu.se/museum-of-zoology/databases (Accessed 22 October 2013).

Ullah, R., Haq, F., Ahmad, H., Inayatullah, M., Saeed, K. and Khan, S., 2012. Morphological characteristics of ladybird beetles collected from District Dir Lower, Pakistan. *Afri. J. Biotechnol.,* **11**: 9149-9155.

Vandenberg, N.J., 2002. Coccinellidae Latreille 1807. In: *American beetles* (Vol. 2): *Polyphaga: Scarabaeoidea through Curculionoidea* (eds. R.H. Arnett, M.C. Thomas, P.E. Skelley and J.H. Frank). CRC Press, Boca Raton, USA. pp. 371–389.

Veeravel, R. and Baskaran, P., 1997. Searching behaviour of two coccinellid predators, *Coccinella transversalis* Fab. and *Cheilomenes sexmaculatus* Fab., on eggplant infested with *Aphis gossypii* Glov. *Int. J. trop. Insect Sci.,* **17**: 363-368. https://doi.org/10.1017/S1742758400019196

Weil, W.U., Debom L.I.U., Pei-yi, Z. and Zhen, Z., 2011. Community structure and diversity of ladybugs in Baihualing of Gaoligong Mountain I. *Pl. Dis. Pests.,* **2**: 46-48.

Zare, K.M., Biranvand, A. and Shakarami, J., 2013. The faunistic survey of lady beetles (coleoptera, coccinellidae) in the Mehriz region (Yazd province), Iran. *Bull. Iraq. Nat. Hist. Mus.,* **12**: 43-51.