International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 02-03-2024, Accepted: 24-03-2024, Published: 16-04-2024
Volume 9, Issue 4, 2024, Page No. 84-97

Lepidopteran diversity of Singoda lake, Visnagar, North Gujarat

Hiteshkumar Parmar[1*], Aditya Parihar[2], Vishal Parihar[3]
[1] Department of Life Science, School of Science, Dr. Subhash University, Junagadh, Gujarat, India
[2] Department of Zoology, Conestoga College, Doon Valley, Dr. Kitchener, Ontario, Canada
[3] Department of Biology, Madhyamik Ashram Shala, Nani Tudiya, Danta, Banaskantha, Gujarat

Abstract
The current studies aim to examine the lepidopteran diversity in Singoda lake, Visnagar, North Gujarat. Three main habitats (Tree Dominated Habitat Scrubs, Herbs dominated and Water Body and Edges) surveyed extensively. The survey was done in morning (07:00 to 10:00 hrs.) and evening (17:00 to 19:00 hrs.) time, employed 8 visits in a month (2 visit/Week) from June to September 2020. The Pollard walk method used for sample collection with total of 32 visits and 40 transects, and sampling was done by random method. Total of 84 species of lepidoptera distributed in 14 family and 69 genera. The Month of July has maximum diversity (H=9.38) and species richness (d=3.36) was observed. The recorded lepidopteran diversity in study area suggest that Singoda lake is very important for a nursing ground to larvae and food for the adults.

Keywords: Lepidoptera, Butterflies, Moths, Diversity indices, Venn Diagram

Introduction

Lepidoptera, including butterflies and moths, play a crucial role in ecosystems as pollinators, contributing to plant reproduction and biodiversity maintenance [04, 26]. Additionally, they serve as indicators of environmental health and are essential prey for many insectivorous animals, supporting food webs and ecosystem stability [20, 06].

Total of 4378 species of lepidoptera recorded in India among them, 1433 species of Butterflies [14] and 2945 species of moth [23].

Tremendous work has been done in many localities in Gujarat, total of 30 species of lepidoptera recorded form the many localities of Gujarat with reference to eleven new locality records [10], In Central Gujarat total of 43 species listed from Gandhinagar [15], plenty of work done in Baroda district by many researchers such as 43 species recorded from urban localities and 33 species from agriculture field of Baroda City [08, 09], 42 species from Wadhwana Irrigation Reservoir, Baroda [07], their after a locality record form south Gujrat Bharuch total of 58 species noted [13], recently 63 species from Ankleshwar city [22].

Second most explored region is Saurashtra region, 27 species recoded from cost of the Mangrol [25], from Gir National Park total of 67 species from various habitat has been recorded [21], total of 27 species of butterflies observed on 30 hostplants; 40 species of butterfly nectaring on 40 species of hostplant in wild flowers Ishwariya hill garden, Rajkot [01, 02], 69 species from Victoria Park Reserve Forest, Bhavnagar [24].

Recently from North Gujarat total of 35 specie from Aravalli hill range [18], Previously such survey done in M. N. College, Visnagar observed 40 species Butterfly [05]; 138 species from HNGU campus, Patan [16]. However, this is the first comprehensive attempt for lepidopteran diversity for the Visnagar rural.

Study area

Singoda lake (N 23.7013017, E 72.5719817) is small water body that expand in total of 248283.03 m^2 (Fig. 1 A, B). Water availability in the lake is depends on the rainfall of the area. The lake is located near Sunshi village, Visnagar. The name Singoda lake is came from previously used for the harvesting of Singoda (Water Chestnut). The climate of the area is during winter is cold and dry, in summer the water is evaporated and water body is screamed, but in monsoon early monsoon (June and July) is very humid and medium ranged of rainfall followed by in the month of August and September the lake is recharged.

Background study of habitat

The area is divided based on habitat characteristics and its vegetation in three distinct zones.

1. Tree Dominated Habitat (61398.94 m^2): This area is mostly dominated by tress medium to large size (Acacia and Baboon trees). Substratum of these area is Dry to Small grass Dominated near to the waterbody (Fig. 1C).

2. Scrubs and Herbs dominated Habitat (124333.67 m^2): This area is mostly dominated by shrub and Herbs plants, during early monsoon this area has maximum flowering plant, but in the monsoon and late monsoon this area is submerged with water (Fig. 1D).

3. Water Body and Edges (50989.32 m^2): This area is largely dominated by waterbody and aquatic plants on edges, total of three water body found in the area among them the
Singoda lake is the largest (43625.14 m^2), During post monsoon this area and edges is submerges in to water. Most of aquatic plants and aquatic grass found in these areas (Fig. 1E, F, G).

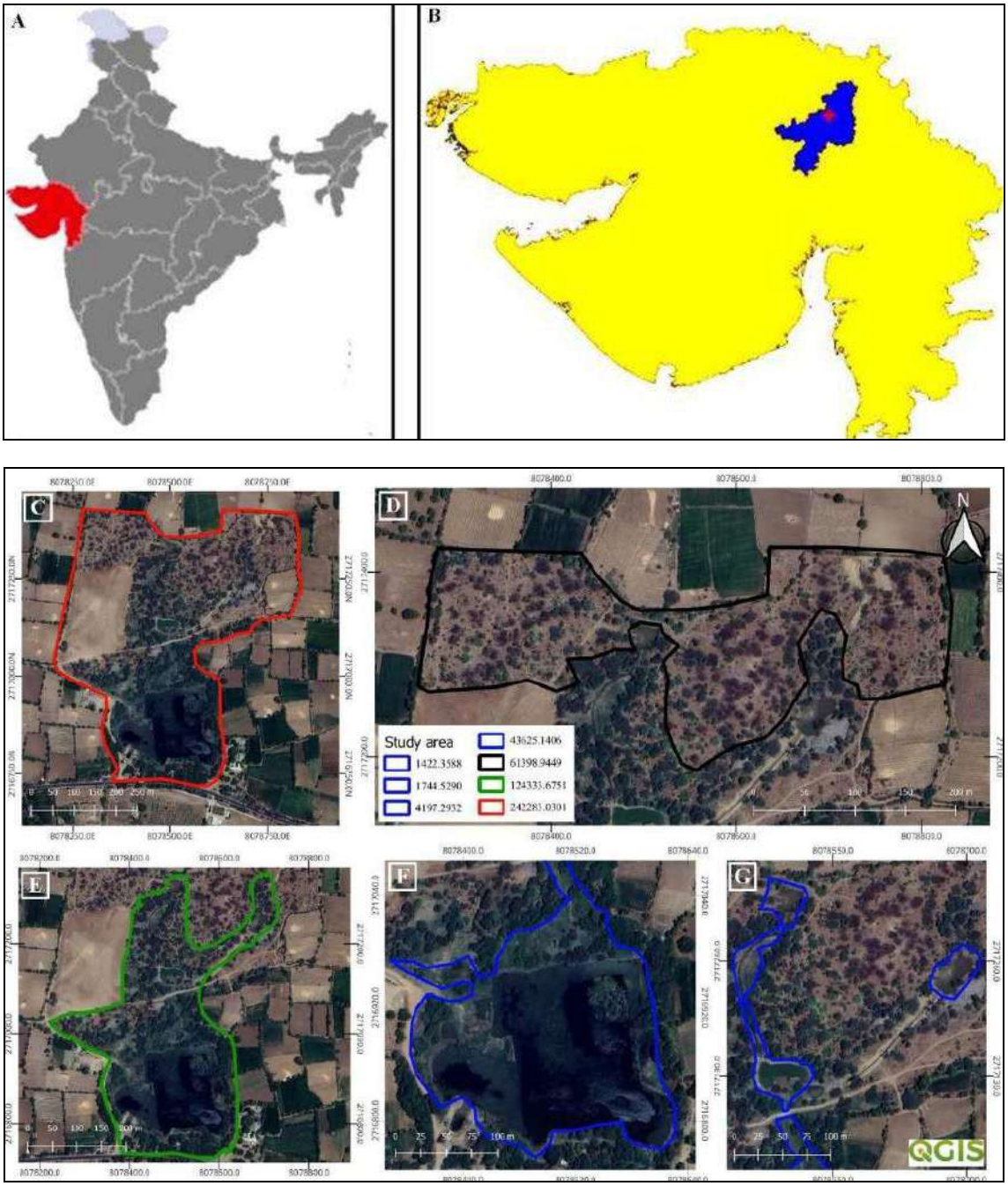

Fig 1A. B: Location of Mehsana District in Gujarat, **B.** Study area, **C.** Tree Dominated Habitat (Medium Dry), **D.** Scrubs and Herbs dominated Habitat (Moist Habitat), **E. F. G,** Water body and Edges.

Methodology

The sampling location, Singoda lake, Visnagar, North Gujarat was surveyed from June 2020 to Sep 2020 to measure the diversity of butterflies and each possible vegetation types where the butterfly species observed. Pollard walk method [19] used for observing butterflies, i.e., On the fixed paths while observing and counting the species. The observation width was limited to about 5m with time concerned (5 min. for each stop). Lepidopteran species were observed throughout the morning (07:00 to 10:00 hrs.) and evening (17:00 to 19:00 hrs.). Total of 32 visits (8 visit/ month) and 40 transects (10m x 100m) were encompass for observations by random method.

Data analysis

PAST v4.16 used to calculate Diversity indices Shannon index, Simpson Diversity, Margalef Species richness and Evenness [11]. Venn Diagram of month-wise species distribution is calculated using Venn Diagram r-program Plugin [03]. For the Map and habitat analyse QGIS v3.34.3 is used. Identification purposes DSLR cameras (Canon 700d, Nikon 5800). Butterflies and moths identification were by field guides, and online databases [12, 14, 23].

Result and Discussion

Total observed 498 individuals of the lepidoptera, belonging to 8 super families, 14 families, 69 genera and 84 species (Table 1; Plate A to F). Among them maximum number of Genus and Species is recorded in the super family Papilionoidea (5 Family, 23 genera and 33 species) were recorded form the study area.

Table 1: Lepidopteran Diversity of Singoda lake, Visnagar.

No.	Species	Common name	Months				Total
			J	Ju	A	S	
Superfamily: Bombycoidea							
Family: Sphingidae (Sphinx Moths)							
1	*Acherontia Lachesis*	Greater Death's Head Hawkmoth	0	0	0	1	1
Superfamily: Geometroidea (Geometrid moths)							
Family: Geometridae (Emerald Moths and Allies)							
2	*Calluga costalis*	-	0	0	0	1	1
3	*Cleora* sp.	-	0	0	0	1	1
4	*Hyperythra lutea*	-	5	0	0	0	5
5	*Hypomecis transcissa*	-	0	0	1	1	2
6	*Isturgia disputaria*	Maltese Bloom	0	8	4	3	15
7	*Odontopera kametaria*	-	0	1	0	0	1
8	*Pelagodes* sp.	-	0	0	0	1	1
9	*Scopula* sp.	-	0	1	1	0	2
10	*Traminda mundissima*	-	0	1	0	2	3
Superfamily: Hyblaeoidea							
Family: Hyblaeidae							
11	*Hyblaea puera*	Teak Defoliator	0	12	0	0	12
Superfamily: Noctuoidea (Owlet Moths)							
Family: Erebidae (Owlet Moths, Tiger Moths, Tussock Moths and Allies)							
12	*Amata passalis*	-	0	2	3	0	5
13	*Anticarsia irrorata*	-	0	0	0	1	1
14	*Artaxa guttata*	-	0	0	0	3	3
15	*Ataboruza divisa*	-	0	0	0	1	1
16	*Culasta indecisa*	-	0	1	0	0	1
17	*Eudocima materna*	Dot Underwing	0	0	2	0	2
18	*Euproctis lunata*	-	0	0	2	0	2
19	*Anomis involuta*	-	0	0	1	0	1
20	*Hipoepa fractalis*	-	0	2	0	0	2
21	*Mocis frugalis*	Sugarcane Looper	0	6	0	0	6
22	*Mocis undata*	Brown striped Semi-looper	0	1	0	0	1
23	*Plecoptera recta*	-	0	0	1	0	1
24	*Utetheisa pulchelloides*	Heliotrope Moth	32	7	0	0	39
Family: Noctuidae (Noctuid Moths)							
25	*Acontia crocata*	-	8	10	0	0	18
26	*Acontia lucida*	Pale Shoulder	0	2	2	0	4
27	*Aegocera venulia*	-	0	13	0	0	13
28	*Amyna axis*	The Eight-spot	0	0	0	2	2
29	*Anadevidia peponis*	-	0	1	0	0	1
30	*Spodoptera exigua*	Beet Army-worm Moth	0	0	1	1	2
31	*Spodoptera litura*	Cotton Leafworm	0	0	0	2	2
Superfamily: Noctuoidea (Owlet Moths)							
Family: Nolidae							
32	*Carea angulate*	-	0	0	0	1	1
33	*Westermannia superba*	-	0	0	1	0	1
Superfamily: Papilionoidea (Butterflies)							
Family: Hesperiidae (Skippers)							
34	*Pelopidas mathias*	Small Branded Swift	0	7	0	1	8
35	*Spialia galba*	Asian Grizzled Skipper	0	1	0	0	1
Family: Lycaenidae (Blues & Hairstreaks)							
36	*Azanus jesous*	Babul Blue	0	0	0	2	2
37	*Azanus ubaldus*	Bright Babul Blue	0	7	1	0	8
38	*Castalius rosimon*	Common Pierrot	0	0	2	0	2

39	*Catochrysops strabo*	Forget-me-not	0	10	1	0	11
40	*Chilades pandava*	Plains Cupid	0	5	0	0	5
41	*Leptotes plinius*	Zebra Blue	0	1	1	0	2
42	*Spindasis vulcanus*	Common Silverline	0	2	1	0	3
43	*Tarucus nara*	Striped Pierrot	0	4	0	0	4
44	*Zizeeria karsandra*	Pale Grass Blue	10	7	1	0	18
Family: Nymphalidae (Brush-footed Butterflies)							
45	*Danaus chrysippus*	Plain Tiger	0	32	3	0	35
46	*Danaus genutia*	Striped Tiger	0	2	0	0	2
47	*Euploea core*	Common Crow	0	1	0	1	2
48	*Hypolimnas bolina*	Great Eggfly	0	2	1	4	7
49	*Hypolimnas misippus*	Danaid Eggfly	3	5	0	1	9
50	*Junonia almana*	Peacock Pansy	2	9	0	0	11
51	*Junonia hierta*	Yellow Pansy	0	1	0	0	1
52	*Junonia lemonias*	Lemon Pansy	0	1	0	0	1
53	*Junonia orithya*	Blue Pansy	3	6	1	0	10
54	*Tirumala limniace*	Blue Tiger	0	3	1	0	4
Family: Papilionidae (Swallowtails)							
55	*Graphium agamemnon*	Tailed Jay	0	0	1	0	1
56	*Papilio demoleus*	Lime Swallowtail	0	2	0	0	2
Family: Pieridae (Whites & Yellows)							
57	*Appias libythea*	Striped Albatross	0	1	0	0	1
58	*Belenois aurota*	Pioneer	0	4	1	0	5
59	*Catopsilia pyranthe*	Mottled Emigrant	0	3	0	1	4
60	*Colotis amata*	Small Salmon Arab	1	6	0	0	7
61	*Colotis aurora*	Plain Orange-tip	0	6	0	0	6
62	*Colotis danae*	Crimson-tip	0	1	0	0	1
63	*Colotis vestalis*	White Arab	0	1	0	0	1
64	*Eurema hecabe*	Common Grass Yellow	0	6	10	0	16
65	*Eurema laeta*	Small grass yellow	0	2	0	0	2
66	*Ixias marianne*	White Orange-tip	0	5	0	0	5
Superfamily: Pterophoroidea **Family: Pterophoridae**							
67	*Sphenarches anisodactyla*	Geranium Plume Moth	0	0	0	1	1
Superfamily: Pyraloidea **Family: Crambidae (Grass Moths)**							
68	*Conogethes punctiferalis*	Yellow Peach Moth	0	0	1	1	2
69	*Diaphania indica*	Cucumber Moth	0	0	0	1	1
70	*Ecpyrrhorrhoe damastesalis*	Teak Leaf Skeletonizer	0	0	0	3	3
71	*Ecpyrrhorrhoe sp.*	Teak Leaf Skeletonizer	0	0	0	1	1
72	*Isocentris filalis*	-	0	0	1	1	2
73	*Noorda blitealis*	-	0	3	1	2	6
74	*Paracymoriza vagalis*	-	0	0	1	0	1
75	*Parapoynx fluctuosalis*	-	0	1	0	0	1
76	*Parapoynx stagnalis*	-	0	0	0	2	2
77	*Autocharis fessalis*	-	0	4	0	0	3
78	*Pygospila tyres*	Spotted Grass Moth	0	8	0	0	8
79	*Pyrausta phoenicealis*	Perilla Leaf Moth	0	0	3	0	3
80	*Sameodes cancellalis*	-	0	5	8	0	13
81	*Scirpophaga incertulas*	Yellow Stem Borer	8	3	0	0	11
82	*Spoladea recurvalis*	Beet Webworm Moth	52	4	0	30	86
83	*Syngamia latimarginalis*	-	0	0	0	2	2
Superfamily: Tortricoidea **Family: Tortricidae**							
84	*Loboschiza koenigiana*	-	0	0	0	1	1

Abbreviation: J-June, Ju-July, A-August, S, September.

The second most abundant Super family is Noctuoidea (Owlet Moths) it contains 3 family, 19 genera and 22 species of Moths. Also, second most abundant species (*Utetheisa pulchelloides*- Heliotrope Moth) belongs to Erebidae Family (Table 1).

Third most dominant Super family is Pyraloidea distributed belonging to only one family Crambidae (Grass Moths) that distributed in 14 genera and 16 species; also, the most abundant species from study area is *Spoladea recurvalis* (Beet Webworm Moth) belongs to Crambidae family.

Temporal Distribution of Lepidoptera

Out of total of 498 individual were distributed in maximum in the month of July (239), June (124), September (76) and August (59). Month-wise super familial distribution of individuals suggests that in the Superfamily Papilionoidea (Butterflies) recorded maximum in the month of July (143 individuals) (Fig. 2).

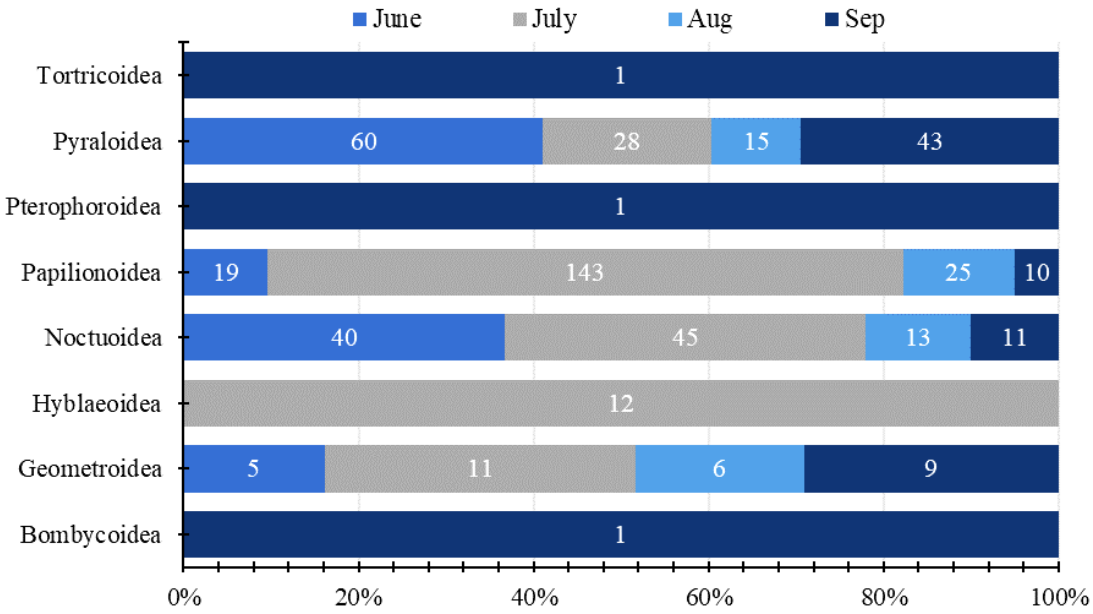

Fig 2: Month-wise Super familial individual of Lepidoptera.

Their after followed by Noctuoidea (Owlet Moths) has maximum number of individuals recorded from month of July (45) and June (40), third highest is Pyraloidea from June (60) and September (43), among this 52 and 30 induvial of *Spoladea recurvalis* (Beet Webworm Moth) recorded form the month respectively (Fig. 3).

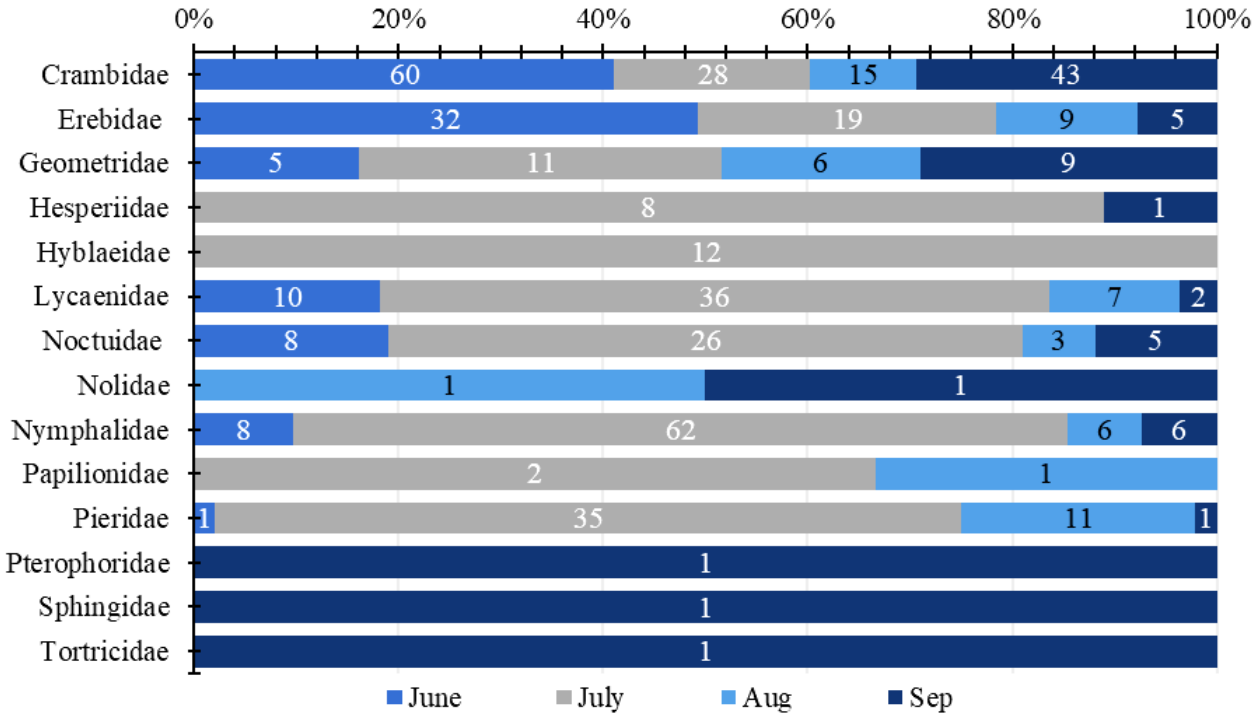

Fig 3: Month-wise Familial induvial of lepidoptera

Among total of 14 families most dominant was Family: Nymphalidae (Brush-footed Butterflies) in month of July (62 individuals) among them *Danaus chrysippus* (Plain Tiger) were most abundantly recorded (Fig. 3). The second most dominant Crambidae (Grass Moths) in month of June (60) among them 52 is form *Spoladea recurvalis* (Beet Webworm Moth).

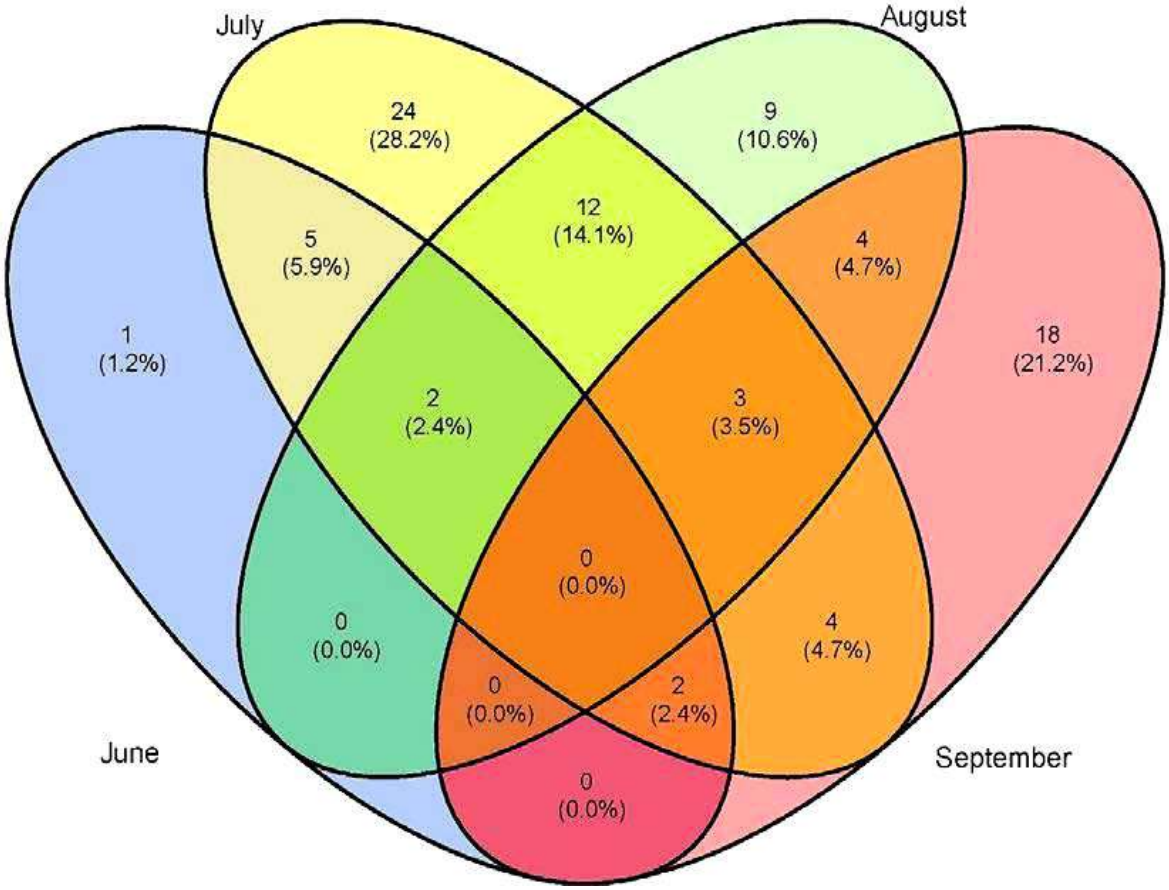

Fig 4: Venn Diagram of month-wise species relationship.

Venn diagram show that the relationship species in terms of recorded species in 4 dimensional scales (Fig. 4). There is total of 24 species were observed in only July (28.2%), among them *Aegocera venulia* (Plate B27) is most abundant found above leaflitter and hiding beneath the leaves of the shrubs and vegetation.

18 species were recorded only from the September (21.2%), among them *Artaxa guttata* (Plate A14) and *Ecpyrrhorrhoe* damastesalis (Plate E70) mostly observed on the tree bark and woody trunk. *Pyrausta phoenicealis* (Perilla Leaf Moth, Plate. F79) is species that found only in the month of August out of Total of 9 species (10.6%). *Hyperythra lutea* (Plate. A4) only species that is found in only June (1.2%).

Species wise lepidopteran similarity suggests that the July-August (17) most similar shared species composition and among them 14.1% species that found only in July and August out of

84. Total of 05 species is observed form out of 09 shared species from June-July. Similarly, 07 from August-September, among them 4.7% species is observed in only in June-July. June- September has lowest similarity (02) species that found.

Month-wise diversity indices

Months-wise diversity indices suggest that in comparatively in the month of July (52, 239) maximum number of species and individuals were observed respectively.

Also, in the month of August (30, 59) similar no of species recorded but the population of these species is affected due to the low land and edges habitat that near the water body is filled with water after heavy rainfall. Then after in the month of September (31, 76) population will grow on the available resources (Fig.4A).

Evenness (J) also suggest that the diversity between the month of June (0.96) and August (0.97) is significant (Fig. 5A). It may due to the resources accessibility in this month is relatively higher, this may lead to these species to live in same niche and habitat.

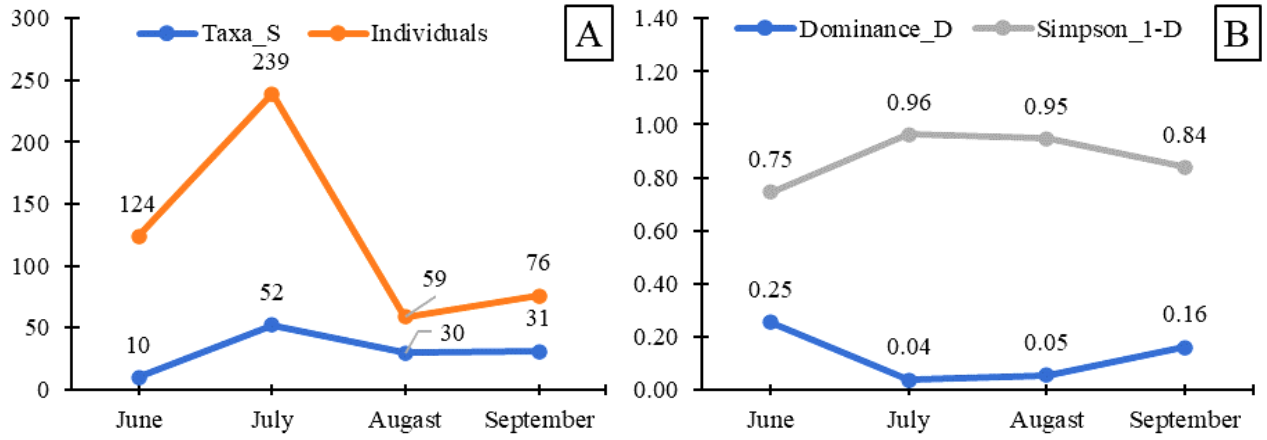

Fig 4: A. Month-wise Individual and Species, B. Dominance and Simpson diversity.

The Dominance (D) is inversely related to and Simpson Diversity (1-D) found significant in the month of July and August Comparatively higher (0.96, 0.95) (Fig. 4B).

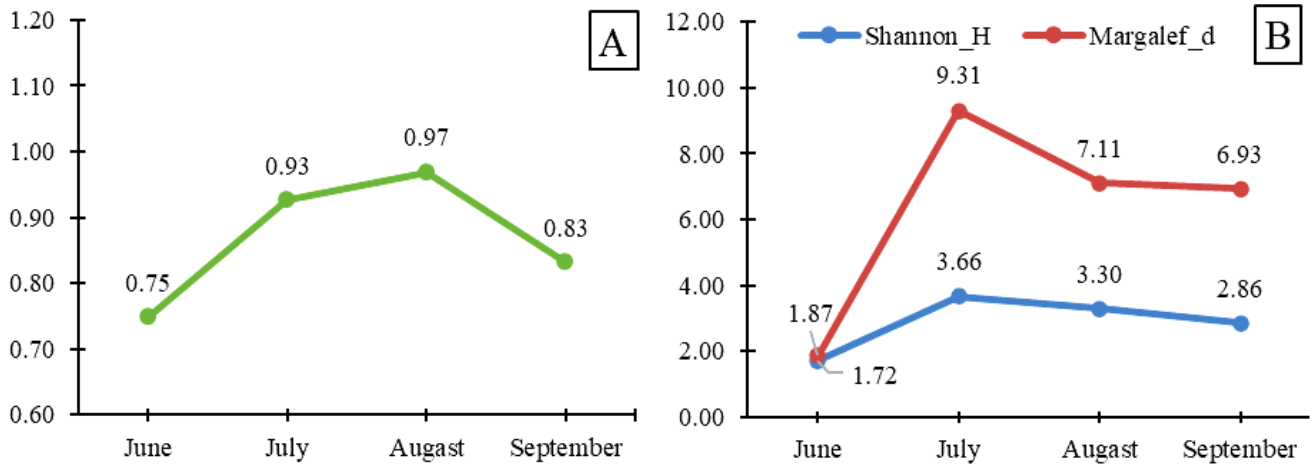

Fig 5: A. Month wise Evenness, B. Shannon and Margalef diversity.

Month-wise Margalef and Shannon diversity index suggest that in the month of July (3.66, 9.31) has significant higher lepidopteran community followed by August (3.30, 7.11). in the month of June, the lowest diversity recorded (1.72, 9.31; Fig. 5B). This may due to recreation of new habitat and resources. In the month of June (0.75) and September (0.82) comparatively low evenness observed. Low evenness index indicates an uneven distribution of species within a community, suggesting that certain species are more dominant while others are relatively rare [17].

In conclusion, the recorded lepidopteran diversity in study area suggest that this habitat is very important for breeding grounds and nectaring plant species provide a food for the adults, during the study period many anthropological activities are disturbing the habitat, and also some prime natural environmental factors such as, after the heavy rainfall all the vegetation at the low land is submerges in the water this leads to habitat destruction, this habitat is most important for the nectaring species of lepidoptera. In the month of September and August population and species richness of the area is rapidly declining due to this prime environment factors. However, this factors also create new habitat and opportunistic species will stay and survive.

Acknowledgement

Authors are thankful to Dr. Vipul Bamaniya for the help in identification of some species. Special thanks to Mr. Dharmik Parmar for the fieldwork support during data collection.

Conflict of Interest Statement

The authors affirm that there is no conflict of interest associated with this research.

Sources of Funding

This study did not receive financial support from any specific grant or funding agencies in the public, commercial, or not-for-profit sectors.

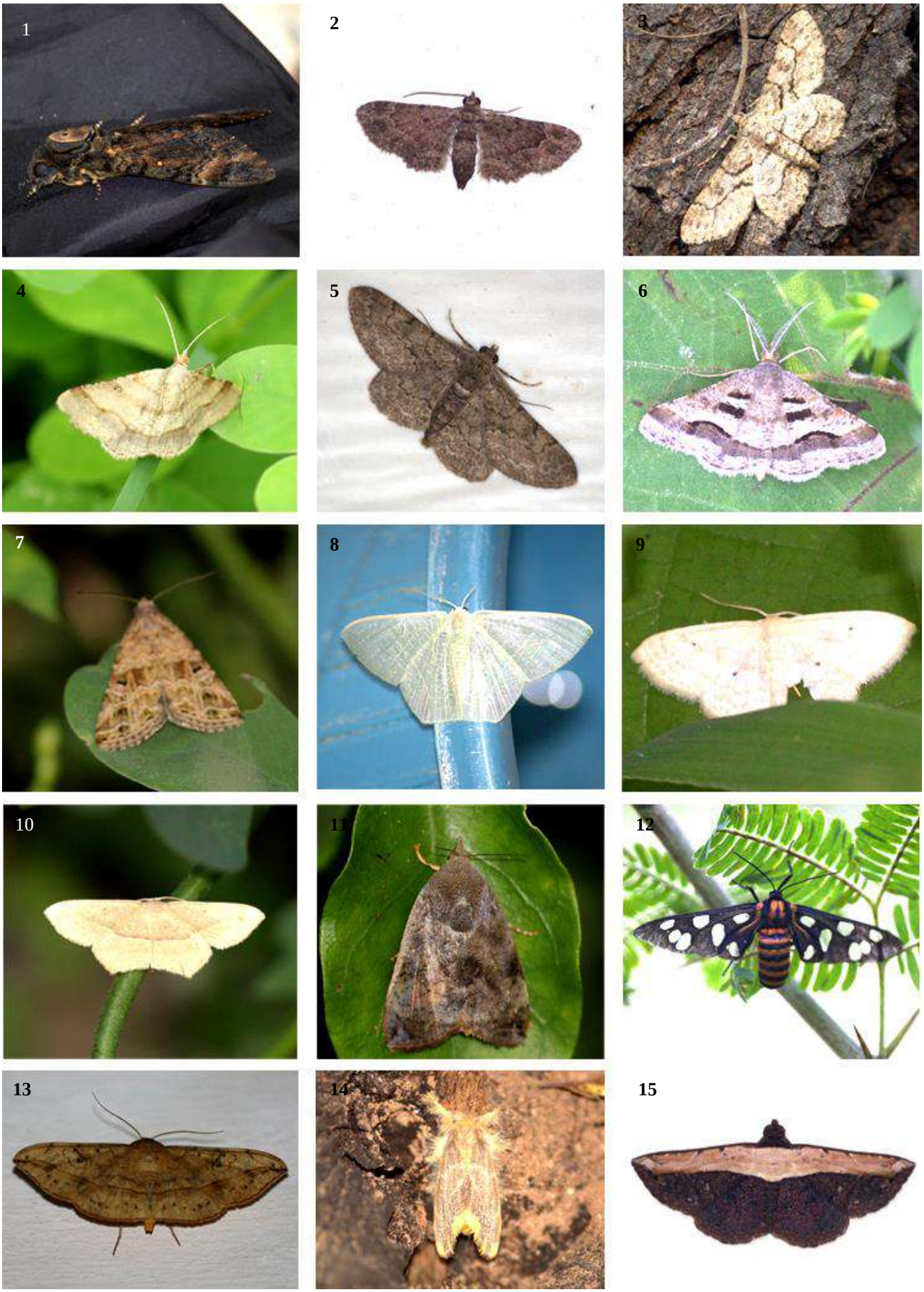

Plate A: 1. *Acherontia Lachesis*, **2.** *Calluga costalis*, **3.** *Cleora* sp, **4.** *Hyperythra lutea*, **5.** *Hypomecis transcissa*, **6.** *Isturgia disputaria*, **7.** *Odontopera kametaria*, **8.** *Pelagodes* sp., **9.** *Scopula* sp., **10.** *Traminda mundissima*, **11.** *Hyblaea puera*, **12.** *Amata passalis*, **13.** *Anticarsia irrorata*, **14.** *Artaxa guttata*, **15.** *Ataboruza divisa.*

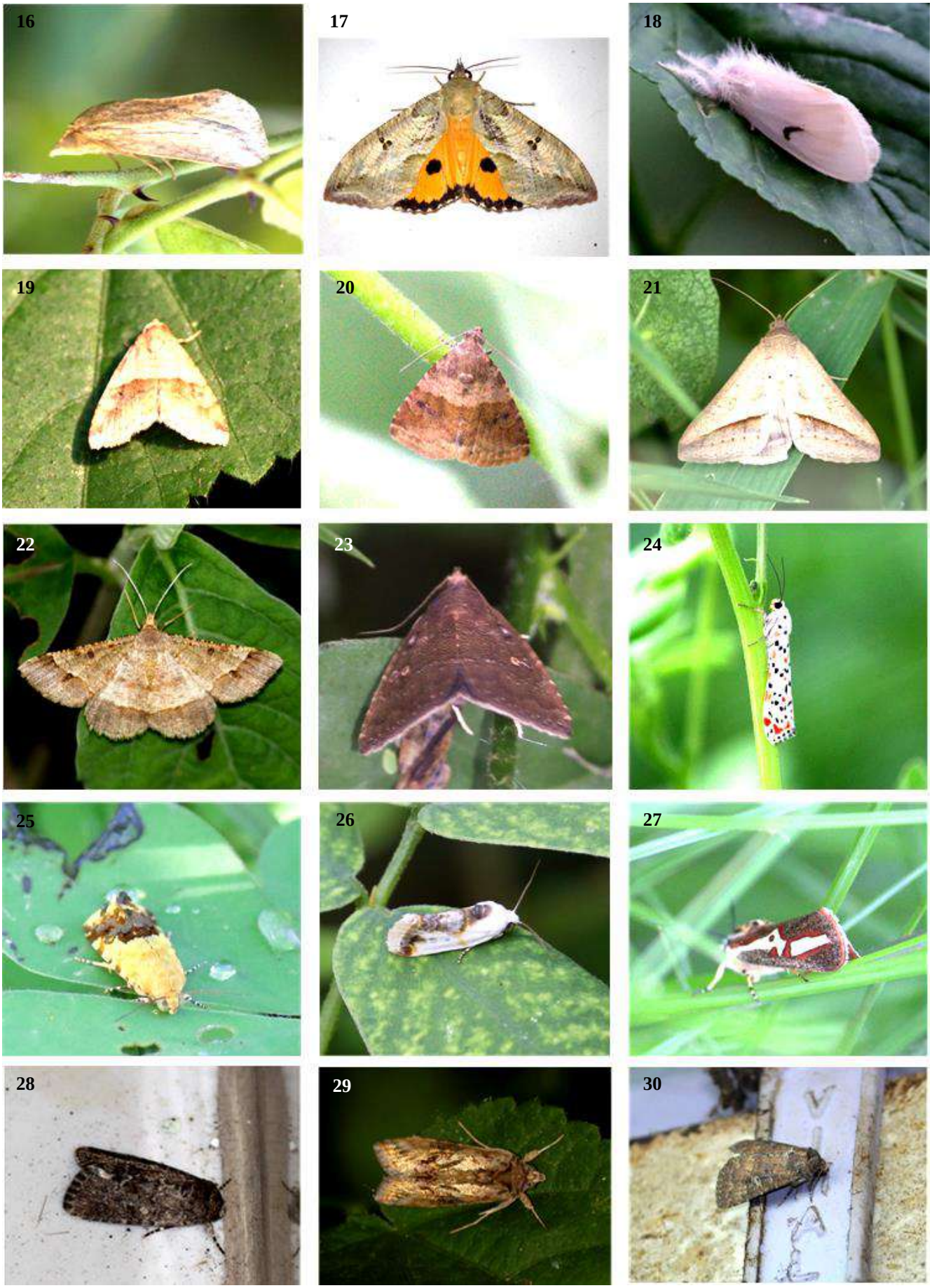

Plate B: 16. *Culasta indecisa*, **17.** *Eudocima materna*, **18.** *Euproctis lunata*, **19.** *Anomis involuta*, **20.** *Hipoepa fractalis*, **21.** *Mocis frugalis*, **22.** *Mocis undata*, **23.** *Plecoptera recta*, **24.** *Utetheisa pulchelloides*, **25.** *Acontia crocata*, **26.** *Acontia lucida*, **27.** *Aegocera venulia*, **28.** *Amyna axis*, **29.** *Anadevidia peponis*, **30.** *Spodoptera exigua.*

Plate C: 31. *Spodoptera litura*, 32. *Carea angulata*, 33. *Westermannia superba*, 34. *Pelopidas mathias*, 35. *Spialia galba*, 36. *Azanus jesous*, 37. *Azanus ubaldus*, 38. *Castalius rosimon*, 39. *Catochrysops strabo*, 40. *Chilades pandava*, 41. *Leptotes plinius*, 42. *Spindasis vulcanus*, 43. *Tarucus nara*, 44. *Zizeeria karsandra*, 45. *Danaus chrysippus.*

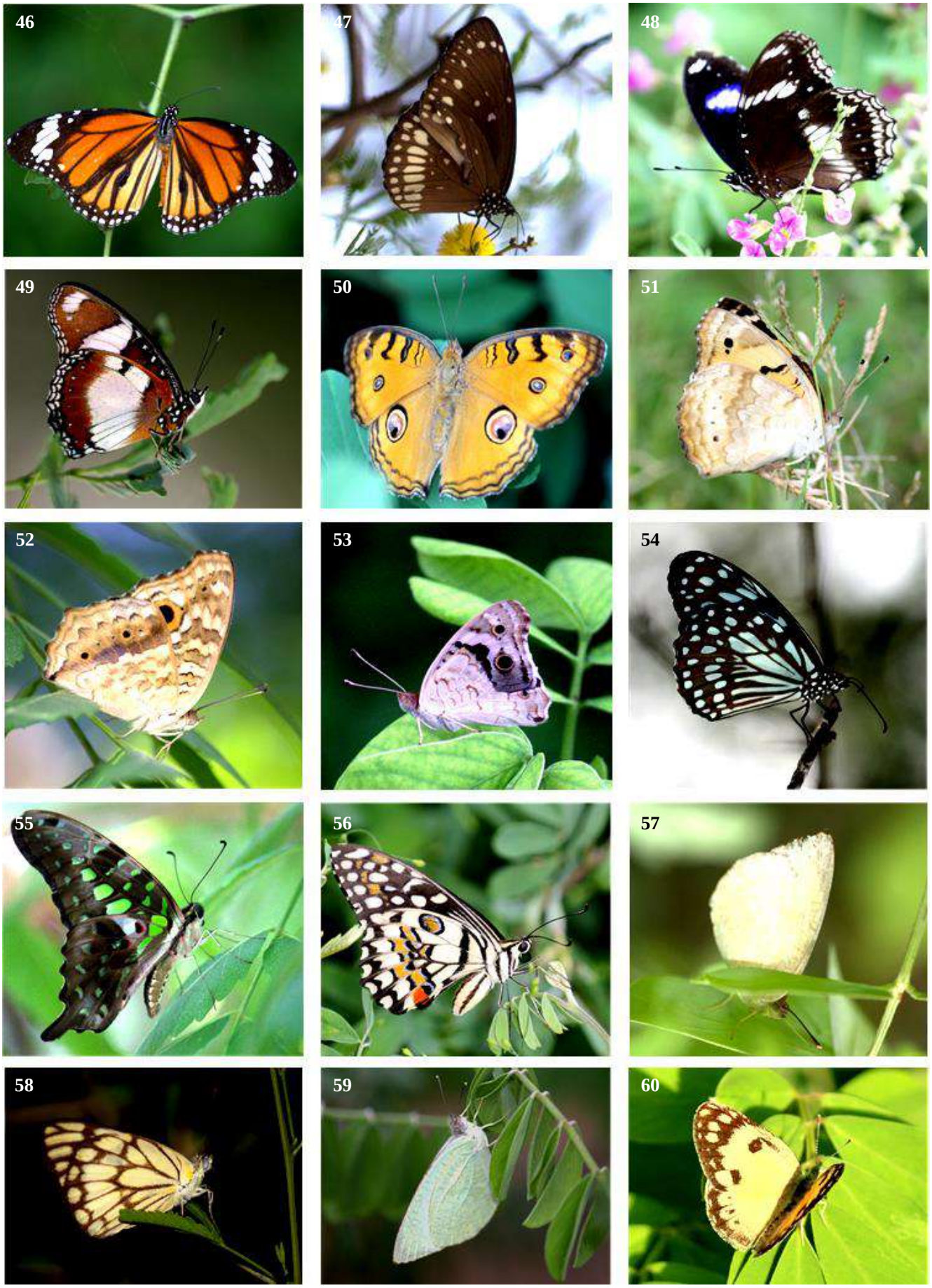

Plate D: 46. *Danaus genutia*, **47.** *Euploea core*, **48.** *Hypolimnas bolina*, **49.** *Hypolimnas misippus*, **50.** *Junonia almana*, **51.** *Junonia hierta*, **52.** *Junonia lemonias*, **53.** *Junonia orithya*, **54.** *Tirumala limniace*, **55.** *Graphium agamemnon*, **56.** *Papilio demoleus*, **57.** *Appias libythea*, **58.** *Belenois aurota*, **59.** *Catopsilia pyranthe*, **60.** *Colotis amata.*

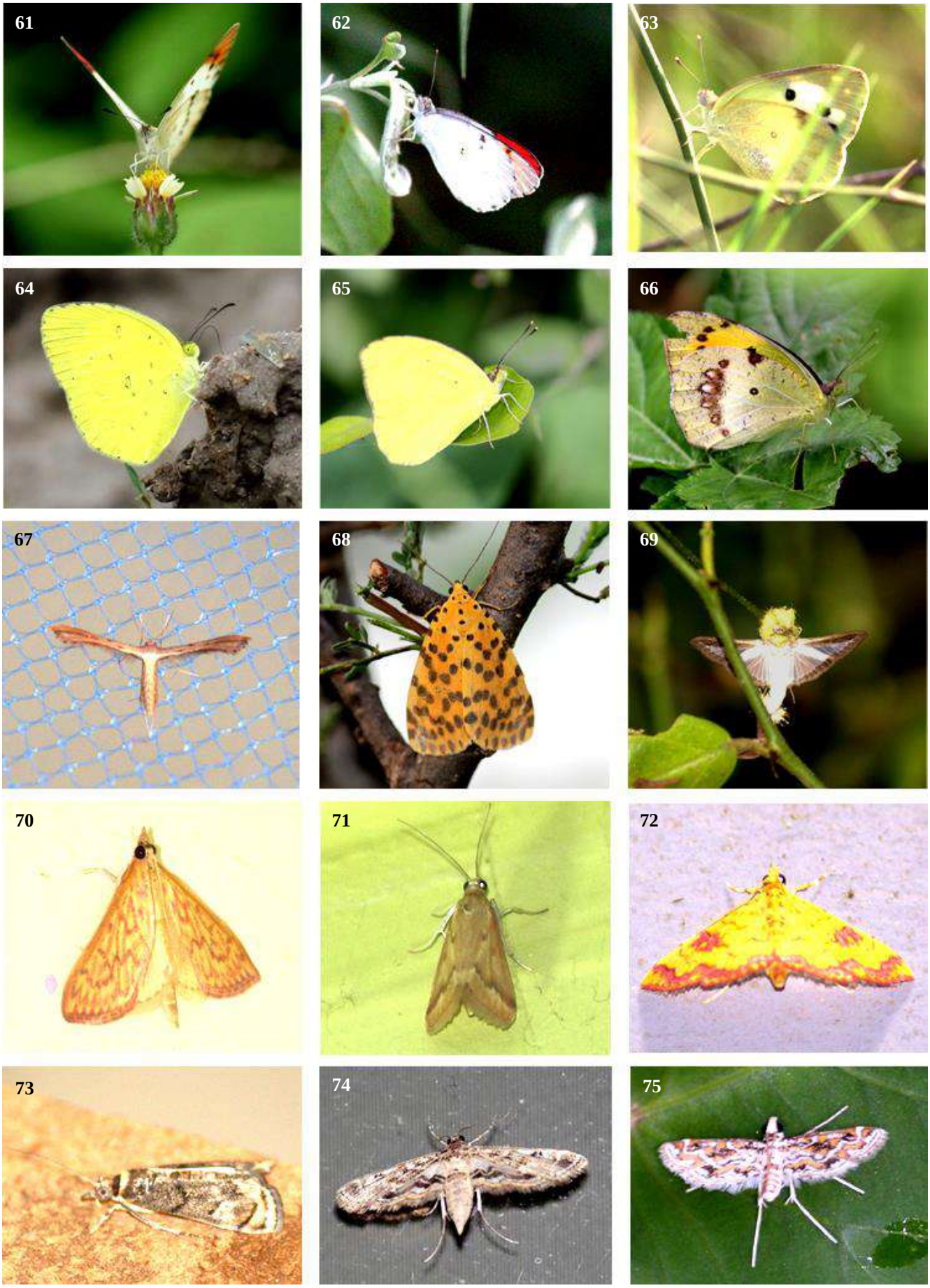

Plate E: 61. *Colotis aurora*, **62.** *Colotis danae*, **63.** *Colotis vestalis*, **64.** *Eurema hecabe*, **65.** *Eurema laeta*, **66.** *Ixias marianne*, **67.** *Sphenarches anisodactyla*, **68.** *Conogethes punctiferalis*, **69.** *Diaphania indica*, **70.** *Ecpyrrhorrhoe damastesalis*, **71.** *Ecpyrrhorrhoe sp.*, **72.** *Isocentris filalis*, **73.** *Noorda blitealis*, **74.** *Paracymoriza vagalis*, **75.** *Parapoynx fluctuosalis.*

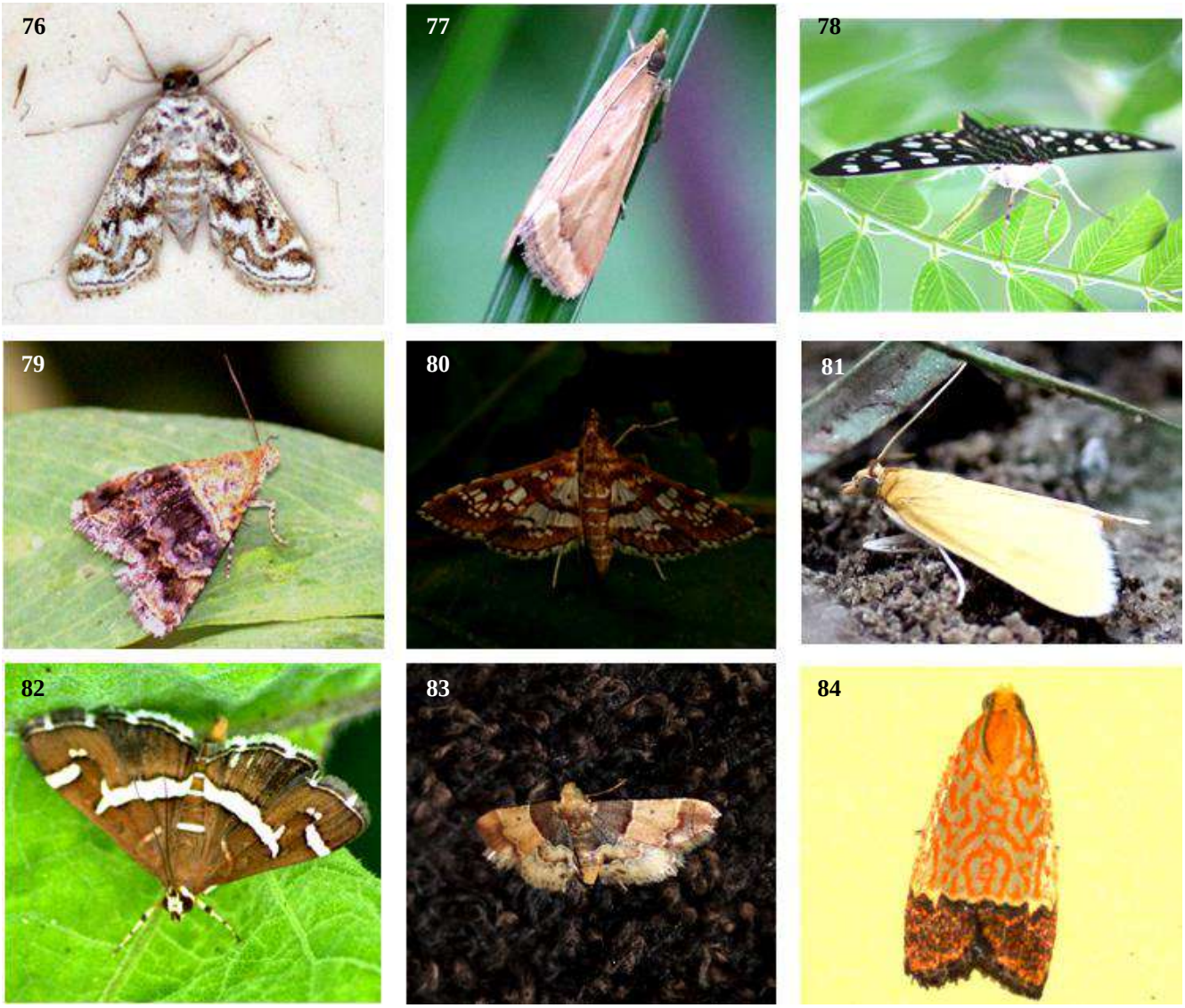

Plate F: 76. *Parapoynx stagnalis,* **77.** *Autocharis fessalis,* **78.** *Pygospila tyres,* **79.** *Pyrausta phoenicealis,* **80.** *Sameodes cancellalis,* **81.** *Scirpophaga incertulas,* **82.** *Spoladea recurvalis,* **83.** *Syngamia latimarginalis,* **84.** *Loboschiza koenigiana.*

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