DIVERSITY AND DISTRIBUTION OF MOTH ASSEMBLAGES ALONG ALTITUDINAL GRADIENT IN GANGOTRI LANDSCAPE

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ABESH KUMAR SANYAL

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Wildlife Institute of India

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Summary

I. General Introduction

Among the challenging issues in insect conservation is to establish the extent of diversity of the insect world, at species, community, and habitat levels. Given the limitation of time and resources, it would be wiser to focus on some target taxa which have the potential to be used as flagships. Lepidoptera, being charismatic invoke the vertebrate approach to insect conservation. But as compared to butterflies, moths have long been regarded as “poor cousins” and have lagged well behind butterflies in popularity and in the attention given to their conservation status and needs. Keeping in view these perspectives, this study intends to document the extent of moth assemblages that exist amongst various habitats in a typical Western Himalayan altitudinal gradient in Gangotri Landscape Area (GLA).

In this study, using the elevation gradient as natural experiment, the faunal structure and diversity of the moth assemblage featuring all the major macro and micromoth families as well as relationships between moths and their biotic and abiotic environments were explored. Specific objectives of the study were: (1) Documenting and prepare taxonomic inventory of rich moth fauna of Gangotri Landscape Area; (2) To assess diversity and distribution of moth assemblages among different elevations and vegetation types of Gangotri Landscape; (3) To analyze the influence of altitude, seasons, vegetation types and anthropogenic disturbance factors on moth assemblages; (4) To investigate morphometric changes (body size and proportional body parts) in moths along altitudinal gradient.

II. Materials & Methods

The study was conducted in Gangotri Landscape Area (GLA), a vast conservation network in the North-Western part of Uttarakhand, in district Uttarkashi. This typical Western Himalayan landscape occupies over 4000km^2 areas bounded in the west by state Himachal Pradesh and in the north by Tibetan Autonomous Region of China. The GLA represents the Biogeographic zone 2B, West Himalaya and covers three high altitude protected areas, Gangotri National Park, Govind National Park and Govind Wildlife Sanctuary. Stratified Random sampling strategy was adopted where along a

transect ranging from lowest to highest altitude, random sites were selected at every 200m vertical distance. At every altitudinal site, one or two light trap stations were established and at each site, two to three nightly catches were performed until at least 50 individuals were sampled. For the abiotic factors governing moth diversity like ambient temperature, relative humidity, wind speed, cloud cover etc. data was collected during light trapping. Additionally rainfall data was collected from Meteorological department. The biotic factors suspected to govern moth diversity like vegetation and anthropogenic disturbances were recorded in nested quadrates of 20 meter^2 surrounding light trapping stations. Moths were collected using a light trap running for 4 hours, in two sessions at a particular site for two consecutive nights. Light traps were set using a solar powered lantern equivalent to 80 Watt White Actinic bulb and gas petromax equivalents to 160 Watt Mercury vapour (MV) bulb. Collected specimens were retained as voucher material and later identified in Zoological Survey of India, Jabalpur and Kolkata.

III. Faunistic Inventory of Moths in Gangotri Landscape Area

A total of 670 morphospecies belonging to 22 families and 356 genera were collected during entire sampling period from 2008-2012. Of these, 351 species (48% of all species) representing 277 genus were identified as valid species. Family Tineidae or fungus moths were represented by 1 genus and 2 species. Family Pterophoridae or plume moths were represented by 3 species and 3 genera. Totricidae or codling moths were represented by 19 morphospecies among which 3 genera were identified. Family Pyralidae were represented by three subfamilies, Epipaschiinae (2 species), Phycitinae (1 species) and Pyraliinae (5 species). Another family of superfamily Pyraloidea, Crambidae or grass moths were represented by 5 subfamilies; Musotiminae (1 species), Nymphulinae (1 species), Pyraustinae (2 species), Crambinae (2 species) and Spilomelinae (20 species). Superfamily Zyganoidea and family Zyganidae was represented by a single species. Superfamily Cossoidea was represented by family Cossidae (2 species) and Limacodidae (6 species). The superfamily Uraniodea contained one family, Uraniidae, with two subfamilies, Microniinae (1 species) and Epiplemiinae (2 species). Family Geometridae was the most diverse family with 5 subfamilies: Ennominae (39 genera and 59 species), Geometrinae (13 genera and 18 species), Larentiinae (22 genera and 28 species), Sterrhinae (6 genera and 7 species) and Desmobathrinae (1 species). Family Drepanidae was represented by 12 genera and 12 species. Superfamily Bombycoidea was represented by five families: Bombycidae (2

genera and 2 species), Eupterotidae (2 genera and 2 species), Lasiocampidae (5 genera and 5 species), Brahmaeidae (1 species) and Saturniidae (3 genera and 4 species). Family Sphingidae or Hawk moths were represented by 3 subfamilies, Macroglossinae (7 genera, 10 species), Smerinthinae (5 genera and 5 species) and Sphinginae (2 genera and 2 species). Superfamily Noctuoidea was represented by 5 families: Notodontidae (16 genera and 17 species); Erebidae having 4 subfamilies, Lymantriinae (8 genera 9 species), Arctiinae (17 genera and 33 species), Catocaliinae (11 genera and 12 species) and Calpinae (7 genera and 7 species); Euteliidae (1 species); Nolidae (3 genera and 3 species) and Noctuidae having 9 subfamilies, Plusiinae (5 genera 6 species), Acontiinae (1 species), Acronictinae (3 genera and 4 species), Cuculliinae (2 genera and 2 species), Amphipyrinae (1 genus, 2 species), Agaristinae (3 genera and 3 species), Heliothinae (3 genera and 3 species), Hadeninae (13 genera 18 species), Noctuinae (9 genera and 15 species) and 4 species of unassigned subfamilies. The complete species inventory is provided here:

Order: Lepidoptera
Suborder: Glossata
Infraorder: Heteroneura
Clade: Ditrysia
SUPERFAMILY: TINEOIDEA
Family: Tineidae Latreille, 1810

1. *Opogona flavofasciata* (Stainton, 1859) **(New record to Uttarakhand)**
2. *Opogona theobroma* Bradley, 1956 **(New record to Uttarakhand)**

Family: Pterophoridae Zeller, 1841

3. *Buckleria paludum* (Zeller, 1841) **(New record to Uttarakhand)**
4. *Deuterocopus socotranus* Rebel, 1907 **(New record to Uttarakhand)**
5. *Diacrotricha fasciola* Zeller, 1851 **(New record to Uttarakhand)**

Clade: Apoditrysia
SUPERFAMILY: TORTRICOIDEA
Family: Tortricidae Latreille, 1803

6. *Clepsis* sp.
7. *Homana* sp.
8. *Dynatocephala omophaea* (Meyrick, 1926) **(New record to Uttarakhand)**

Clade: Obtectomera
SUPERFAMILY: PYRALOIDEA
Family: Pyralidae Latreille, 1802
Subfamily: Epipaschiinae

9. *Macalla* sp.
10. *Lista haraldusalis* (Walker, 1858) **(New record to Uttarakhand)**

Subfamily Phycitinae

11. *Epicrocis hilarella* Ragonot, 1888 **(New record to Uttarakhand)**

Subfamily: Pyralinae

12. *Diloxia fimbriata* Hampson, 1896 **(New record to Uttarakhand)**
13. *Endotricha olivacea*lis (Bremer, 1864) **(New record to Uttarakhand)**
14. *Orybina flaviplaga* Walker, 1863
15. *Sacada discinota* (Moore, 1866) **(New record to Uttarakhand)**
16. *Orthopygia igniflualis* (Walker, 1859) **(New record to Uttarakhand)**

Family: Crambidae Latreille, 1810

Subfamily: Musotiminae

17. *Cymoriza ustalis* Walker, 1865 **(New record to Uttarakhand)**

Subfamily: Nymphulinae

18. *Eoophyla peribocalis* (Walker, 1859)

Subfamily: Pyraustinae

19. *Herpetogramma luctuosalis* (Guenée, 1854)
20. *Hyaloplaga pulchralis* Moore, 1867

Subfamily: Crambinae

21. *Euchromius ocellea* (Haworth, 1811)
22. *Ancylolomia* sp.

Subfamily: Spilomelinae

23. *Cirrhochrista brizoalis* (Walker, 1859)
24. *Cotachena histricalis* (Walker, 1859) **(New record to Uttarakhand)**
25. *Dichocrocis definita* (Butler, 1889)
26. *Dysallacta negatalis* (Walker, 1859) **(New record to Uttarakhand)**
27. *Endocrossis flavibasalis* (Moore, 1867) **(New record to Uttarakhand)**
28. *Glyphodes crithealis* (Walker, 1859)
29. *Glyphodes bivitralis* Guenée, 1854
30. *Goniorhynchus signatalis* (Walker, 1866)
31. *Lamprosema commixta* (Butler, 1879) **(New record to Uttarakhand)**
32. *Nomophila noctuella* (Denis & Schiffermüller, 1775)
33. *Omiodes noctescens* (Moore, 1888) **(New record to Uttarakhand)**
34. *Pleuroptya balteata* (Fabricius, 1798) **(First time record from India)**
35. *Pleuroptya quadrimaculalis* (Kollar, 1844)
36. *Pleuroptya ruralis* (Scopoli, 1763) **(New record to Uttarakhand)**
37. *Polygrammodes sabelialis* Guenée, 1854 **(New record to Uttarakhand)**

38. *Sameodes cancellalis* (Zeller, 1852) **(New record to Uttarakhand)**
39. *Spoladea recurvalis* (Fabricius, 1775)
40. *Syllepte verecunda* (Warren, 1896)
41. *Syngamia falsidicalis* (Walker, 1859)
42. *Terastia egialealis* (Walker, 1859)
43. *Dichocrocis punctiferalis* (Guenée, 1854)

SUPERFAMILY: ZYGAENOIDEA

Family: Zygaenidae Latreille, 1809

44. *Chalcosia suffusa* Leech, 1898

Cade: Macroheterocera

SUPERFAMILY COSSOIDEA

Family Cossidae Leach, 1815

45. *Xyleutes strix* (Linnaeus, 1758)
46. *Zeuzera multistrigata* Moore, 1881

Family Limacodidae Duponchel 1845

47. *Altha subnotata (Walker, 1865)*
48. *Chalcoscelides castaneipars* (Moore, 1865)
49. *Miresa albipuncta* (Herrich-Schäffer, 1854)
50. *Phocoderma velutina* (Kollar, 1844)
51. *Scopelodes unicolor* Westwood 1841
52. *Scopelodes venosa* Walker, 1855

SUPERFAMILY: URANIOIDEA

Family: Uraniidae Blanchard, 1845

Subfamily: Microninae

53. *Micronia aculeata* Guenée, 1857

Subfamily Epiplemiinae

54. *Orudiza protheclaria* Walker, 1861
55. *Epiplema bicaudata* Moore, 1867

SUPERFAMILY GEOMETROIDEA

Family: Geometridae Leach, 1815

Subfamily: Ennominae

56. *Abraxas peregrina* Inoue, 1995
57. *Abraxas irrorata* Moore, 1867
58. *Abraxas sylvata* (Scopoli, 1763)
59. *Abraxas picaria* Moore, 1868
60. *Anonychia lativitta* (Moore, 1888)
61. *Anonychia violacea* Moore, 1888 **(New record to Uttarakhand)**
62. *Biston bengaliaria* (Guenée, 1857)
63. *Biston falcata* (Warren, 1893) **(New record to Uttarakhand)**

64. *Buzura suppressaria* (Guenée, 1858)
65. *Psilalcis inceptaria* (Walker, 1866) **(New record to Uttarakhand)**
66. *Phthonandria atrilineata* (Butler, 1881)
67. *Menophra bicornuta* Inoue, 1990
68. *Menophra subplagiata* (Walker, 1860)
69. *Medasina interruptaria* (Moore, 1867) **(New record to Uttarakhand)**
70. *Medasina albidaria* (Walker, 1866)
71. *Medasina cervina* (Warren, 1893) **(New record to Uttarakhand)**
72. *Thinopteryx crocoptera* Kollar, 1844
73. *Elphos pardicelata* Walker, 1862
74. *Erebomorpha fulguraria* Walker, 1860 **(New record to Uttarakhand)**
75. *Fascellina plagiata* (Walker, 1866)
76. *Hirasa muscosaria* (Walker, 1866)
77. *Ourapteryx convergens* Warren 1897 **(New record to Uttarakhand)**
78. *Ourapteryx sciticaudaria* Walker 1862
79. *Ourapteryx ebuleata* (Guenée, 1858)
80. *Arichanna tenebraria* (Moore, 1867) **(New record to Uttarakhand)**
81. *Gnophos albidior* (Hampson, 1895) **(New record to Uttarakhand)**
82. *Heterolocha phoenicotaeniata* (Kollar, 1844)
83. *Hypomecis ratotaria* (Swinhoe, 1894) **(New record to Uttarakhand)**
84. *Loxaspilates hastigera* Butler, 1889 **(New record to Uttarakhand)**
85. *Semiothisa nora* (Stoll, 1780)
86. *Semiothisa sufflata* (Guenée, 1858)
87. *Xandrames latiferaria* (Walker, 1860)
88. *Odontopera heydena* (Swinhoe, 1894) **(New record to Uttarakhand)**
89. *Odontopera lentiginosaria* (Moore, 1867) **(New record to Uttarakhand)**
90. *Odontopera obliquaria* (Moore, 1867)
91. *Odontopera kametaria* (Felder, 1873)
92. *Heterocallia temeraria* (Swinhoe, 1891)
93. *Peratophyga hyalinata* (Kollar, 1844)
94. *Percnia belluaria* Guenée, 1858
95. *Plagodis inustaria* (Moore, 1867) **(New record to Uttarakhand)**
96. *Plagodis reticulata* Warren, 1893
97. *Pseudomiza cruentaria* (Moore, 1867)
98. *Pseudopanthera himaleyica* (Kollar, 1848)
99. *Psyra similaria* Walker, 1866

100. *Psyra debilis* Warren, 1888 **(New record to Uttarakhand)**
101. *Psyra falcipennis* Yazaki, 1994 **(First time record from India)**
102. *Psyra angulifera* Walker, 1866
103. *Hyperythra lutea* (Stoll 1781)
104. *Ophthalmitis herbidaria* (*Guenée, 1858)*
105. *Opisthograptis sulphurea* (Butler, 1880) **(New record to Uttarakhand)**
106. *Opisthograptis tridentifera* (Moore, 1888) **(New record to Uttarakhand)**
107. *Sirinopteryx rufivinctata* (Walker, 1862) **(New record to Uttarakhand)**
108. *Stenorumia* sp.
109. *Tanaoctenia haliaria* (Walker, 1861) **(New record to Uttarakhand)**
110. *Luxiaria* sp.
111. *Zeheba* sp.
112. *Krananda* sp.
113. *Lomographa* sp.
114. *Heterostegane subtessellata* Walker 1862

Subfamily: Geometrinae

115. *Agathia hemithearia* Guenée, 1857
116. *Chlorissa gelida* (Butler, 1889)
117. *Hemithea tritonaria* (Walker, 1863)
118. *Chlorissa distinctaria* (Walker, 1866)
119. *Chlorochaeta inductaria* (Guenée, 1857) **(New record to Uttarakhand)**
120. *Chlorochaeta quadrinotata* (Butler 1889)
121. *Chlorochaeta pictipennis* (Butler, 1880) **(New record to Uttarakhand)**
122. *Comostola subtiliaria* (Bremer, 1864)
123. *Anisozyga gavissima* (Walker, 1861)
124. *Herochroma cristata* (Warren, 1894)
125. *Aporandria specularia* (Guenée, 1857)
126. *Mixochlora vittata* (Moore, 1867)
127. *Ornithospila avicularia* (Guenée, 1857)
128. *Pingasa rubicunda* Warren, 1894 **(New record to Uttarakhand)**
129. *Pingasa alba* Swinhoe, 1891
130. *Pingasa ruginaria* Guenée, 1857
131. *Tanaorhinus reciprocata* (Walker, 1861)
132. *Thalassodes veraria* Guenée, 1857

Subfamily: Larentiinae

133. *Photoscotosia miniosata* (Walker, 1862)
134. *Photoscotosia multilinea* Warren, 1893 **(New record to Uttarakhand)**

135. *Photoscotosia amplicata* (Walker, 1862)
136. *Photoscotosia metachryseis* Hampson, 1896 **(New record to Uttarakhand)**
137. *Laciniodes plurilinearia* (Moore, 1867)
138. *Cidaria aurata* Moore, 1867 **(New record to Uttarakhand)**
139. *Docirava aequilineata* (Walker, 1863)
140. *Docirava pudicata* (Guenée, 1858*)*
141. *Ecliptopera postpallida* Prout, 1940 **(First time record from India)**
142. *Electrophaes recta* Yazaki, 1994 **(New record to Uttarakhand)**
143. *Euphyia coangulata* Prout, 1914 **(First time record from India)**
144. *Eupithecia rajata* Guenée, 1858
145. *Eustroma chalcoptera* (Hampson, 1895) **(New record to Uttarakhand)**
146. *Hydrelia bicolorata* (Moore, 1867) **(New record to Uttarakhand)**
147. *Stamnodes pamphilata* Felder, 1875 **(New record to Uttarakhand)**
148. *Trichopterigia rufinotata* (Butler, 1889) **(New record to Uttarakhand)**
149. *Triphosa rubrodotata* (Walker, 1862) **(New record to Uttarakhand)**
150. *Colostygia albigirata* (Kollar, 1844)
151. *Perizoma albofasciata* (Moore, 1888) **(New record to Uttarakhand)**
152. *Perizoma seriata* (Moore, 1888)
153. *Euphyia stellata* (Warren, 1893) **(New record to Uttarakhand)**
154. *Xanthorhoe hampsoni* Prout, 1925 **(New record to Uttarakhand)**
155. *Venusia crassisigna* Inoue, 1987 **(First time record from India)**
156. *Venusia roseicosta* Yazaki, 1994 **(First time record from India)**
157. *Heterothera dentifasciata* (Hampson, 1895) **(New record to Uttarakhand)**
158. *Dysstroma* sp.
159. *Chartographa* sp.
160. *Rheumaptera* sp.

Subfamily: Sterrhinae

161. *Scopula pulchellata* (Fabricius, 1794)
162. *Timandra griseata* Warren, 1897
163. *Rhodostrophia pelloniaria* (Guenée, 1858) **(New record to Uttarakhand)**
164. *Rhodometra sacraria* (Linnaeus, 1767)
165. *Problepsis vulgaris* Butler, 1889
166. *Problepsis albidior* Warren, 1899
167. *Chrysocraspeda olearia* Guenée 1857

Subfamily: Desmobathrinae

168. *Eumelea rosalia* Stoll, 1781

SUPERFAMILY: DREPANOIDEA

Family: Drepanidae Boisduval, 1828

169. *Agnidra discispilaria* Moore, 1867 **(New record to Uttarakhand)**
170. *Auzata semipavonaria* Walker, 1862
171. *Drepana pallida* Moore, 1879
172. *Tethea oberthueri* (Houlbert, 1921)
173. *Teldenia vestigiata* (Butler, 1880)
174. *Cyclidia substigmaria* (Hübner, 1825)
175. *Gaurena dierli* Werny, 1966 **(First time record from India)**
176. *Habrosyne conscripta* Warren, 1912 **(First time record from India)**
177. *Macrocilix mysticata* (Walker, 1863)
178. *Nordstromia duplicata* (Warren, 1922) **(New record to Uttarakhand)**
179. *Oreta pavaca* Moore, 1866
180. *Thyatira batis* (Linnaeus, 1758)

SUPERFAMILY: BOMBYCOIDEA

Family: Bombycidae Latreille, 1802

181. *Triuncina religiosae* Helfer, 1837
182. *Mustilia sphingiformis* Moore, 1879

Family: Eupterotidae Swinhoe, 1892

183. *Apona caschmirensis* (Kollar, 1844)
184. *Eupterote* sp.

Family: Lasiocampidae Harris, 1841

185. *Trabala vishnou* (Lefebvre, 1827)
186. *Gastropacha pardale* (Walker, 1855)
187. *Euthrix laeta* (Walker, 1855)
188. *Malacosoma indica* (Walker, 1855)
189. *Paralebeda plagifera* (Walker, 1855)

Family: Brahmaeidae Swinhoe, 1892

190. *Brahmaea wallichii* (Gray, 1831)

Family: Saturniidae Boisduval, 1837

191. *Antheraea assamensis* (Helfer, 1837)
192. *Caligula thibeta* (Westwood 1853)
193. *Antheraea paphia* (Linnaeus, 1758)
194. *Loepa katinka* (Westwood, 1848)

SUPERFAMILY: SPHINGOIDEA

Family: Sphingidae Latreille, 1802

Subfamily: Macroglossinae

195. *Acosmeryx anceus* (Stoll, 1781)
196. *Daphnis nerii* (Linnaeus, 1758)
197. *Hippotion boerhaviae* (Fabricius, 1775)
198. *Hippotion rosetta* (Swinhoe, 1892)
199. *Macroglossum bombylans* (Boisduval, 1875)
200. *Rhopalopsyche nycteris* (Kollar, 1844)
201. *Theretra alecto* (Linnaeus, 1758)
202. *Theretra nessus* (Drury, 1773)
203. *Theretra oldenlandiae* (Fabricius, 1775)
204. *Nephele comma* Hopffer, 1857

Subfamily: Smerinthinae

205. *Ambulyx* sp.
206. *Amplypterus panopus* (Cramer, 1779)
207. *Clanis stenosema* Rothschild & Jordan, 1907
208. *Leucophlebia lineata* Westwood, 1848
209. *Marumba sperchius* (Ménétriés, 1857)

Subfamily: Sphinginae

210. *Psilogramma increta* (Walker, 1864)
211. *Agrius convolvuli* (Linnaeus, 1758)

SUPERFAMILY: NOCTUOIDEA

Family: Notodontidae Stephens, 1829

212. *Allodonta sikkima* (Moore, 1879)
213. *Cyphanta xanthochlora* Walker, 1865
214. *Bireta longivitta* Walker, 1856
215. *Formofentonia orbifer* (Hampson, 1892)
216. *Gazalina apsara* (Moore, 1859)
217. *Oligoclona chrysolopha* (Kollar, 1844)
218. *Ginshachia gemmifera* (Moore, 1879)
219. *Homocentridia concentrica* (Oberthür, 1911) **(First time record from India)**
220. *Neodrymonia* sp.
221. *Phalera grotei* Moore, 1859
222. *Phalera sangana* Moore, 1859 **(New record to Uttarakhand)**
223. *Neopheosia fasciata* (Moore, 1888)
224. *Ptilodon saturata* (Walker, 1865) **(New record to Uttarakhand)**
225. *Semidonta biloba* Oberthür, 1880 **(First time record from India)**
226. *Rachia plumosa* Moore, 1879 **(New record to Uttarakhand)**

227. *Damata longipennis* Walker, 1855
228. *Tarsolepis remicauda* Butler, 1872 **(New record to Uttarakhand)**

Family: Erebidae Leach, 1815

Subfamily: Lymantriinae

229. *Arctornis comma* (Hutton, 1865)
230. *Somena scintillans* Walker, 1856
231. *Artaxa vitellina* (Kollar, 1848)
232. *Laelia exclamationis* (Kollar, 1848)
233. *Dasychira cerebosa* (Swinhoe, 1903) **(New record to Uttarakhand)**
234. *Lymantria concolor* Walker, 1855
235. *Lymantria mathura* Moore, 1865
236. *Himala argentea* (Walker, 1855)
237. *Leucoma clara* (Walker 1865) **(New record to Uttarakhand)**

Subfamily: Arctiinae

238. *Amsacta lactinea* (Cramer, 1777)
239. *Areas galactina* (Hoever, 1840)
240. *Areas imperialis* (Kollar, 1844)
241. *Argina astrea* (Drury, 1773)
242. *Asura calamaria* (Moore, 1888)
243. *Chrysorabdia bivitta* (Walker, 1856)
244. *Chrysorabdia viridata* (Walker, 1894)
245. *Creatonotos gangis* (Linnaeus, 1763)
246. *Creatonotos transiens* (Walker, 1855)
247. *Agylla beema* (Moore 1865) **(New record to Uttarakhand)**
248. *Agylla prasena* (Moore, 1859)
249. *Eilema caniola* (Hübner, 1827) **(First time record from India)**
250. *Eilema antica* (Walker, 1854)
251. *Estigmene quadriramosa* (Kollar, 1844)
252. *Utetheisa lotrix* (Cramer, 1779)
253. *Macrobrochis pallens* (Hampson, 1894)
254. *Miltochrista cuneonotata* (Walker, 1855) **(New record to Uttarakhand)**
255. *Panaxia principalis* (Kollar, 1844)
256. *Panaxia similis* (Moore, 1879) **(New record to Uttarakhand)**
257. *Sidyma albifinis* Walker 1856
258. *Spilosoma melli* (Daniel, 1943)
259. *Spilosoma casigneta* (Kollar, 1884)
260. *Spilosoma erythrozonata* (Kollar, 1844)

261. *Spilosoma obliqua* Walker, 1855
262. *Spilosoma strigatula* Walker, 1855
263. *Spilosoma unifascia* (Walker, 1855)
264. *Spilosoma punctaria* (Stoll, 1782) **(New record to Uttarakhand)**
265. *Spilosoma melanostigma* Erschoff, 1872
266. *Spilosoma leopardina* (Kollar, 1844)
267. *Chionaema coccinea* Moore 1878
268. *Chionaema peregrina* (Walker, 1854)
269. *Chionaema signa* Walker, 1854
270. *Ceryx imaon* (Cramer, 1780)

Subfamily: Catocalinae

271. *Anomis mesogona* (Walker, 1857)
272. *Arcte coerula* (Guenée, 1852)
273. *Bastilla acuta* (Moore, 1883)
274. *Bastilla crameri* (Moore, 1885)
275. *Catocala armandi* Ponj, 1888 **(First time record from India)**
276. *Dysgonia algira* Linnaeus, 1767
277. *Hypopyra vespertilio* (Fabricius, 1787)
278. *Ophiusa tirhaca* (Cramer, 1780)
279. *Remigia discios* (Kollar, 1848)
280. *Spirama retorta* (Clerck, 1764)
281. *Lagoptera juno* (Dalman, 1823)
282. *Trigonodes hyppasia* (Cramer, 1779)

Subfamily: Calpinae

283. *Bamra lepida* (Moore, 1867)
284. *Calesia haemorrhoa* Guenée, 1852
285. *Cymatophoropsis sinuata* (Moore, 1879)
286. *Ericeia pertendens* (Walker, 1858)
287. *Lacera procellosa* Butler, 1879
288. *Oraesia emarginata* (Fabricius, 1794)
289. *Othreis fullonia* (Clerck, 1764) **(New record to Uttarakhand)**

Family: Euteliidae Grote, 1882

290. *Eutelia adulatrix* (Hübner, 1813)

Family: Nolidae Hampson, 1894

291. *Gabala argentata* Butler, 1878 **(New record to Uttarakhand)**
292. *Risoba prominens* Moore, 1881

293. *Xanthodes transversa* (Guenée, 1852)

Family: Noctuidae Latreille, 1809

Subfamily: Plusiinae

294. *Autographa nigrisigna* (Walker, 1857)

295. *Autographa purpureofusa* (Hampson, 1894) **(New record to Uttarakhand)**

296. *Chrysodeixis acuta* (Walker, 1857)

297. *Erythroplusia pyropia* (Butler, 1879)

298. *Plusiopalpa dichora* Holland, 1894

299. *Thysanoplusia orichalcea* (Fabricius, 1775)

Subfamily: Acontiinae

300. *Pseudeustrotia dimera* (Hampson, 1910) **(New record to Uttarakhand)**

Subfamily: Acronictinae

301. *Auchmis indica* (Walker, 1865)

302. *Diphtherocome fasciata* (Moore, 1888)

303. *Diphtherocome pallida* (Moore, 1867)

304. *Nacna malachite* (Oberthür, 1880) **(New record to Uttarakhand)**

Subfamily: Cuculliinae

305. *Cucullia pullata* (Moore, 1881)

306. *Valeriodes heterocampa* (Moore, 1882) **(New record to Uttarakhand)**

Subfamily: Amphipyrinae

307. *Amphipyra monolitha* Guenée, 1852

308. *Amphipyra cupreipennis* Moore, 1882 **(New record to Uttarakhand)**

Subfamily: Agaristinae

309. *Mimeusemia peshwa* (Moore, 1859)

310. *Episteme lectrix* (Linnaeus, 1764)

311. *Aegocera bimacula* Walker, 1854 **(New record to Uttarakhand)**

Subfamily: Heliothinae

312. *Helicoverpa armigera* (Hübner, 1827)

313. *Aspila peltigera* (Schiffermüller, 1776)

314. *Pyrrhia umbra* (Hüfnagel, 1766)

Subfamily: Hadeninae

315. *Anapoma albicosta* (Moore, 1881)

316. *Apamea aquila* Donzel, 1837

317. *Callopistria albolineola* (Graeser, 1888)

318. *Callopistria placodoides* (Guenée, 1852) **(New record to Uttarakhand)**

319. *Callopistria repleta* Walker, 1857

320. *Callopistria rivularis* Walker, 1858

321. *Euplexia plumbeola* Hampson, 1894 **(New record to Uttarakhand)**

322. *Euplexia semifascia* (Walker, 1865)
323. *Euplexia tibetensis* Warren, 1912 **(First time record from India)**
324. *Ebertidia haderonides* Boursin, 1968 **(First time record from India)**
325. *Haderonia culta* (Moore, 1881) **(New record to Uttarakhand)**
326. *Heliophobus texturata* (Alphéraky, 1892) **(First time record from India)**
327. *Leucania compta* Moore, 1881 **(New record to Uttarakhand)**
328. *Lophotyna albosignata* (Moore, 1881)
329. *Phlogophora subpurpurea* Leech, 1900 **(First time record from India)**
330. *Polia scotochlora* Kollar, 1848
331. *Prospalta leucospila* Walker, 1857 **(New record to Uttarakhand)**
332. *Spodoptera littoralis* (Boisduval, 1833)

Subfamily: Noctuinae

333. *Chersotis* sp.
334. *Diarsia albipennis* (Butler, 1889)
335. *Diarsia nigrosigna* (Moore, 1881)
336. *Hermonassa consignata* Walker, 1865 **(New record to Uttarakhand)**
337. *Hermonassa incisa* Moore, 1882 **(New record to Uttarakhand)**
338. *Hermonassa sinuata* Moore, 1881 **(New record to Uttarakhand)**
339. *Ochropleura triangularis* Moore, 1867
340. *Ochropleura flammatra* (Denis & Schiffermüller, 1775)
341. *Trichoridia hampsoni* (Leech, 1900)
342. *Xestia bdelygma* (Boursin, 1963) **(First time record from India)**
343. *Xestia angara* Hacker & Peks, 1990
344. *Xestia junctura* Moore, 1881
345. *Estimata clavata* (Hampson, 1907) **(New record to Uttarakhand)**
346. *Euxoa hypochlora* Boursin, 1964 **(First time record from India)**
347. *Agrotis ipsilon* (Hüfnagel, 1766)

Subfamily: Unassigned

348. *Axylia renalis* Moore, 1881
349. *Bryopolia centralasiae* (Staudinger, 1882) **(New record to Uttarakhand)**
350. *Dasypolia atrox* Hacker & Peks 1993
351. *Anaplectoides perviridis* (Warren, 1912) **(First time record from India)**

The species compilation with their specific altitude and habitat information provided in this chapter produces an initial baseline data which if accessible to wide range of users, will accelerate the rate of description, documentation and better understanding of Himalayan moth fauna.

IV. Alpha Diversity in different Altitude & Vegetation Zones

Knowledge of spatial diversity patterns is a key prerequisite for the development of effective strategies in biodiversity conservation. Using the diversity and characteristics of species assemblages found in different habitat types, the communities of moth assemblages in different vegetation classes was compared. A total of 10,869 adult moths representing 670 morphospecies in 22 families were recorded. Fisher's alpha was highest, 85.37±3.31 in 1400m-1900m, and lowest 48.02±1.75 in 2900-3400m. Observed and estimated species richness using Chao1 did not vary much, signifying that sampling was almost complete at local scale. As all the sites were sampled with different intensities, the rarefaction method was used as a suitable alternative for the diversity measure. Sampling inadequacy was evident in all the altitudinal zones, recoding highest number of species and individuals in 1400-1900m zone and in the 3000-3500m zone respectively. Within 5 vegetation types sampled Alpha diversity (Fisher's alpha) and Simpson's index were highest in Subtropical Pine Broadleaved Mix forest (80.89±3.56, 105.18±7.56) and Western Mix Coniferous forest (82.66±2.84, 108.23±2.4) and lowest in Subalpine forest (47.47±1.9, 62.36±2.94). The estimated total species richness using Chao1 was 673 ± 7.43 (SD), and using Jacknife2 691±5.29 (SD) for the complete sample. The ratio of observed to estimated (Chao1) number of species was 94% suggesting that at least 6% more species are to be expected in the area than were actually collected. From all species recorded, 144 were singletons (21% of all species) and 158 were doubletons (23% of all species). Along increasing altitude, Fisher's Alpha showed a continuously decreasing trend except a diversity peak in around 2700m, while abundance was lowest in lowest altitudinal levels sampled while it showed a continuously increasing trend with increasing altitude and having double peaks at around 2400m and 3300m. Overall the moth species assemblage was successful enough to tell apart one habitat type from other and their positioning reflected a gradual transition from lowest altitude habitat to higher ones with little overlapping with habitat types at next altitude level. The Global R statistics from ANOSIM from 1% threshold level was 0.27 with p=.0001 demonstrating that the overall difference between sites were large and statistically significant. Pair wise ANOSIM test showed most difference in species composition occurred between Pine Broadleaved Mixed forest and Subalpine Forest (R = 0.58, P = 0.0007). From SIMPER 18 species were identified which contributed around 50% to the difference between groups of sites of two most dissimilar habitats.

V. Factors Determining Distribution Pattern of Moths

The patterns of abundance fluctuations were not identical among the moth families along the altitudinal gradient and differential responses of moth ensembles were determined by different habitat parameters. Among 22 families of moth recorded, four major families were selected for analysis: majority of individuals were from family Geometridae (n=3646), Erebidae (n=1621), Noctuidae (n=1492) and Crambidae (n=498). The canopy cover had a positive influence on Erebidae species richness (0.713) and abundance (0.565) and Crambidae species richness (0.847) and abundance (0.810), diversity of overall moth assemblage (0.444). Average height and Average GBH of tree had significant negative effect on Noctuidae species richness and abundance. Grazing intensity had significant negative effect on Crambidae species richness (-0.524) and abundance (-0.477). Among all the synthetic environmental, vegetation and disturbance variables obtained from NMDS, the environmental axes had significant negative effect on the abundance of family Erebidae. The overall result of CCA was encouraging since it clearly explained the suits of environmental, vegetation and disturbance parameters which influenced the community composition and assemblage structure of moths, especially for Erebidae, Noctuidae and Crambidae. The data available on geometrid moths suggests that the family is more generalist as high diversity and abundance was recorded in all types of forest. Family Erebidae and Noctuidae were more specialized to reflect ecological differences between habitats. Noctuid moths responded more sensitively regarding anthropogenic disturbance factors. Small families like Crambidae were more influenced by grass cover and grazing related activities. Among 39 species selected as indicator based upon degree of specificity and fidelity for the five different forest types, 15 species met the indicator criteria, while 24 species met the criteria of detector species. Species with highest indicator percentage (87.1) was from subalpine forest. This very specialized habitat was also characterized by highest number of indicators as well as detectors, signifying an assemblage of species with high conservation values typifying the habitat itself. Proportion of Noctuidae species to Geometridae species increased significantly (r^2= 0.59, p=0.012) with increasing grazing intensity validating usefulness of this particular faunal index to indicate the level of grazing related disturbances in quick habitat assessment program. Overall, the moth assemblage structure and composition had much potential to be used as indicators

representing the quality of vegetation zones as well as anthropogenic disturbance altering them.

VI. Seasonal Variation of Moth Assemblage

Patterns in temporal variation of insect population abundances or community composition, and their underlying processes, are of major interest to ecologists. Moth assemblage reacts to changing season differently from butterflies owing to their nocturnal habit. In forest ecosystems, moths are mostly herbivores in their larval stage and are thus particularly sensitive to environmental changes that affect plant quality and quantity as their diets. Broadly the study area showed occurrence of four main seasons: Summer or Pre-Monsoon from mid April to mid June. Monsoon sets in from mid June and continues up to mid September. The Post-Monsoon season is from mid September to November. The remaining months of winter from December to March were not considered for analysis as light trapping was not possible in those months due to very low night temperature resulting in absolutely no nocturnal insect activity. In the study period (2011-2012), maximum rainfall occurred during month of July and August and minimum rainfall during January and October. Mean number of species and individuals caught per trap night was highest in the monsoon and lowest in post-monsoon. Alpha diversity measured as three different indices, was highest in monsoon in all the three altitudinal zones, viz. low, medium and high. In medium and low altitudes, diversity recorded was higher in pre-monsoon than post-monsoon. In lower altitude zone, the magnitude of difference between three seasons was less pronounced compared to other zones. Overall, moths were most abundant in monsoon season in high altitude. At the family level, mean relative abundances of most common Geometridae species were highest in middle altitude in pre-monsoon season; for Erebidae the mean relative abundance was highest in mid altitude in monsoon, whereas relative abundance of most common Noctuid species was highest at high altitude in monsoon. Pair wise ANOSIM test showed most difference in species composition occurred between monsoon and post-monsoon season ($R = 0.35$, $P = 0.0001$), while significant difference was also there between monsoon and pre-monsoon ($R = 0.2$, $P = 0.003$). The least difference was between pre and post-monsoon which was also insignificant ($R = 0.01$, $P = 0.39$).

The high-elevation moth communities were far more variable inter-annually. There is a clear indication that irrespective of habitat and taxonomic group considered, there was a

unimodal peak in moth activity with species richness and abundance at its highest during the monsoon season. The strikingly similar trend in annual rainfall pattern and the activity-peak in moth assemblage suggest that a seasonal correlation with rainfall is typical of moth communities.

VII. Changes in Body Size of Geometridae along Altitudinal Gradient

Body size distributions along altitudinal gradient are long been of interest in various studies with different group of animals. By investigating morphometric changes in body size and proportional body parts in moths along altitudinal gradient, the study attempted to add further insight into this much debated topic. Four morphometric characters were measured: (a) the forewing length (distance from wing base to apex), (b) maximum forewing width, (c) maximum thorax width/ body width, and (d) body length (distance from frons to tip of the abdomen). Measurements were performed with a calliper rule (Mitutoyo 0.05m, No.505-633) at a degree of accuracy of 1mm from specimens set in standard manner (wings spread at a right angle to the body axis). Only male specimens were measured and analyzed because sexes are often dimorphic in body size and males were much more abundant in the samples. Two different approaches were considered: first, in a structure-oriented approach, the pattern of major body size parameters with increasing altitude was seen, secondly, in a more taxa-specific approach, body size changes along elevation gradient were investigated among different subfamilies of Geometridae. Among nine variables considered for the correlation test, there was significant positive effect of altitude for only Fore Wing Length (FWL) (r=.127) and Maximum Forewing Width (MFW) (r=.108), other relationships being weaker. Regression between altitude and FWL of four Geometridae subfamilies revealed very consistent pattern. Correlations in Larentiinae and Geometriinae are significant where an increase of wingspan with increasing altitude is revealed. The relationships were not significant for Ennominae and Sterrhinae. Wingspan variability across sites tended to decrease in all the three taxa examined. Hence, while consistently increasing patterns of wingspan size can be found across the elevational gradient, in all the taxa there is a lower variability of wingspan at higher elevations compared to lower altitudes. Species rich Geometridae assemblage in Himalayan altitudinal gradient reveals that analysis of data of smaller and monophyletic units can be the first suitable step to show that body size relationships can be shaped by ecological and physiological constrains under the concept of Bergman's rule.

VIII. Synthesis & Perspectives

This study is an important step towards better understanding of a long-neglected but diverse and charismatic herbivorous insect assemblage in Himalayan temperate altitudinal gradient. Biogeographic pattern among sampled moth assemblages revealed domination of Indo-Malayan components. High percentage of Himalayan endemics among moth species suggested that this assemblage is long adapted to Himalayan climatic gradient and human or climate induced perturbations may threaten their future survival. About practicality of using light trap for sampling moth, it can be clearly said that this is the only method that enables a wide array of taxonomic groups to be sampled quantitatively in large numbers, though timing of light trapping should be carefully planned in Himalayan high altitudes, where some species are on wings for a very narrow window of time. Overall the study revealed moth assemblages has all the potential as model terrestrial insect group for monitoring wider changes in habitat quality and should be promoted for concurrent conservation management target.

CHAPTER I

GENERAL INTRODUCTION

1.1 Insect Conservation Perspectives

Insects, as the most diverse group of animals with which we share our world, add substantial variety and diversity to the extraordinary rare veneer of life on this biotic jewel we call Earth. Yet this insect diversity, the manifestation of millions of years of evolution, is under threat of attrition, as populations are lost, genetic diversity reduced, species go extinct, and the biomes and resources on which they depend succumb to human cupidity. It has been estimated that perhaps a quarter of all insect species are heading for extinction over the next few decades. In a mere blink of geological eyelid, the ecological impact of human is causing the demise of vast amount of earth's biodiversity. This variety not only has intrinsic value, but also may have much practical, utilitarian value which is only starting to be explored.

Among the challenging issues in insect conservation is to establish the extent of diversity of the insect world, at genetic, population, and species levels. We then need to know which components of that diversity are being lost from which habitats and from where in the world. Insect diversity is so great and the challenge of its conservation so urgent, often we need to put in place actions that, through some value judgment, will conserve as much variety as possible rather than to treat each component species individually. To do this, we may need to use surrogates, which stand in for much of the diversity which we cannot adequately measure.

Insects, and many other terrestrial invertebrates, present some special challenges, simply because they are so varied, so diverse, and so unknown. They are also very much part of the fabric of terrestrial and freshwater ecosystems as we know them, and indeed are often intimately associated with plants. The vast number of insect species, both described and undescribed, ensures their participation in an even greater number of food web interactions. Many of the interactions are highly specific, be they between herbivores and plants, predators and prey, or hosts and parasites. Our lack of detailed knowledge of the

biology of most species renders their contribution to such integrated scenarios very difficult to evaluate. The challenge of studying insects begin to multiply when we consider that many species can be sampled only during short periods of the year, and many disperse widely across landscape and may not reside in the area in which they are sampled. Furthermore, many are small, cryptic, and intrinsically difficult to find and study. These challenges differ greatly from those facing investigators of vertebrates and plants.

Past generation of entomologists have polished many of the traditional methods used to sample insects, largely through the transition of "collecting techniques" to more quantitative or standardized methods, with many new approaches and refinements continuing to be developed. Today, the purpose of sampling insects is not necessarily only for scientific advance. We now also sample insects for the purpose of ensuring that we conserve as much insect diversity as possible (Samways 2005). We do this for insects in their own right, as well as to conserve functionally important contribution that insects make to ecology and society.

1.2 Lepidoptera as Flagship Group for Insect Conservation

Knowledge of insects is uneven across different major taxonomic groups. Many groups are poorly documented, with knowledge unlikely to improve greatly in immediate future. In contrast, some insect groups are accepted as well-known and 'popular' - amongst these, Lepidoptera are paramount, this familiarity stemming largely from hobbyist interests, mainly collecting. Lepidoptera have a special place in human perception, culture and nature appreciation. 'Big colorful butterflies invoke the 'vertebrate' approach to Lepidoptera conservation because they are …. charismatic species that imply 'heroic' conservation measures should be taken ….' (Kitching 2007). In addition (a) many are themselves targets for individual species conservation and (b) many species or assemblages may be valuable 'tools' in being putative surrogates for wider conservation of the biotopes in which they occur. It is perhaps important to emphasize that, despite many advocacies for use of butterflies and, more rarely, of other Lepidoptera as indicators or surrogates, rather few studies have actually demonstrated this by statistical analyses (Fleishman & Murphy 2009).

Lepidoptera, as 'Ambassadors of biodiversity', fall unevenly into three major functional groups: 'butterflies', 'macromoths', 'microlepidoptera', as terms used widely amongst hobbyists. These groups differ greatly in attributes suitable for use as flagships. Butterflies tops the list because of (i) low species richness within a sound taxonomic framework so that many taxa are both recognizable and identifiable reliably; (ii) long history of collector interests based on aesthetic appeal and diurnal activity likely to have led to production of illustrated handbooks facilitating further interests; (iii) reasonable general framework of biological understanding and distributional information. These advantages are shared with some larger moths, mainly showy families such as Saturniidae (with economic benefits as additional advantage) and Sphingidae, or diurnal taxa that may be thought of as 'honorary butterflies' because they are visible. In contrast, many other macromoths are nocturnal and less accessible, and with Microlepidoptera, belong firmly to the largely unknown insects still viewed with considerable suspicion and for which knowledge is grossly inadequate to make any detailed case for species conservation need. Two practical problems are associated with moths for their inability to gain flagship status: (i) high numbers of unidentified or difficult to identify species and (ii) flagships are ideally conspicuous - most moths, being crepuscular or nocturnal in activity, are not seen as easily unless they are deliberately sought. Many people are largely unaware of them. In contrast, the conspicuousness of diurnal butterflies renders them far more accessible, with the greater interest contributing to greater knowledge. Far more people appreciate butterflies than appreciate moths, with one outcome being that reliable information on conservation status and needs is also markedly less for moths. Species accorded flagship status are a minute fraction of the total number of around 160,000 described Lepidoptera and an estimated 500,000 species that may exist (Kristensen *et al.* 2007). Only in parts of Europe is it currently possible to evaluate conservation status of many Microlepidoptera. Elsewhere, however, in any practical sense, moths are both unknown and unknowable as candidates for species-focused conservation. In Indian perspective also, butterfly taxonomy and distribution have been relatively well studied whereas moth study lacks significant additions since the work of Hampson, Bell and Scott in their "Fauna of British India" series (1892-1937) and Cotes and Swinhoe's "A Catalogue of Moths of India" (1886).

1.3 Literature Review on Moth Studies

1.3.1 Global Overview

Studies on moths started long back in the early 19th century. Hubner (1806-1823) described different species of *Zophodia, Palpita, Trichoplusia* etc. Boisduval (1829) contributed pioneer works on the description of Genus *Macroglossum, Asterocampa* and many more of the family Saturniidae. Subsequently, Herich-Schaffer (1854) published some records of Saturniidae from North America. Wallengren (1856 and 1860) described some moths of forests of Genus *Therisimima.* Felder (1874) described families Castiniidae, Saturniidae from Australia. Snellen (1890) described some species of Gracillariidae. In the early twentieth century, Forbes (1923) published a valuable document on the Lepidoptera of New York and neighboring countries.

From the late 20th century till date, J. D. Holloway did the most pioneering work on moths of south-east Asia. He published several family-wise volumes of literatures on the taxonomy of Bornean moths which are still considered to be the foremost references for any moth related work in Oriental region. In the 'Moths of Borneo' (1985-2011) volumes he provided detailed morphology with genital characters of Bornean moths. C. Z. Yang of Beijing Agricultural University published two volumes of 'Moths of Northern China' in 1978. H. S. Barlow (1982) published a taxonomic literature on the moths of south-east Asia. Common (1990) published the first comprehensive, illustrated book describing the diversity, distribution, larval host plants and behavior of Australian Moth. Ian J. Kitching of British Natural History Museum published an illustrated book on world Sphingid in the year 2000. Moths of Nepal were studied in detailed under the leadership of Haruta (1994-2002). In recent decade, molecular techniques have boosted the pace of taxonomic research manifold. There are several published examples of phylogeny reconstruction in different families of moth through barcoding viz. Janzen *et al.* (2009), Zahiri *et al.* (2011), Zahiri (2012), Wilson *et al.* (2011), Regier *et al.* (2012), etc.

Apart from taxonomy, ecology related works on moths started much late in the 20th century. Intachat, Holloway and Speight (1997 and 1999) wrote two papers on impacts of forest management practices and logging on Geometrid moth population and diversity in

Peninsular Malaysia. They have also worked on the effect of seasons on Geometrid moth population in Malaysia. Ricketts, Daily, Ehlrich and Fay (2001) worked on the countryside biogeography of moths in a fragmented landscape in native and agricultural habitats in Andean Montane forest. Brehm and Fiedler (2004) assessed morphometry of some Geometrid moths along elevational gradient in Andean rainforest. Summerville and Crist (2004) worked on the suitability of forest moth taxa as an indicator of habitat disturbance. Hilt & Fieldler (2005) also worked on Andean moths in which they studied the diversity and composition of Arctiidae along a successional gradient. Beck and Khen (2007) worked on the beta diversity of Geometrid moths from northern Borneo. Beck *et al.* (2011) published a literature on the link between the environment and diversity and abundance of Andean moths. Brehm *et al.* (2013) assessed the pattern of phylogenetic diversity of geometrid moths along the elevation gradient in tropical Andes.

1.3.2 Studies on Moth in India

Major contribution to the taxonomy of moth fauna of India was done by the Britishers in pre-independence era. The faunistic records of Indian Lepidoptera were done long back by Linnaeus (1758), Cramer (1775), Fabricius (1775), Donovan (1800), Kollar (1844), Walker (1854), Cotes and Swinhoe (1886), Butler (1886) and Swinhoe (1885). Moore (1888) worked on many lepidopteran specimens collected by J. H. Hockings. He collected moth specimens from Andaman and Nicobar, Bengal and North-West Himalayas and prepared an extensive checklist of moth species found in these areas. Snellen (1890) studied Pyralid specimens collected by Henry J. Elwes and late Otto Moller from Sikkim. In 1891, Hampson published document on Lepidopterous Fauna of Nilgiris. Hampson (1892, 1894, 1895 and 1896) also published the best consolidated accounts of Indian moth fauna till date in four volumes of the 'Fauna of British India'. Moreover, he (1903, 1908 and 1919) prepared supplementary paper and studied new moths collected by Mons. Warren (1888) and Rothchild (1920) contributed significantly to the documentation and biology of the Indian crop-pests. Edward Meyrick (1910-1914) was the first to publish detailed descriptions of Indian Microlepidoptera. The fifth volume of the 'Fauna of British India' which only included Sphingid description was prepared by Bell and Scott (1937). 'The Ecology and Control of the Forest Insects' by Beeson (1941)

is still considered to be the most pioneering work on the biology of the Indian moths. Sevastopulo (1956) published notes on Heterocera of Kolkata.

Indian authors have also contributed significantly to the taxonomic research of moths of the country after independence. Arora and Gupta (1979) published monograph of Indian Saturniidae. Mandal and Bhattacharya (1980) studied the subfamily Pyraustinae from Andaman-Nicobar Island. Arora and Chaudhury (1982) contributed to the moth fauna of Arunachal Pradesh and adjoining areas of Assam in North-East India. Arora (1983) prepared the first document on the moth fauna of Andaman & Nicobar. Gupta *et al.* (1984) studied the Lymantriidae of India. Mandal and Ghosh (1991) described some species of moths from Tripura. Chandra (1993 and 1996) published his works on moths from Bay Islands and Great Nicobar Biosphere Reserve. Arora (1997, 2000) published some moth species from the Nanda Devi Biosphere Reserve and some Pyralid species of economic importance. Mandal and Ghosh (1997), Mandal and Maulik (1997), Ghosh and Choudhury (1997) and Bhattacharya (1997) contributed considerably to the moth fauna of West Bengal. Moth fauna of Meghalaya and Sikkim are well documented by Mandal & Ghosh (1998) and Ghosh (2003), respectively. Srivastava (2002) published a book titled 'Taxonomy of Moths in India'. Rose (2001) prepared an inventory of the moth fauna of Jatinga, Assam. Kirti and Sodhi (2003) contributed to the documentation of Arctiidae of Sikkim. Rose & Pooni (2004, 2005) recorded 18 species belonging to superfamily Pterophoroidea and 16 species belonging to superfamily Tortricoidea from North Western part of India. Walia (2005) recorded 184 species of Geometridae moth from different locations in Himachal Pradesh. Mathew (2006) prepared a consolidated account on the Indian Pyralids. Chandra (2007) studied moth diversity of Madhya Pradesh and Chhattisgarh and described 142 species of moths from 16 families. Smetacek (2008) has listed 887 species of moths from Nainital district of Kumaon Himalaya, Uttarakhand. Gurule *et al.* (2010) documented 70 species of moths of family Noctuidae from Nashik district of Maharashtra. Sidhu *et al.* (2010) listed 109 species microlepidoptera from family Pterophoridae. Chandra and Sambath (2013) have published 102 species from Tawang district, Arunachal Pradesh. Sanyal *et al.* (2011, 2013) have studied the diversity and distribution of moth assemblages across different vegetation zones in the Gangotri Landscape, Western Himalaya.

1.4 Uttarakhand Himalaya & Backdrop of Current Study

The Himalaya, as part of the world's largest mountain ecosystem, harbors a diverse and unique assemblage of biodiversity due to its position in the tri-junction of the Oriental, Palaearctic and Ethiopian realms. Being recognized as globally important biodiversity hotspot, Himalayan system is characterized by sharp environmental gradients due to rapid geoclimatic variations generating diverse vegetation and community types (Chawla *et al.* 2008). Here a wide range of altitude, rainfall, climate, geological conditions, river systems, and topography have given rise to an immense diversity of ecosystems, from subtropical broadleaf forests along the foothills to temperate broadleaf forests in the mid hills, mixed conifer and pure conifer forests in the higher hills, and alpine meadows above the treeline. This great ecosystem diversity ultimately gives rise to immense biological diversity.

Uttarakhand, located in the central sector of Himalaya, is considered to be the part of both Central and Western Himalaya region and provides an epitome of the geological architecture of the whole Himalaya. The 88% mountainous state has its 62% geographical area under forest cover. Uttarakhand has 12 Protected Areas; 6 National Parks, 6 Wildlife Sanctuaries and 2 Conservation Reserves. Apart from the Protected Areas, Nanda Devi Biosphere Reserve and Valley of Flowers National Park are among 2 World Natural Heritage Sites. According to scientific studies done by Botanical Survey of India (BSI), Uttarakhand is floristically super-diverse state of India, with reported ca. 4700 species of flowering plants representing nearly 25% of Indian Angiosperm flora. Uttarakhand state is bestowed with great faunal diversity. As per Zoological Survey of India (ZSI), Northern Regional Centre, Dehradun, Uttarakhand houses the faunal biodiversity of 3748 species belonging to 1848 genera and 427 families of both vertebrates and invertebrates; to be precise there are 499 genera with 1060 vertebrates and 1349 genera with 2688 species of invertebrates found in Uttarakhand. The enormous faunal diversity is represented by 93 species of Mammals (which is about 25% of the known Indian species), 743 species of birds, including migratory winter visitors (representing 60% of the Indian avifauna), 72 species of reptiles and about 439 species of butterflies.

Moth diversity of the state is also well documented. Cotes & Swinhoe (1886) mentioned 81 species from Uttarakhand. Hampson and Bell & Scott in their Fauna of British India (1892-1937) recorded 67 species of moth from the state. Smetacek (2008) recorded 887 species of moth from three locations in Nainital district over a span of thirty years. Zoological Survey of India in the State Fauna Series (2010) documented 44 species of Arctiidae (Majumdar 2010), 41 species of Sphingidae (Majumdar & Kumar 2010), 5 species of Lasiocampidae and 21 species of Lymantriidae (Maulik 2010).

But if we look into the research initiatives for insects in Uttarakhand or Western Himalayan landscape, there is still much deficiency in the popular appeal as well as systematic inventorying of this highly important faunal component. In comparison with higher animals, the knowledge about insect diversity is incomplete and biased towards few popular groups or selected sampling localities. Taxonomic complexity, lack of experts for specific taxa and paucity of reference material collection in India (Smetacek 2013) have added up to this issue. As a consequence, long term monitoring for key insect groups are still in very rudimentary state. In view of this lack of knowledge about insect diversity in Himalayas, Wildlife Institute of India initiated a research project in 2008 titled "An Assessment of Entomofauna for Management and Conservation of Biodiversity in Gangotri Landscape" with the aims of assessing ecological diversity and distribution pattern of major insect groups and their response to anthropogenic pressures. A typical western Himalayan Landscape in the state of Uttarakhand, the Gangotri Landscape harbors high diversity of Himalayan fauna of conservation importance. The area is also of tremendous importance securing the future of India's major river systems, as upper catchments of two of India's greatest rivers, Ganga and Yamuna falls under this landscape. Instead of studying the entire insect community in Gangotri Entomofauna project, attention was given to identifying and selecting an easy-to-monitor assemblage that serves as a surrogate for the entire insect community and acts as an indicator of changes in habitat quality (Uniyal *et al.* 2013). Order Lepidoptera was a natural choice for this purpose. Moths, despite being taxonomically complicated group, have some edges over butterflies as a focal group in ecological monitoring. Butterflies are not easily trapped (Kitching *et al.* 2000) and are often poorly represented in dense forest environments as they prefer open, sunny habitats. Although they have been advocated as

indicator taxa in grasslands and tropical forests, they account for only about 15% of the lepidopteran species diversity worldwide (Summerville & Crist 2004). In contrast, the nocturnal families of larger Lepidoptera are sufficiently speciose and diverse to offer powerful discrimination in detecting ecosystem level impacts (Holloway 1977, 1985). Most families of moth are readily attracted to light traps, which, used with care, can provide a standard measure of the fauna present in a particular habitat. Moths are increasingly being targeted for individual conservation management and as tools for signaling wider environmental changes in response to anthropogenic activities, particularly those involving changes to vegetation. Keeping these advantages of studying moth in mind, current study was envisioned and carried out under the umbrella of Gangotri Entomofauna project. For this study, the diversity of an entire moth assemblage, featuring all the major macro- and micro- moth families, of a Himalayan temperate altitudinal gradient was investigated. Using the elevation gradient as natural experiment, the faunal structure and diversity of the moth assemblage as well as relationships between moths and their biotic and abiotic environments were explored. The term "assemblage" is defined here as populations of co-occurring species which are taxonomically and geographically restricted (Fauth *et al.* 1996). When populations are further restricted by their utilization of the same types of resources (e.g. plants), they are appropriately known as "ensembles".

1.5 Aims & Objectives

Specifically, in the subsequent five major chapters, I explore diversity and faunal structure, as well as relationships between moths and their abiotic environments, to scrutinize the following objectives:

- Documenting and prepare taxonomic inventory of rich moth fauna of Gangotri Landscape Area.
- To assess diversity and distribution of moth assemblages among different elevations and vegetation types of Gangotri Landscape.
- To analyze the influence of altitude, seasons, vegetation types and anthropogenic disturbance factors on moth assemblages.

- To investigate morphometric changes (body size and proportional body parts) in moths along altitudinal gradient.

The thesis is organized into following chapters:

Chapter I: General Introduction, discussing current insect conservation scenario, Lepidoptera as flagship group for insect conservation, past studies on moth in India and backdrop of current study.

Chapter II: Materials & Methods, describing the study area Gangotri Landscape, study design and sampling strategy, light trapping and specimen preparation methodology, moth as study organism describing their brief morphology and identifiable characters.

Chapter III: Faunistic inventory & composition of moth assemblage, collected and identified from different families, giving species account with species photographs.

Chapter IV: Alpha diversity, investigating intra-habitat diversity pattern of moth assemblages in different altitude and vegetation zones.

Chapter V: Factors determining distribution pattern, dealing with multiple habitat variables correlated with beta-diversity of major families of moth and comments about suitability of different species as indicator species.

Chapter VI: Seasonality, examining the temporal variation in species richness and abundance of different families in different elevation zones.

Chapter VII: Morphometry, investigating body size variation in Geometridae moths along elevation gradient, and

Chapter VIII: Synthesis & Perspectives, jotting down main findings of the study with comments on biogeographic affinities of the assemblage and light trapping as suitable monitoring tool.

CHAPTER II

MATERIALS & METHODS

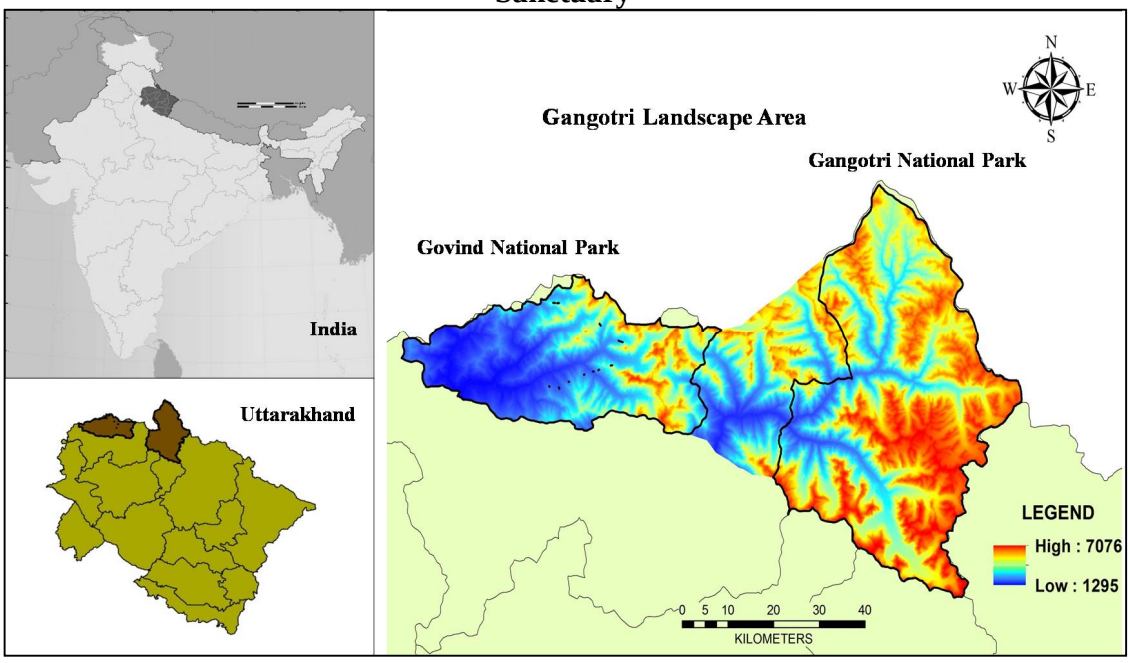
2.1 Study Area: Gangotri Landscape

The study was conducted in Gangotri Landscape Area (GLA), a vast conservation network in the North-Western part of Uttarakhand, in district Uttarkashi. This typical Western Himalayan landscape occupies over 4000m^2 areas bounded in the west by state Himachal Pradesh and in the north by Tibetan Autonomous Region of China. The GLA represents the Biogeographic zone 2B, West Himalaya (Rodgers & Panwar 1988), Garhwal sub region and covers three high altitude protected areas and their adjoining areas (Figure 2.1): Gangotri National Park (GNP) (N30°50′-31°12′ and E78°45′-79°02′), Govind National Park (GVNP) (N31°02′–31°20′ and E77°55′–78°40′) and Govind Wildlife Sanctuary (GWLS). The landscape forms the upper catchments of main tributaries of two of the India's greatest rivers, Bhagirathi of Ganga in GNP and Tons of Yamuna in GVNP. The altitude of the area varies from 1200m to over 6500m and this great variation in altitude yield an exceptionally high habitat diversity that ranges from subtropical forests in lower altitudes to subalpine forests above 3200m. A major portion of the landscape also falls under alpine conditions that are characterized by moist alpine habitats in the Greater Himalaya and dry alpine habitat in the Trans Himalaya sections of the landscape. The climate of the area is the typical Western Himalayan climate, with medium to high rainfall during July-August at lower altitudes. The average annual rainfall is 1500mm, and it is extremely cold, with three to four months of snowfall in winter, with a permanent snowline in the higher reaches. In spite of this great diversity in the landscape there have been very few intensive studies on the floral and faunal elements in the region except some pilot surveys by Wildlife Institute of India (Uniya & Ramesh 2004, Sathyakumar 1994) and Zoological Survey of India (Kumar & Gupta 2004).

As the main objective of the study was to look into the diversity and distribution of moth assemblages as response to altitudinal gradient, maximum altitudinal variation was to be covered within short geographical distance. From this respect, GVNP and GWLS were

ideal as they show a huge altitudinal gradient from 1200m to over 5000m and were natural choice for intensive study area. On the other hand, GNP was sampled occasionally to make the inventory picture more complete. All the sampling locations in the landscape are provided in Table 2.1.

Fig.2.1: Location of Gangotri Landscape and the Protected Areas covered for sampling, viz. Gangotri National Park, Govind National Park and Govind Wildlife Sanctuary

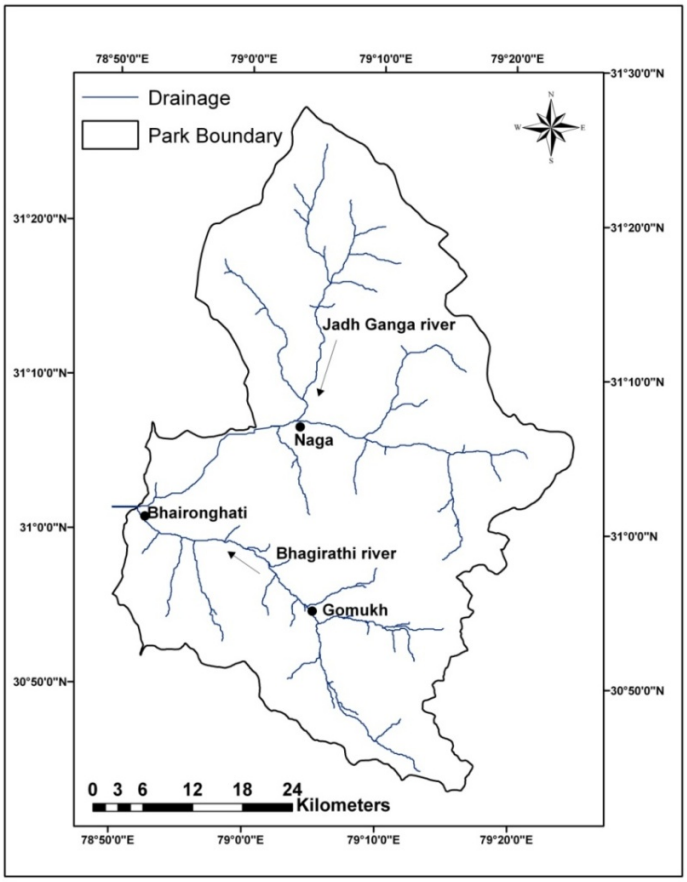


2.1.1 Gangotri National Park

The Gangotri National Park area is located between Latitude 78°45' to 79°02' East and Longitude 30°50' to 31°12' North (Figure 2.2). Administratively, Gangotri National Park area lies in the Uttarakashi district of Uttarakhand covering a total area of 2,390 km^2. The Goumukh Glacier, the origin of the River Ganges is located inside the park. Gangotri, after which the park has been named, is one of the holy shrines of Hindus. The park area forms a viable continuous corridor between Govind NP and Kedarnath WLS. The northeastern park boundary is located along the international boundary with China (Tibet). The park area is characterized by high ridges, deep gorges and precipitous cliffs, rocky craggy glaciers and narrow valleys that make the catchment of river Bhagirathi.

The area exhibits altitudinal variation from 1,800 to 7,083m. Due to variation in the altitude and aspect, a high diversity of vegetation exists in the park. The landscape immediately north of main central thrust (MCT) in the state of Uttarakhand, India represents a unique cold, arid ecosystem that has largely escaped the attention of ecologists, geographers and natural resource managers, owing to remoteness, harsh climatic conditions and inaccessibility owing to security reasons as Indian Army has occupied the area and entry of visitors, tourists etc. is prohibited in the Nilang valley. Along with part of Gangotri glacier (Greater Himalaya), the area is under protection as Gangotri NP. This area forms a narrow strip (50-80 km wide) between the crest of Greater Himalaya and water divide between Satluj and Yarlung-Tsangpo that also forms the international boundary between India and Tibet (Valdiya 2001, Mazari 2007, Chandola *et al.* 2008). This area exhibits close affinities with Tibetan plateau both in terms of topography and species composition.

Fig.2.2: Map of Gangotri National Park



So far, 15 species of mammals and 150 bird species are documented from the park. The endangered mammals and pheasant species are: Snow leopard (*Uncia uncia*), Black bear (*Selenarctos tibetanus*), Brown bear (*Ursus arctos*), Musk deer (*Moschus chrygsogaster*), Bharal (*Pseudois nayaur*) Himalayan tahr (*Hemitragus jemlahicus*), Himalayan monal (*Lophophorus impejanus*), Koklass (*Pucrasia macroplopha*), and Snow cock (*Tetraogallus himalayensis*).

The forests of the park are Himalayan moist temperate type. Major vegetation consists of Chir pine (*Pinus roxburghii*), deodar (*Cedrus deodara*), oak (*Quercus* sp.) and other broad-leaved species like Maples (*Acer* sp.), Walnut (*Juglans regia*), Hazel (*Coryllus jacquemontii*) and Burans (*Rhododendron arboreum*).

2.1.2 Govind Wildlife Sanctuary and National Park

Govind NP and Govind WLS are part of high Western Himalayan highland situated in Purola Tehsil of the Uttarkashi district in Uttarakhand state and lies between Lat - 31° 02' – 31° 20' N and Long - 77° 55' – 78° 40' E (Figure 2.3). Two major rivers, Rupin and Supin, flow through the Govind NP and Govind WLS and merges at Netwar village, forming the river Tons. The altitude varies from 1,290-6,323m. The Govind WLS covers 953.12 km^2 of which 472.08 km^2 have been demarcated as National Park encompassing the upper catchment of river Tons. Tons river source lies in the 6316m high Banderpunch glacier zone. The origin of the Tons river is at the convergence of two feeder streams; the Rupin river from the northern part of the Tons catchment near the Himachal Pradesh and the Supin river rises from tributaries from glaciers at north and north-eastern part of Tons catchment. Supin joins Tons at Sankri, which is upstream of confluence of Rupin with Tons at Netwar. These two feeder streams converge near the mountain hamlet of Netwar and the channel downstream is known as Tons river.

Geologically the entire PA lies in the Himalaya stratigraphical zone and as such is in vicinity of main central thrust. It is, therefore, under serious impact of tectonic movement. As a result rocks are not only tightly folded but also broken into sheets one over other, forming tall heaps. The internal configuration of these sheets is complicated cleavage and developed inside thrust fold. Heavy rains and earthquakes seriously affect

them. The whole area is prone to large scale landslide. Geologists have broadly divided the hills inside the PA into three main categories:

1. Munsyari Jutog Category: This conforms to Almora hills category, primarily consists of augenneiss and granites and forms a continuous chain of rocks in the top most part in the eastern side of the PA. Some granite boulders are found in the beds of the Tons and the Rupin rivers, usually felspathic granite is found but there are boulders of tourmaline also. Most of the alpine grasslands and Betula-Kharsu formations are found on these.

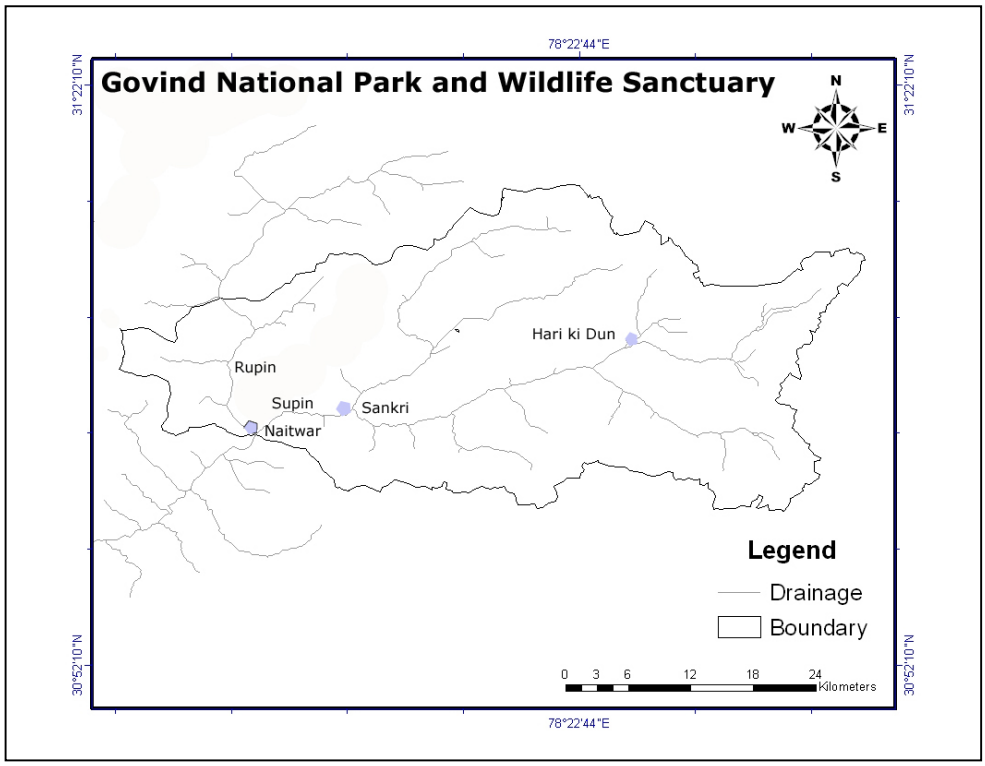
2. Chail Category: Locally named as "Barkot Hill category" conforms to Ramgarh hill ranges and consists of phelite, quartzite and slate. The schists are interbedded in the quartzite formations and vary from hard slates to soft mica schists. The beds are usually of small extent and their distribution is haphazard. Shales and mica-schists occur scattered in distribution. The soil produced varies from sandy loam to stiff clay depending on the nature of the schists. Quartzite is the continuation of the Bawar series of quartzites. It consists of a fine grained glossy quartzite interbedded with schist at places. This series is probably of most Miocene age.

3. Jaunsar Mountain Category: This conforms to Berinag mountain ranges of Kumaon and consists of mainly Quartzites and Sariste-Quartz schists. This is spread over a fairly large area. The age of this mountain category has not been ascertained.

The Govind PA is an excellent representative of the Himalayan Ecosystem. It is one of the oldest PA in the state. This tract is estimated to be over 20 to 25 million years old. The descriptions in the scripture e.g. Puranas and Kedarkhand revealed that there had been extensive and dense forest of Deodar and magnificent trees inside the PA. The people had great reverence for deodar which they considered as God's tree, so did not touch this forest except for felling of few trees required for their bonafied use. Later with increase of population, areas were cleared and terraced for cultivation in gentler slopes. Most of the present villages and their cultivated land in Rupin, Supin and Sankri ranges are in the habitat of deodar. As there was no check in shifting cultivation, the chir pine started regenerating itself and thus reafforested neglected cultivations. In recent years the PA has come into lime light because of various interface problems with people such as

cattle grazing in prime alpine meadows during summer. The climate of the area is variable, with subtropical climate in lower part of the valley having hot and more or less humid monsoon season from July to September, pleasant autumn and spring. The winter is cold and dry bracing with clear and bright weather alternating with occasional winter rains and snowing at high elevations. The average rainfall is 1500mm, with extreme cold and snow during the three to four month winter. Maximum rainfall is experienced during month of July and August and minimum rainfall during the months of January and October. A permanent snowline occurs at 5000m elevation.

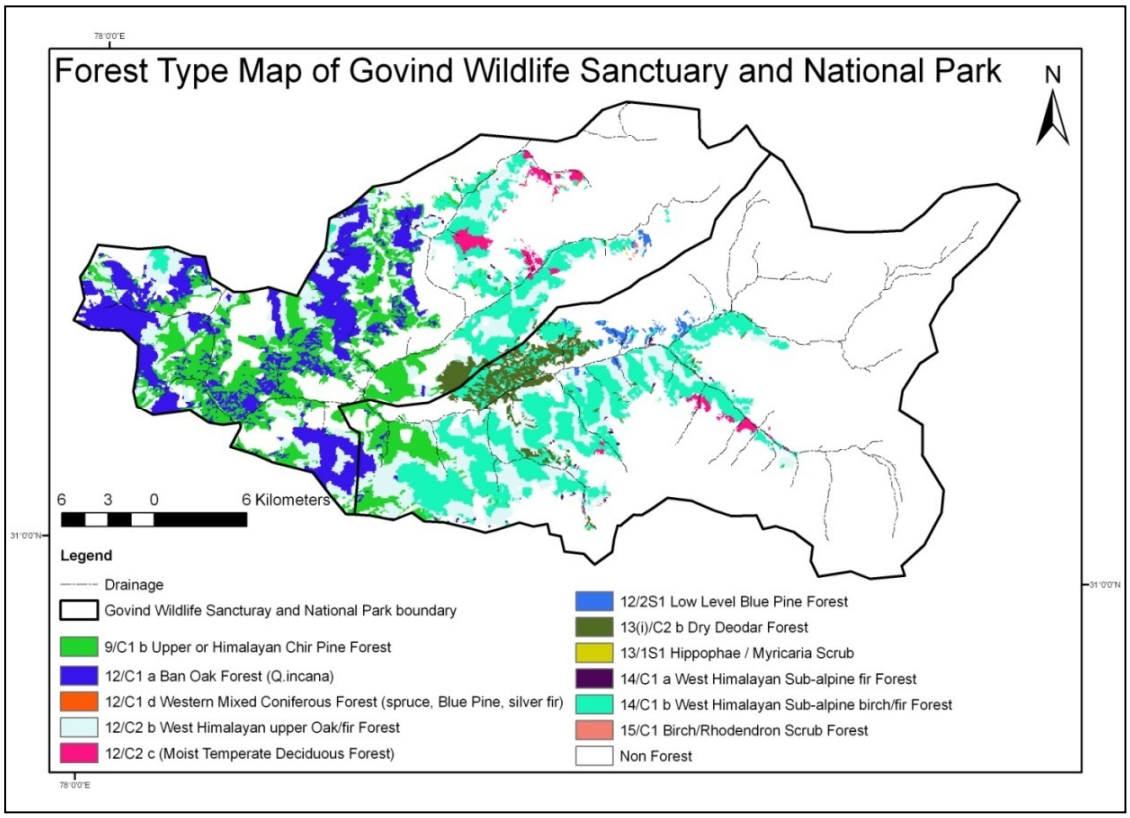
Fig.2.3: Map of Govind National Park and Wildlife Sanctuary



The forests in Tons valley are generally dense and the tree height in canopy usually varies from 15-30m. There is an admixture of the species of tropical, temperate and sub-alpine in these forests. The deciduous species generally shed their leaves from January to mid March. The forests bordering habitations suffers heavily from lopping and felling. Fortunately, considerable area and parts of the valley forest is not under serious threat and supports luxuriant growth of dense forest. About 47 villages are scattered throughout

the Govind NP and Govind WLS (Anonymous 1986). The people subsist mainly on livestock, cultivation, and forest products.

Fig. 2.4: The broad vegetation types of Govind Wildlife Sanctuary and National Park



The fauna of the study area is poorly known other than a few scattered references on the mammals, birds, reptiles, butterflies, dragonflies and damselflies, Hymenopterans and Chilopods. This PA is the only site in the state Uttarakhand where Government of India initiated Project Snow Leopard. This area also represents the easternmost distribution of Western Tragopan. Dang (1968) published a report on the preliminary survey of Har-ki-dun and adjacent valleys, with special reference to blue sheep and brown bear. A report from Wildlife Institute of India (Anonymous 1986) reported 11 species of mammals from the study area. Later Sathyakumar (1994) reported about 20 species of large mammals from the Govind Pashu Vihar. Kumar *et al.* (2004) published a list of 257 taxa belonging to nine faunal groups (viz. Odonata, Lepidoptera, Hymenoptera, Chilopoda, Amphibia, Reptilia, Aves and Mammals). A total of 244 species of birds and 32 species of mammals

have been recorded so far from the area (Uniyal *et. al.* 2013). Major wildlife species are Snow leopard (*Uncia uncia*), Brown bear (*Ursus arctos*), Musk deer (*Moschus chrysogator*), Himalyan tahr (*Hemitragus jemlahicus*), Asiatic jackal (*Canis aureus*), Red fox (*Vulpes bengalensis*), Leopard cat (*Prionailurus bengalensis*), Leopard (*Panthera pardus*), Yellow throated marten (*Marets flavigula*), Mountain weasel (*Mustela altaica*), Asiatic black bear (*Ursus thibetanus*), Sambar (*Cervus unicolor*), Barking deer (*Muntiacus muntjak*), Bharal (*Pseudois nayaur*), Royale's pika (*Ochotona roylei*), Red giant flying squirrel (*Petaurista petaurista*) and Indian crested porcupine (*Hystrix indica*). The important avifauna of the area is Himalayan bearded vulture, Western tragopan, Satyr tragopan, Himalayan monal, Koklass and Cheer pheasant which are also scheduled species in Indian Wildlife (Protection) Act, 1972 (Anonymous 2006).

2.1.3 Major Forest Types in Gangotri Landscape Area

A great variation in topography and altitude in the landscape results in diversity of vegetation. According to the "Revised Survey of Forest Types" by Champion & Seth (1968), following types of forests were recognized and sampled inside the Gangotri National Park and Govind National Park and Wildlife Sanctuary:

Group 9: Sub-tropical Pine Forest

9/C1b Sub-tropical Himalayan Chir pine forest: This type of forest extends up to 1800m in the landscape. The forests are of pure Chir (*Pinus roxburghii*) with common associates like Banj (*Quercus incana*), Ayar (*Lyonia ovalifolia*), Burans (*Rhododendron arboreum*), Kunis (*Alnus nitida*) and Himari (*Ulmus wallichiana*). The associated broad leaved species are Kadam (*Prunus cerasoides*), Kaphal (*Myrica sapida*), Kirmola (*Acer oblongum*), Busha (*Meliosma pungens*) on the cool aspects. On higher altitude Kail (*Pinus wallichiana*) tends to invade Chir, especially if the area is fire protected. The under growth is usually of grasses, mainly Golda (*Chrysopogon fulvus*), Kumras (*Heteropogon contortus*). Shrubs are generally absent or very rare, the chief ones being Bhenkal (*Prinsepia utilis*), Kanth-Mahua (*Glochidion velutinum*) etc. On dry slopes subjected to fire and grazing Suru (*Euphorbia royleana*) is found whereas on moister

places Banwan (*Myrsine africana*), Tushari (*Debregeasia hypoleuca*), Hinsalu (*Rubus ellipticus*) etc. are found.

Heavy grazing and frequent fires have been responsible for lack of regeneration in many areas. Good regeneration, however, occurs wherever fire protection has been effective. Sampling plots N1400A-C, N1600A-C, N1800 and BH1600 were classified under this type of forest.

Group 12: Himalayan Moist Temperate Forest

12/C1a Banj Oak forest (*Quercus incana*): Banj forests are found above Chir forest up to 2250m. Between 1500m-2100m Banj formation descend down the moist nalas. In Chir forest the comparatively smaller occurrence of Banj is probably due to the fact that the slopes being steep and hence less moist are more suitable for coniferous formations than for Banj or Moru. The forest are generally well stocked except near the villages and are irregular in age, regeneration is deficient though found at places. The main associates are Burans, Ayar, Kaula (*Machilus odoratissima*) etc. Undergrowth is fairly dense in moister places but is sparse otherwise. The most frequent species are Kalahinsar (*Rubus lasiocarous*), Matoi (*Desmodium tiliafolium*), Bhetkukhra (*Lontcera quinquelocularis*), Chamboi (*Wikstoremia canescens*), Kasmoi (*Berberis aristata*), Masuri (*Coriaria nepalensis*), Darli (*Cedrela serrata*) etc. Mosses and lichens are found on trees and epiphytic growth of ferns takes place in monsoon. Golringal (*Arundinaria falcata*) is found as undergrowth in protected shady portions.

12/C1b Moru Oak forest (*Quercus dilatata*): The Moru forest occurs only locally in the PA and is usually confined to nalas above Banj and below temperate moist deciduous forests at an altitude of nearly 2250m. These forests are mixed with Banj in lower and with either Kharsu or high level moist deciduous species in the upper side. The deciduous species that are usually mixed with Moru are Kathbhuj (*Betula alnoides*), Utis (*Alnus nepalensis*), Marik (*Acer caesium*), Kanjal (*Acer* spp.), Pangar (*Asculus indica*), Khangsi (*Cornus macrophylla*) etc. The undergrowth consists of Bhutnoi (*Vibernum continifolium*), Kanderu (*Liex dipyrena*), Chhedula (*Rhamnus virgata*) etc with some

ringals in the nalas. The forests are of mixed age classes with fairly good proportion of younger age classes.

12/C1c Moist Deodar forest: The typical Deodar (*Cedrus deodara*) forests are mainly confined between 1900m to 2700m. Large tracts of Deodar is absent in the landscape, and here the Deodar zone is occupied mainly by Kail (*Pinus wallichiana*). The forests are not pure and mixed with varying proportion of Kail. The steeper and rocky areas have more Deodar while in easier slopes Kail tends to invade Deodar. A second storey of scattered trees of Burans, Moru, Ayar etc. is present. The ground cover consists of shrubs like Kala-hinsar, Kasmoi, Matoi, Bhat-kukhra, Chambai etc. Kandar (*Vities semicordata*), Malkauni (*Ckematies montana*), Mathiari (*Hedera nepalensis*), Kuyu (*Rosa muschata*) etc. are found among climbers.

12/C1d Western Mixed Coniferous forest: These are found from an altitude of 2400m to 3000m or more in the Deodar zone. It is composed of four elements viz. Fir (*Abies spectabilis*), Spruce (*Picea smithiana*), Deodar and Kail in various proportions mixed with broad leaved species. The proportion of Fir and Spruce is high in the cooler aspects and on easier ground while Deodar has higher proportion on steeper areas. The growth is very fine and height up to 50m may be attained. Ban, Moru, Burans are found in lower elevations. In the moister areas deciduous species like Akhrot (*Juglans regia*), Pangar, Kanjal etc are found. Kharsu (*Quercus semicarpifolia*) is also found in upper reaches. Towards the upper limits an under storey of Thuner (*Taxus baccata*) has developed in moist situations. The ground flora consists of herbs like Banapsa, Somaiya (*Valeriana wallichie*), ferns like *Adiantum venustum* and grasses like *Oplsimenus undulatifolius, Bromus uniloidus* etc. Weed growth of *Impatiens* spp. takes place in rains.

12/C1e Moist Temperate Deciduous forest: These forests occupy the cool and moist areas within the temperate region between 2100m to 2750m. The main species are Pangar, Akhrot, Kathbhuj, Champ-Kharik, Bhotia badam etc. A scatter of Morinda (*Abies pindrow*) and Rai (*Picea smithiana*) may be present, confined to raised grounds on spurs. Small patches of Papri (*Buxus wallichiana*) are also found. The shrubs are similar to those found in mixed coniferous forest (12/C1d).

12/C2a Kharsu Oak (*Quercus semicarpifolia*): This type is common above Deodar forests on southern slopes on exposed sites and above the fir forests in cooler sites. The altitudinal zone is 2500m upwards and may extend up to the tree limit especially on southern aspects. The forests are fairly dense. The height of oak is 12-22m. Brown moss hangs on the trees. Kharsu is predominant crop. It may be mixed with some Moru at places. A scattering of conifers mainly Morinda, Rai or Deodar may also be found in a few places. The other species usually found with Kharsu are Mohal (*Pyrus lanata*), Burans etc. The shrubs are represented by *Rosa sericea, Berberis iabeliana* etc.

12/C2b West Himalayan upper Oak-Fir forest: It is usually found above 3000m altitude. The forests are almost two storeyed with Morinda (*Abies pindrow*) occurring either in strips or singly over a crop at Kharsu and some mixed deciduous species. Kanderu, Papa mohal, *Rosa sericea*, Guia etc are found as ground cover.

12/DS2 Himalayan Temperate Park land: This is a park like land with trees of deciduous species or Morinda standing over a grassy turf. They are generally found in places where the graziers are in habit of keeping their flocks for a long time. Generally this type is found on easy sloped grounds in Fir-Kharsu forests. These are generally derived from a mixed deciduous forest or mixed coniferous forest by burning, lopping and grazing. Stray trees of Jamnoi (*Prunus cormita*), Kanjal, Morinda etc. are found. The shrubby growth is characterized by browsed stray clumps of *Lonicera angustifolia, Rosa sericea* etc. The ground flora consists of *Primula denticulate, Fragaria indica, Rumex nepalensis* etc.

Group 14: Sub-Alpine Forest

14/C1a West Himalayan Sub-alpine High Level Fir forest: This type of forest occupies large tracts above 3000m in cool and protected sites. The forests are dense and the trees are short boled and ill formed. The main species are *Abis spectabilis* with a little mixture of Morinda. Small pockets of Kail are also found. Semru (*Rhododendron campanulatum*) is quite common as under growth. Other species are *Lovicera angustifolia, Berberis* sp. etc. The ground cover consists of mainly herbaceous growth like *Trillium govanianum, Strobilanthes artopurpureous, Viola serpens* etc.

14/C1b West Himalayan Birch-Fir forest: The main species is Bhuj (*Betula utilis*) with a little *Abies spectabilis*. Sometimes a little Kail and Kharsu also extended to this type. *Rhododendron campanulatum* forms fairly dense undergrowth. The ground cover consists of herbs like *Anemona obtusifolia*, ban-kabri, *Viola serpens, Aconitum* sp., *Primula* sp., *Corydalis govaniana, Fragaria* sp., *Allium govanianum* etc.

14/DS1 Sub-alpine pastures: The grasses found in these pastures are *Agrophyron longearistatum, A. semicostatum, Brachypodium sylvaticum, Bromus asper, B. japonica, Festuca sp., Milliunr effusums, Oryzopisis* sp., *Poa* sp., etc. Shrub by growth of guia, *Spirea lindleyara* and *Rosa sericea* are also present at places.

Group 15: Moist Alpine Scrub

15/C1 Birch-Rhododendron Scrub forest: This type of forest is quite common on the cool aspects in protected sites. Short boled Bhuj is found with extensive colonies of Semru. Some Kharsu may also extend to this type. The undergrowth is of alpine shrubs *Sorbus foliolosa, Berberis* sp, *Lonicera parviflora* etc. The ground cover consists of herbs like *Primula denticulate, Corydalis* sp, *Polygonum vaccinifolium, Saxifraga* sp. etc.

15/C2 Deciduous Alpine scrub: This type of forest is characterized by dense scrub of Semru with stunted shrub like growth of Bhuj. It is found locally above the tree limit, i.e. 3350m, but extend down the nalas or snow slides.

15/C3 Alpine Pasture lands: Alpine pasture lands are found throughout the landscape above the timber limit except on rocky precipitous areas. The type is broken by colonies of *Rhododendrons* or *Junipers*. The ground cover is formed by grasses and alpine herbs mainly *Primula* sp., *Iris kumaonensis, Anemone* sp., *Potentilla* sp., *Fragaria vesca, Aconitum* sp. etc.

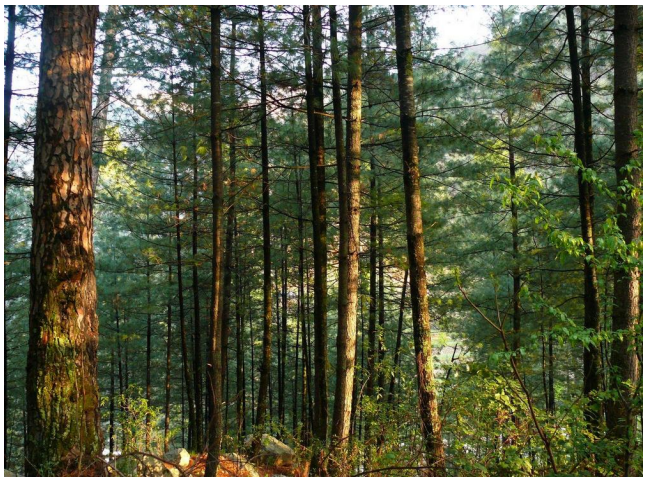
Plate: Major Forest Types in Gangotri Landscape Area



Sub-tropical Himalayan Chir pine forest



Oak Forest



Moist Deodar Forest



Western Mixed Coniferous Forest



Moist Temperate Deciduous Forest



Kharsu Oak Forest

Plate: Major Forest Types in Gangotri Landscape Area



Temperate Parkland & Upper Oak-Fir Forest



Subalpine High Level Fir Forest



West Himalayan Birch-Fir Forest



Subalpine Pasture



Birch-Rhododendron Scrub Forest



Deciduous Alpine Scrub

2.2 Study Design & Sampling Strategy

To explore moth diversity in various elevation and vegetation categories, different sampling stratum was selected based on altitude, vegetation types, and land use practices. Within these stratums, sites were selected randomly. These sites were situated in the centre of plots with a homogeneous vegetation cover, so that moth catches at weak light sources would largely reflect the local communities. The minimum distance between neighboring sites was 50m, with lamps not being visible from neighboring sites. Trap sites were chosen such that the immediate vicinity of the trap was to provide moths shelter from wind or rain, and giving maximum possible light catchments area.

Stratified Random sampling strategy was adopted for the objectives to be met. In this strategy, along a transect ranging from lowest to highest altitude; random sites were selected at every 200m vertical distance. For example, if a gradient started from 1400m and extended up to 3600m, twelve sites were chosen at 1400m, 1600m, 1800m, 2000m and so on. At every altitudinal site, one or two light trap stations were established and at each site, two to three nightly catches were performed until at least 50 individuals were sampled. Sites which did not reach 50 benchmark were not included in further statistical analysis. Sampling, i.e., light trapping was performed in such a manner that two adjacent altitudinal sites were never sampled one after another. A gradient was covered in downward fashion, i.e., starting at highest altitudinal site, i.e., 3600m and sampling downward moving towards lower areas. This was to minimize overlapping of species assemblage from two neighboring altitudinal sites.

This basic study design as a flexible approach to record moth diversity and factors affecting their distribution pattern along altitudinal gradient was repeated along the entire landscape studied. Gangotri National Park, being a true high altitude protected area, starts almost at 3000m and stretches beyond 5000m. Due to absence of suitable natural forest in lower altitude areas of this PA, 18 sampling locations here (Table 2.1) were only used for completing inventory. Whereas the Govind Wildlife Sanctuary, starting from 1400m altitude and representing unbroken and undisturbed natural forest patch up to alpine meadows at 3600m, was perfect area to use the elevation gradient as natural experiment. 84 sampling locations in GWS and GVN (Table 2.1) were distributed along three main

gradients all starting from Netwar at 1400m: Kedarkanta (KK) gradient, Taluka (TK) gradient and Changsil (CG) gradient (Fig. 2.5). Light trapping were performed in these 84 sampling locations in the period 2009-2012 covering all the major seasons: Pre-monsoon (April-June), Monsoon (June-August) and Post-monsoon (September-November). In a single season at least two complete gradients were tried to be covered.

For the abiotic factors governing moth diversity like ambient temperature, relative humidity, wind speed, cloud cover etc. data was collected during light trapping. Additionally rainfall data was collected from Meteorological department. The biotic factors suspected to govern moth diversity like vegetation and anthropogenic disturbances were recorded in nested quadrates of 20 square meter surrounding light trapping stations. Initially, each series was designed such that, in a particular altitudinal site, within a homogenous vegetation type, one set of quadrates will be centered on the position of the light trapping station and the two others will be randomly located 50m from the centre (Plate 2.2). $20x20m^2$ large quadrates were used to quantify species richness, abundance, and the diameter at breast height of all trees greater than 10cm GBH. Canopy cover was measured using a densitometer at 8 points spaced at 10m intervals along the perimeter of each $20x20m^2$ quadrate. Within $20x20m^2$ quadrates, two $5x5m^2$ medium quadrates were used to quantify species richness and abundance of shrubs and saplings. Two $1m^2$ small quadrates nested within each shrub plot were taken account to measure species richness, abundance, and percent cover of herbaceous layer. All the disturbance parameters were measured within $20x20m^2$ large quadrate.

Table 2.1: All the light-trapping sites in Gangotri Landscape Area with location & altitude (GNP: Gangotri National Park, GVS: Govind Wildlife Sanctuary, GVP: Govind National Park)

Site Code	Location (PA)	Atitude (m)	GPS Coordinates
DV34	Devghat (GNP)	3400	30°59′44.4″ N,78°58′57.8″ E
CW34	Chirwasa (GNP)	3452	30°58′52.5″ N,79°01′17.0″ E
GA30	Gujarati Ashram (GNP)	3025	30°59′38.1″ N,78°57′02.1″ E
BW36	Bhojwasa (GNP)	3650	30°57′09.0″ N,79°03′01.7″ E
BG28	Bharonghati (GNP)	2834	31°01′36.2″ N,78°52′04.7″ E
HS26	Harsil (GNP)	2600	31°02′32.7″ N,78°44′51.7″ E
BH16	Bhatwari (GNP)	1560	30°04′07.5″ N,78°06′21.6″ E

NT14	Netwar I GVS)	1456	31°03′39.5″ N,78°07′38.0″ E
NT16	Netwar II (GVS)	1648	31°04′26.3″ N,78°06′46.2″ E
NT18	Sankri (GVS)	1890	31°04′00.3″ N,78°07′06.0″ E
NT14	Netwar I (GVS)	1405	31°04′15.4″ N,78°06′22.6″ E
NT14	Netwar I (GVS)	1430	31°04′13.6″ N,78°07′09.9″ E
NT18	Sankri (GVS)	1890	31°04′27.6″ N,78°07′23.8″ E
KK22	Kedarkanta22 (GVS)	2230	31°04′13.0″ N,78°08′19.2″ E
KK22	Kedarkanta22 (GVS)	2200	31°03′49.9″ N,78°08′51.7″ E
JM24	Jarmola24 (GVN)	2435	31°03′51.3″ N,78°07′12.1″ E
JM24	Jarmola24 (GVN)	2405	31°03′50.2″ N,78°07′38.7″ E
JK24	Jakhol 24 (GVS)	2420	31°06′07.7″ N,78°13′39.1″ E
KK24	Kedarkanta24 (GVS)	2400	31°03′09.1″ N,78°08′17.1″ E
TK22	Taluka21 (GVN)	2196	31°05′11.5″ N,78°16′07.5″ E
CH20	Changsil20 (GVS)	2030	31°07′56.8″ N,78°02′46.9″ E
CH26	Changsil26 (GVS)	2650	31°07′32.2″ N,78°01′41.4″ E
CH34	Changsil34 (GVS)	3420	31°07′24.0″ N,77°59′10.4″ E
KK20	Kedarkanta20 (GVS)	2000	31°03′39.5″ N,78°07′38.0″ E
KK26	Kedarkanta26 (GVS)	2600	31°03′09.1″ N,78°08′17.1″ E
KK28	Kedarkanta29 (GVS)	2905	31°02′37.8″ N,78°09′05.5″ E
KK32	Kedarkanta32 (GVS)	3240	31°01′43.1″ N,78°09′42.6″ E
TK24	Taluka24 (GVN)	2460	31°04′15.7″ N,79°16′13.4″ E
TK26	Taluka26 (GVN)	2605	31°04′03.1″ N,78°15′06.7″ E
TK28	Taluka28 (GVN)	2800	31°03′45.5″ N,78°15′48.6″ E
TK30	Taluka30 (GVN)	2980	31°03′08.7″ N,78°17′24.9″ E
TK32	Taluka33 (GVN)	3270	31°02′36.5″ N,78°15′45.3″ E
HD34	Har-Ki-Dun34 (GVN)	3470	31°08′09.3″ N,78°23′57.8″ E
HD30	Har-Ki-Dun30 (GVN)	3020	31°08′28.1″ N,78°24′36.9″ E
HD32	Har-Ki-Dun32 (GVN)	3250	31°07′55.0″ N,78°23′28.1″ E
CH24	Changsil24 (GVS)	2400	31°07′30.7″ N,78°01′58.2″ E
CH30	Changsil30 (GVS)	3100	31°07′20.2″ N,77°59′58.1″ E
CH32	Changsil33 (GVS)	3233	31°07′18.2″ N,77°59′34.9″ E
CH34	Changsil34 (GVS)	3460	31°07′24.0″ N,77°59′10.4″ E
CH26	Changsil26 (GVS)	2652	31°07′35.3″ N,78°01′31.7″ E
CH22	Changsil22 (GVS)	2300	31°07′36.6″ N,78°02′34.0″ E
CH18	Changsil18 (GVS)	1800	31°07′54.9″ N,78°03′35.9″ E
GT32	Gangotri32 (GNP)	3280	31°01′36.2″ N,78°52′04.7″ E
GT32	Gangotri32 (GNP)	3220	30°59′38.1″ N,78°57′02.1″ E
GT30	Gangotri30 (GNP)	3008	30°59′48.9″ N,78°55′39.4″ E

Fig 2.5: Sampling Locations in Gangotri Landscape Area

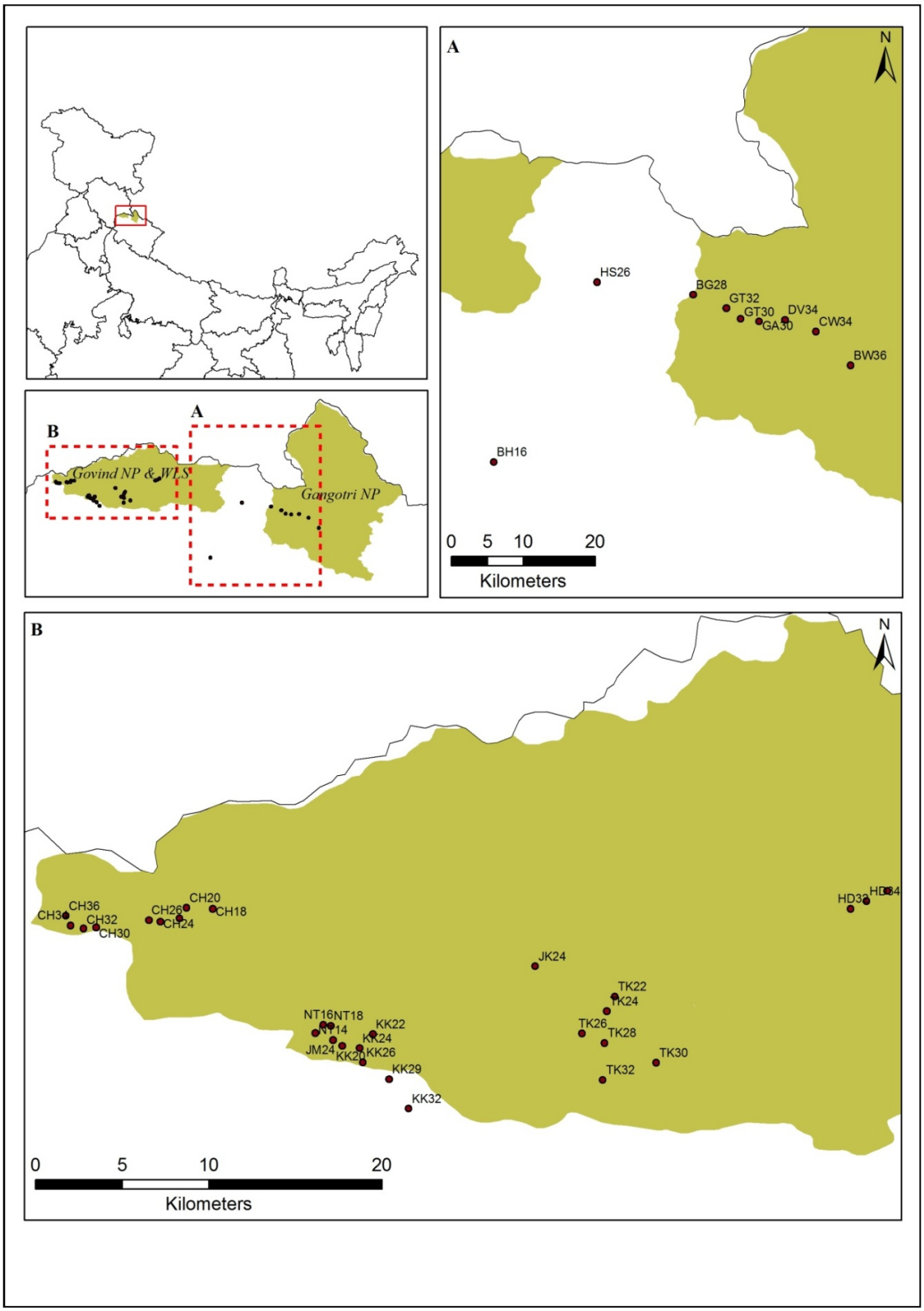
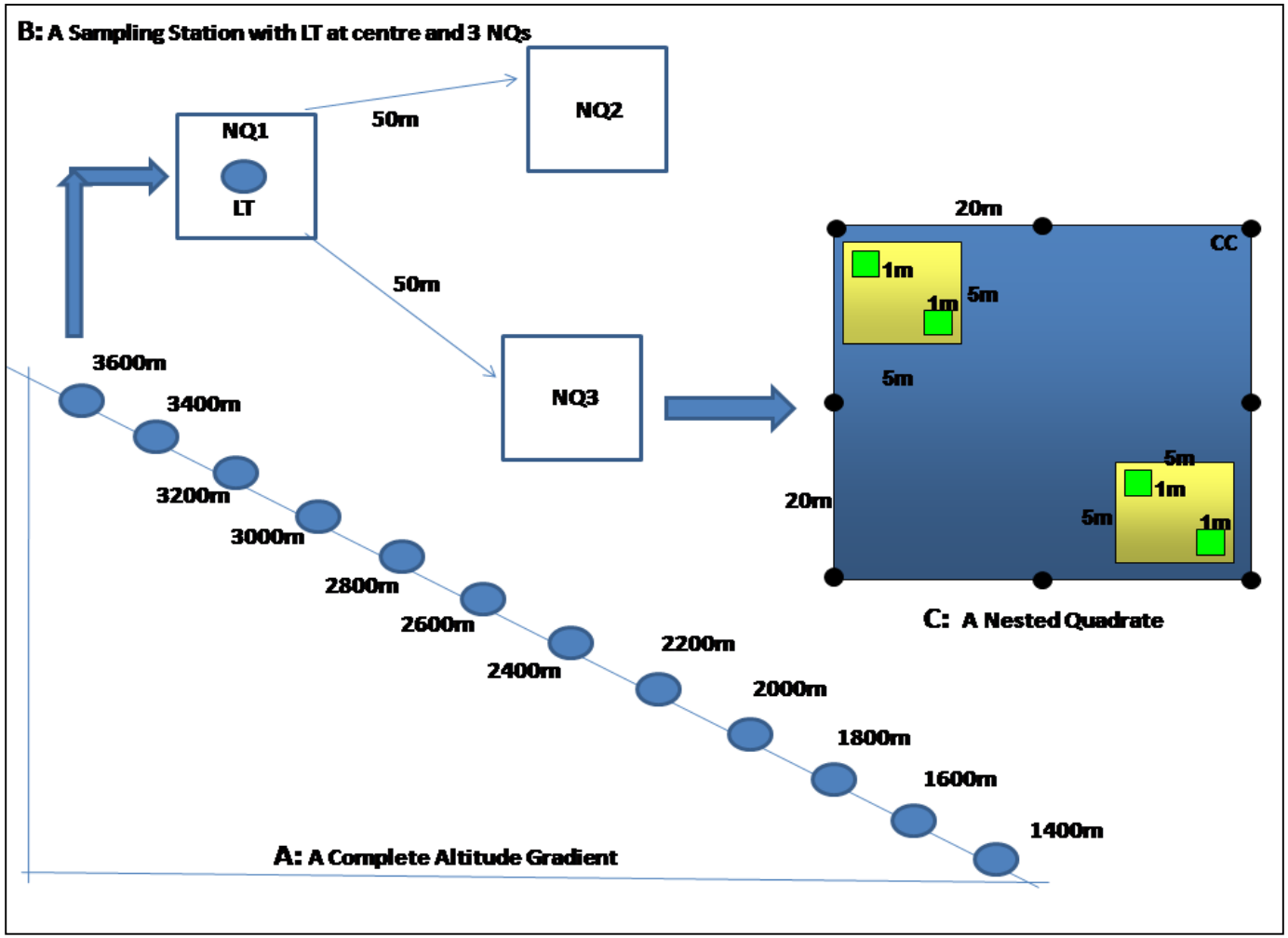


Plate: Sampling Scheme showing (A) one complete altitude gradient from 1400m to 3600m, (B) A sampling station with Light Trap (LT) at centre with NQ1 (Nested Quadrate) centering it and NQ2 & NQ3 at 50m random distance, (C) One single NQ of 20x20m with eight canopy cover (CC) points and two 5x5m medium and four 1x1m small quadrates



2.3 Light Trapping and Specimen Preparation

There are three main methods of collecting moths: Netting, luring with bait or specific pheromones and light-trapping. Netting is done primarily on the day for day-flying species of moth or in the night also around a light-trap. For moths, catches at baits are very much smaller and less diverse than those made by light-trap. However, they include a select minority of group that is rarely sampled at night such as some Noctuids. In temperate regions baiting is proving a valuable method of estimating noctuid moth diversity. By far the most successful method of collecting night-flying Lepidoptera is light-trapping. Though not without it biases, it is the only method that enables a wide array of taxonomic group to be sampled quantitatively in large numbers. There is extensive discussion of the advantages and disadvantages of light trapping in the literature, as well as the effect of light wave length (particularly in the ultraviolet), intensity, trap-type, climatic factors (such as wind, humidity, temperature, rainfall), moon light, trap sites, sex differences (males are generally taken in greater frequency than females) and time from emergence. Though the most moths come to light during the main flush of activity in the first four hours of full darkness, there are few species or groups that fly at dusk, dawn or in the small hours after midnight. These species can only be secured by running the light throughout the night.

Altogether 96 trapping nights were performed to record 10,869 individuals of moth representing 670 morphospecies. Moths were collected using a light trap running for 4 hours, in two sessions at a particular site for two consecutive nights, e.g. first night from 8 pm to 12'O clock midnight and second night from 12'o clock midnight to 4 am. This was to ensure recording all the moths flying in a particular site or habitat in different quarters of night. Light traps were set using a solar powered lantern equivalent to 80 Watt White Actinic bulb and gas petromax equivalents to 160 Watt Mercury vapour (MV) bulb. At some nights, particularly in lower altitude sites where electricity was available, 80 Watt Tungsten Filament bulbs were used instead of MV light. The light sources or combination of them were placed in front of a white 10′ x 6′ cloth sheet hung between two vertical poles in such a way that it touches the surface and extends forward over the ground slightly. This was to ensure enough resting place for an individual moth after they

were attracted to light for live photography and collection. Some species were very active around a light trap and never used to sit on the white sheet. They were collected using insect net. Individual moths were collected in a wide-mouth glass jar filled with Benzene vapour evaporating from a cotton swab soaked in liquid Benzene and placed at the bottom of the glass jar. To prevent direct contact of the moth with the Benzene-soaked cotton swab, 2-3 filter papers were placed above the cotton swab. This ensured instant killing of the specimen without manual handling which might result for descaling and damaging the specimen.

Any scientific method is based on the principle that results of studies should be repeatable and verifiable over time. Research methods are made repeatable through description of the procedures used; results and interpretation are verifiable through peer review; cited references identify sources of previous data, interpretation or comparison. However, all these components of a study may be rendered useless if there is no way to verify the identity of the study organisms themselves. This can only be achieved by the deposition of properly prepared voucher specimens in recognized research collections, where they are maintained under long-term care and available for subsequent examination and verification. The ideal Lepidoptera specimen is one that has collected in good condition, then killed and spread whilst still in perfect condition. Such a specimen has maximum information content both biologically and taxonomically. The voucher material was collected and curated following Dickson (1976).

The collected moth specimens were pinned with entomological pins of different size depending on size of the specimen, usually in the following morning of collection. For macro-moths usually large sized white nickel platted pins No. 3 (41 x 0.42 mm), No. 5 (30 x 0.40 mm), No. 16 (26 x 0.30 mm), No. 100E2 (19 x 0.25 mm) were used depending upon the size of moth. For micro-moths usually small sized pins; i.e. minutest (12 x 0.30 mm), No.100 B2 (13 x 0.19 mm), No. 100 A1 (8 x 0.10 mm) were used. The angle and positioning of the pin are crucial in the successful spreading of the wings of a specimen. Specimen pinned by entomological pin of suitable size pass downwards and backwards through mesothorax on the centre-line of the body; two-thirds of the pin kept below the specimen and one-third above (Robinson *et al.* 1994). Relaxing, setting a specimen and

labeling of the specimens were both laborious and time consuming. The wings of a pinned specimen were spread on spreading board or thick thermocol sheet before rigor mortis sets in. The size of setting board used was determined by the size of the abdomen and wingspan of the specimen. In case of using thermocol sheet, gutter was made by a cutter according to requirement of abdomen size of the specimen to be set.

For setting the specimen, spreading strips of plastic or butter paper were used according to size of moth specimen. Pinned specimen was kept in the groove of spreading board in central and vertical position making sure that legs were not trapped under the wings; setting strips placed on either side and fixed by normal stainless steel pins. The wings were moved using the setting needle or watchmaker forceps, by pushing the wing forward from just behind the subcostal vein. The fore-wing was pulled forward just little way, holding the setting strip tight with left hand, while same procedure was followed for the hind-wing. The wings were stretched to its correct position i.e. the hind edge of the forewing positioned at the right angle to the longitudinal axis of the body. Setting strips were palced across the wing, and with the help of setting pins, they were kept tightly over the wings. Other side was also set in same manner. When both sides were set, abdomen was checked whether it is straight and horizontal. Antennae were positioned in parallel to the forewing costa beneath the setting strip.

After setting, specimen has to be preserved dry for further laboratory investigations. For natural sun drying, spreading boards with set specimen were kept in direct sun-light in warm dry places for few days, covered with glass for protection from birds and ants. A macro-moth took about three days while micro-moths required about two days to be dried completely. The average time for completely drying the set specimen was higher in monsoon and had high chances of specimens getting wet by moisture. Humid weather or rain affected the set specimens and there also remains chances of the speciemn to be infected with fungus. Set specimens were checked regularly by gently trying to move the abdomen to see whether it was hard enough. After complete drying of set specimens, setting pins were removed carefully holding the setting strips with one hand. After complete removal of setting pins and strips, dried voucher specimens were stored in insect boxes with proper label which included information on collection date, collection

locality, habitat and GPS coordinates and the name of the collector. Wooden insect boxes were used to temporarily store voucher specimens. Naphthalene balls were kept as pest-repellent, which also prevents the growth of fungus and were replaced periodically as they are volatile. Silica gels were also used as dehydrating agent which absorbs the moisture in insect boxes. After coming back from the field, all the boxes were stored in warm, dry, air-tight cabinet to protect them from pest and moisture attack.

The entire voucher specimens were then photographed before permanent preservation, so that, initial identification and digital archiving can be done. Specimens were photographed with Nikon SLR D70 with wide angle macro-lens kit under bright sunlight, mounted on thermocoal sheet; a measuring ruler was kept horizontally to record accurate size measurement of wing span. After all the identification procedures, the voucher specimens were deposited in National Zoological Collection at Zoological Survey of India for future reference.

Plate: Collection of Moths in Light Trap & Preservation of Specimens



Light Trapping by Solar Lantern



Light Trap station in Alpine Meadows



Counting Specimen at a Light Trap



Specimen Stretching



A Stretch Board for Drying Specimens



Collection Box

2.4 Moth as Study Organism

In the class Insecta, the Lepidoptera fall within the division of Endopterygota. Members of this order are readily distinguished from other orders having two pairs of membranous wings, usually clothed on both surfaces with overlapping scales on the head, body and appendages of the adult. The mouthparts of the adults are frequently modified into a long coiled proboscis, which occurs in no other order. The classification of Lepidoptera at subordinate level has undergone a series of periodical changes. Hampson (1892) attempted division into Rhopalocera (Butterflies) and Heterocera (Moths) on the basis of antennal structure. On the basis of size, the suborder Macrolepidoptera and Microlepidoptera were recognized. Hinton (1946) had proposed a classification primarily based on the female genitalia.

About 1, 27,000 species of moths are reported from the world (Alfred *et al.* 1998). Recent estimates of diversity within Lepidoptera from the Indian sub-region reveal that about 15,000 species of moth and butterfly belonging to 84 families are known from India (ZSI 2012), including 1641 species and subspecies of butterfly (Varshney 2006), and the rest is moth (Chandra 2011).

2.4.1 General Morphology of Moth

The head of Lepidoptera is typically dominated by a pair of large compound eyes composed of many ommatidia. Immediately dorsal to the compound eyes may be ocelli, although these are frequently lost. Ocelli are typically small, but can be noticeably larger in a few microlepidopteran families. The dorsal region between the compound eyes is the vertex, which is bordered anteroventrally by the frons. Scale vestiture can differ between these two regions and can be useful for identification. Chaetosemata are patches of regularly arranged, slender scales located dorsal to the compound eyes and posterior to the ocelli, and are found in many different families. Each antenna is composed of a basal and usually broad scape that is followed by the second segment termed the pedicel, and a followed by a slender, multi-segmented flagellum. It is often scaled dorsally, and these scales may be arranged in rows on the flagellum, the number of which may be important in identification. Most Lepidoptera have well-developed, three segmented labial palps. Maxillary palps are five segmented, but are usually reduced in size and number of

segments in all but some of the most basal lineages. The most basal lineages may also have functional mandibles, although these are difficult to see. Most Lepidoptera have a coiled proboscis (sometimes termed a haustellum), although this can be secondarily reduced or lost entirely. In some lineages the proboscis is covered by overlapping scales, at least basally, and this is one of the most useful characters in identifying microlepidoptera (Barlow 1982).

The thorax is divided into a prothorax, mesothorax, and metathorax, of which each has a pair of legs and the last two have a pair of wings each. When the wings are spread open, triangular, scaled projections, termed tegulae jut slightly outwards from the forewing base. The scale covering of the wings usually conceals their transparency and venation. The most basal lineages have homoneurous wings, which have a forewing and hindwing that are similarly veined and shaped and may be coupled together by a jugal lobe on the posterior edge of the forewing. However, the vast majority of the Lepidoptera have heteroneurous wings in which shape and venation differ between forewings and hindwings. In many of these families, the wings are coupled together by a frenulum, which is a curved bristle or series of bristles originating on the leading edge of the base of the hindwing that latches into a retinaculum on the underside of the forewing. Each leg is composed of a coxa which rests next to the thorax, a tiny trochanter, an elongate and usually thick femur, a long slender tibia, and the tarsus (usually composed of five tarsomeres) ending in a pair of claws. The tibiae on the prothorax usually have an elongate scaled projection, termed an epiphysis. The tibiae located on the meso- and metathoracic segments often have movable spurs, with the mid-legs typically having two, and the hind-legs typically having four.

The abdomen is usually rather soft and consists of eight segments and terminal genitalia. The dorsal plates of the abdomen are termed tergites and the ventral plates sternites. Females will often have hairy ovipositor lobes at the end of the abdomen, though these may be modified into a sclerotized piercing structure in some taxa. Males have a pair of claspers associated with the genitalia, and these may be visible without dissection, especially if the scales are brushed off at the tip of the abdomen.

2.4.2 Morphology Significant for Classification

For the identification process, seeing a specimen under a simple dissecting Binocular microscope reveals certain characters which are important to zeroing down to Families, subfamilies and even up to Genus. Those external morphological characters are described here in a dichotomous scheme following Dombroskie (2011).

I. HEAD

Vertex: The vertex is the top part of the head between the compound eyes. It can be rough-scaled, i.e. scales on them are erected, or, smooth-scaled, i.e. scales on them are flattened.

Frons: The frons is the front part of the head between the compound eyes. It also can be either rough-scaled or smooth-scaled.

Compound Eye: The compound eyes are the large eyes visible and are made of tiny lenses called ommatidia. Compound eyes can be hairy, when fine hairs are present between the individual facets of the compound eye and are noticeably long, or, hairless, when fine hairs are absent between the individual facets of compound eye or are not noticeably long.

Ocelli: Ocelli are two very small, single lensed eyes that are situated just dorsal to the compound eyes when present. It can be present or absent or are completely concealed by long scales.

Antenna

Eye cap: A broadening of the antennal base that can partially or fully cover the compound eye. This character is only present in some tiny microlepidoptera.

Number of scale rows per antennal segment: The antenna often has scales on each segment that may be arranged in rows. These are often only on the dorsal part of the antenna. The number of rows can be 0, 1, 2 and 3 or more per antennal segment or the scales are not in apparent rows.

Antennal Length: The approximate length of the antennae compared to the length of the forewing (FW) measured from the wing base along the costa to the apex. It can be <1/2 FW length, >1/2 FW length, >1 FW length, >2 FW length.

Antennal type: The antenna can be Filiform, a simple thread-like antenna or weakly pectinate with the pectinations less than twice the antennal shaft, Pectinate, the antennal segments have projections diverging off of them that are longer than twice the shaft width, Elongate club, roughly the distal quarter or more of the antenna is thicker than the basal part, Hooked, the antennal tip is hooked which is often in combination with an abrupt club, Abrupt club, the very tip of the antenna is thickened or it is thickened just before, and the apex is hooked. In some species the structure of antennae is substantially different between males and females and shows some sexual dimorphism (Barlow, 1982). In general, the antennae of male have a more complicated structure than those of female to receive chemical signals in the form of pheromones from newly emerged females.

Labial palps: Orientation of labial palps: It can be Ascending, point upwards following the contour of the head, and when really long can project backwards as well, Porrect, point forwards, Descending, point downwards and are normally parallel.

Labial palp length: The length of the labial palps relative to the compound eye, >2X length of compound eye, or <2X length of compound eye.

Labial palp vestiture: The presence or absence of erect scales or scale tufts on the labial palps. It can be Palps tufted, erect scales are present throughout or in tufts on the labial palp giving it a rough appearance, or, Palps smooth, the scales on the labial palp are closely appressed to it.

Proboscis: The proboscis is located on the lower front part of the head when present and is often coiled. When coiled, the proboscis may be hidden between the labial palps, but can still be seen from a ventral view. The proboscis can be Naked, is completely shiny and naked, lacking appressed scales, or, Scaled, it has appressed scales on it at least near the base. When the proboscis is very short and not visible at all due to dense erect scales, it is marked as Absent.

II. THORAX

Dorsal thoracic scale tuft: A tuft of erect scales is raised dorsally above the rest of the thoracic scales. This is typically mid-dorsal, though there may be smaller paired tufts. They may be Present, or may be Absent, all scales on the dorsal surface of the thorax are uniform in height.

Wings

Wings reduced: The wings are reduced or absent. Reduced wings are not functional and do not extend to the middle part of the abdomen. This is found only in the females of a few group.

Normal size: Wings are present and normally fully functional. They extend beyond the middle of the abdomen.

Forewing

Raised scales on forewing: Tufts of scales are present on the forewings that are raised above the surface. The tufts are often composed of modified scent scales that look different than other wing scales. They may be Present, or, Absent, all scales on the forewing are appressed to the surface.

Coastal fold in male: The basal portion of the costa is folded back over itself. This is present in males of certain groups and they usually have modified scales tucked in underneath the fold. It may either be Present, or Absent.

Forewing Notch: There are one or more deep notches in the outer margin. They may be either Present or Absent.

Forewing pattern: There can be specialized spots and lines names according to their position on the dorsal surface of the wing only. They are

Reniform spot: The true reniform spot is found just beyond the middle of the forewing towards the costa, and just inside the postmedial line when present. This is typical of noctuids.

Orbicular spot: The true orbicular spot is found just before the middle of the forewing towards the costa, and just beyond the antemedial line when present. This is typical of noctuids.

Claviform spot: The true claviform spot is found just before the middle of the forewing towards the inner margin, just below the orbicular spot when present. This is typical of noctuids.

Discal spot/dot: The discal spot is usually small and located close to the centre of the medial area of the forewing. It is rarely present when the reniform, orbicular, or claviform spots are present.

Antemedial line: The antemedial line is located roughly one third of the way from the forewing base and before the orbicular spot when present. The line may be incomplete and even a strong indication of this line at only the costa or inner margin or a series of dots should be marked as present. It is also marked as present when it forms the edge of a basal patch or medial band.

Medial line: The medial line is located roughly at the centre of the forewing and between the orbicular and reniform spots when present. This line may be incomplete and even a strong indication of this line at only the costa or inner margin or a series of dots should be marked as present. It is also marked as present when it forms the edge of a patch or band.

Postmedial line: The postmedial line is located roughly two thirds of the way from the forewing base and after the reniform spot when present. This line may be incomplete and even a strong indication of this line at only the costa or inner margin or a series of dots should be marked as present. It is also marked as present when it forms the edge of a medial or terminal band.

Subterminal line: The subterminal line is located just before the outer margin of the forewing and after the postmedial line when present. This line may be incomplete and even a strong indication of this line at only the costa or inner margin or a series of dots should be marked as present. It is also marked as present when it forms the edge of a medial or terminal band.

Streaks and dashes: Obvious dashes or streaks run through the forewing. They can be single or multiple. Sometimes the wing veins will be traced with paler scales, when these form a broad streak mark.

Iridescence/shine: At least some of the scales on the forewing appear reflective or change colour when the viewing angle of the wing is changed. Typically these are iridescent or extremely shiny.

Forewing Transparent or coloured: There are at least some patches on the forewing that are transparent and lacking of scales or atleast some or all the scales on forewing are differently coloured.

Hindwing: All the characters refer to the dorsal surface of the wing.

Hindwing fringe length: The fringe is the elongated scales that border the outer margin of the hindwing. It can be either >Hindwing width, the length of the fringe is longer than the hindwing width (measured perpendicularly from the inner margin of the hindwing for the greatest distance to near the anal margin) or, <Hindwing width, the length of the fringe is shorter than the hindwing width. The former one is character of small microleps where the later one is the state in larger microleps and macroleps.

Hindwing tail: The hindwings are projected into tails. The tail may be Present or Absent.

Hindwing notch: There are one or more deep notches in the outer margin. They may be Present or Absent.

Hindwing pattern: All of these characters refer to the dorsal surface of the wing. The hindwing can be Boldly patterned, i.e. of contrasting colours or can be as simple as the outer part of the wing being distinctly darker than the inner part, or, Not Boldly Patterned, i.e. can grade subtly from one shade to another, but never distinctly so. Hindwing pattern can be Similar to forewing pattern, i.e. in continuation with the forewing pattern which is most common in the leps that rest with their wings open and hindwings exposed, or, Different to forewing pattern.

Hindwing discal spot/lunule: A spot is often present in the middle of the hindwing which can sometimes be crescent-shaped (lunule). It can either be Present or Absent.

Hindwing colour: At least some of the scales on the hindwing appears reflective or change colour when the viewing angle of the wing is changed. Typically these are iridescent or extremely shiny. Hindwing can be of different coloured.

III. WING VENATION

The wing veins, represented by a special notation, are of great value in moth classification. The more primitive groups, Micropterigidae, Agathiphagidae, Lophocoronidae and Exoporia, in which the venation of forewings and hindwings is similar, are said to be Homoneurous. The more advanced groups, in which the number of veins in the hindwing is less than that of the forewing, are said to be Heteroneurous. The following terminology is based on the Comstock-Needham system which gives the morphological description of insect wing venation (Scoble 1995).

There are six main series of veins in the moth wing: costa (C), subcosta (Sc), radius (R), media (M), cubitus (Cu) and anal veins (A). The costal vein runs along and strengthens the costa margin of the wing. The subcostal veins on the more primitive groups may have two branches (Sc1 & Sc2). In most groups Sc is a simple vein running from the base of the wing, more or less parallel to the costa for most of its length and finally reaching the costa. A short humeral vein running from near the base of Sc to the costa may be present. The radius has two main branches, R1 and the radial sector (Rs). R1 is nearly always a simple vein. Rs may have as many as four branches (R2 to R5) and any of the veins R1 to R5 may be partially or completely fused. In the hindwing of heteroneurous forms R1 is usually fused, partly or completely, with Sc (Sc+R1) and Rs runs as an unbranched vein the margin of margin of the wing. The media in both forewing and hindwing has an anterior branch MA and a posterior branch MP; each of these may have two branches, M1 and M2 and M3 and M4 respectively. M4 is rarely present in Lepidoptera, and the other branches of Mmay fuse or coalesce. Near the base of the wing cubitus divides into two branches, an anterior branch (CuA), usually with two branches (CuA1 and CuA2), and a posterior branch (CuP). The area between the stem of CuA and the stem of R is

called the discal cell or simply the cell, the distal end of which is usually closed by cross-veins (discocellular veins) between M1, M2 and M3. CuP persists as a strong tubular vein in the more primitive groups, but in the more advanced groups, it is reduced, vestigial or lost entirely.

In addition to providing the wings with the necessary strength for flight, the veins supply the wings with haemolymph, which circulates outward from the thorax through the costal, radial and median veins, returning through the cubital and anal vein.

Characters of wing venation can be studied better if a wetting agent such as absolute alcohol or ethyl acetate is applied. The wings then increase in transparency and the veins can be seen if the wing is illuminated from behind and viewed under a microscope.

IV. LEGS

Hind tibial spur length: The hind tibia usually has two sets of movable spurs, one set near the apex, and one near the middle. Spurs when they are visible usually are situated in closely set pairs that spread outwards in a “V”. The spurs are often covered in scales and are usually prominent except when the tibiae are excessively hairy. The length can be >1/2 length of the 1st tarsomere, i.e. at least one of the apical pair of tibial spurs is longer than half of the length of the first tarsomere, or, <1/2 length of the 1st tarsomere.

Hind tibial spines: Spiniform setae are present that protrude from the scaly covering. These spiniform setae are usually much darker than the surrounding scales so they are apparent, however, in some small microleps they can be concolourous , but they are excessively long. In some specimens where the scales of the tibia are excessively long and dense, these spiniform setae will be very difficult to see.

Hind tarsal spines: Darkly pigmented spiniform setae are present on the ventral surface of the tarsomeres. These do not include paired spiniform setae at the apical end of each tarsomere since these are present in most Lepidoptera.

Other important thoracic character states that are helpful in identification process are Thorax width, Forewing length, Forewing width, Hindwing width, Ratio of forewing

length: thorax width, Ratio of forewing length: forewing width, Ratio of forewing width: hindwing width.

V. ABDOMEN

Ovipositor: The abdominal tip of most female Lepidoptera is fleshy; however, in some taxa there is a sclerotized and elongated ovipostitor which extends beyond the abdominal scales. It can be either Present or Absent.

Abdominal dorsal scale tuft: A tuft of erect scales is raised dorsally above the rest of the abdominal scales. This doesn't includes anal scale tufts at the tip of the abdomen. They are may be Present or Absent.

Abdominal pattern: The abdomen has a contrasting pattern on it. So, it can be Boldly patterned or Not boldly patterned.

Internal Structure: GENITALIA

The study of the genitalia is important for moth taxonomy in addition to development, anatomy and natural history. The genitalia are complex and provide the basis for species discrimination in most families and also in family identification. The genitalia are attached onto the tenth or most distal segment of the abdomen. Lepidoptera have some of the most complex genital structures in the insect groups with a wide variety of complex spines, setae, scales and tufts in males, claspers of different shapes and different modifications of the ductus bursae in females.

The arrangement of genitalia is important in the courtship and mating as they prevent cross-specific mating and hybridisation. The uniqueness of genitalia of a species led to the use of the morphological study of genitalia as one of the most important keys in taxonomic identification of taxa below family level.

There are three basic configurations of genitalia in the majority of the Lepidoptera based on how the arrangement in females of openings for copulation, fertilisation and egg-laying has evolved:

Exoporian: Hepialidae and related families have an external groove that carries sperm from the copulatory opening (gonopore) to the (ovipore) and are termed Exoporian.

Monotrysian: Primitive groups have a single genital aperture near the end of the abdomen through which both copulation and egg laying occur. This character is used to designate the Monotrysia.

Ditrysian: The remaining groups have an internal duct that carry sperm and form the Ditrysia, with two distinct openings each for copulation and egg-laying.

Male Genitalia: Genitalia in male and female of any particular Lepidopteran species are adapted to fit each other like a lock (female) and key (male). In males, the ninth abdominal segment is divided into a dorsal 'tegumen' and ventral 'vinculum'. They form a ring-like structure for the attachment of genital parts and a pair of lateral clasping organs (claspers or 'harpe'). The male has a median tubular organ (called the aedeagus) which is extended through an eversible sheath (or 'vesica') to inseminate the female. The males have paired sperm ducts, however, the paired testes are separate in basal taxa and fused in advanced forms.

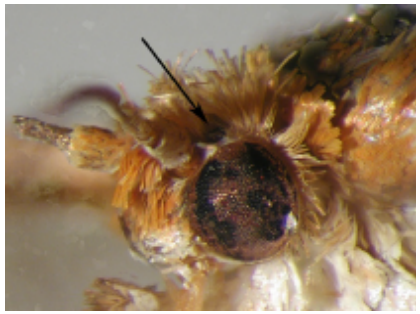
Female Genitalia: The internal female reproductive system consists of paired ovaries and accessory glands which produce the yolks and shells of the eggs. Female insects have a system of receptacles and ducts in which sperm is received, transported and stored. The oviducts of the female join together to form a common duct called the Oviductus Communis which leads to the vagina.

When copulation takes place, the male places a capsule of sperm (referred to as spermatophore) in a receptacle of the female called the Corpus Bursae. The sperm, when released from the capsule, swims directly into or via a small tube into a special seminal receptacle called spermatheca, where the sperm is stored until it is released into the vagina for fertilization during egg laying, which may occur hours, days, or months after mating. The eggs pass through the ovipore. The ovipore may be at the end of a modified ovipositor or surrounded by a pair of broad setose anal papillae.

Plate: General Morphological characters of moth significant for identification; (a) Head with Frons, Vertex & Compound Eye; (b) Ocellus; (c) Labial Palp; (d) Maxillary Palp; (e) Filiform Antenna; (f) Pectinate Antenna; (g) Hooked Antenna; (h) Antenna with abrupt Club; (i) Costal Fold of Forewing; (j) Tibial Spur; (k) Tibial Spines; (l) Tarsal Spines (Source: Dombroskie 2011).



a)



b)



c)



d)



e)



f)



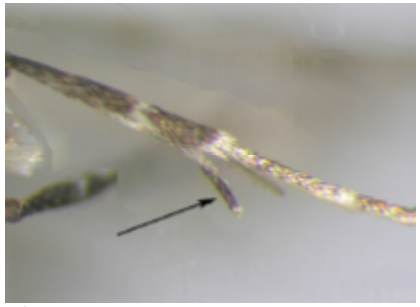
g)



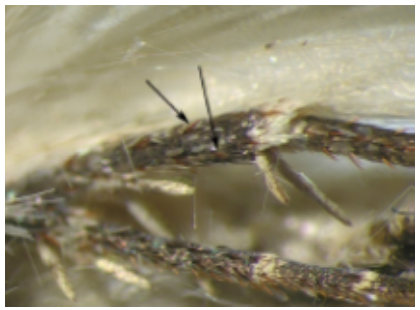
h)



i)



j)

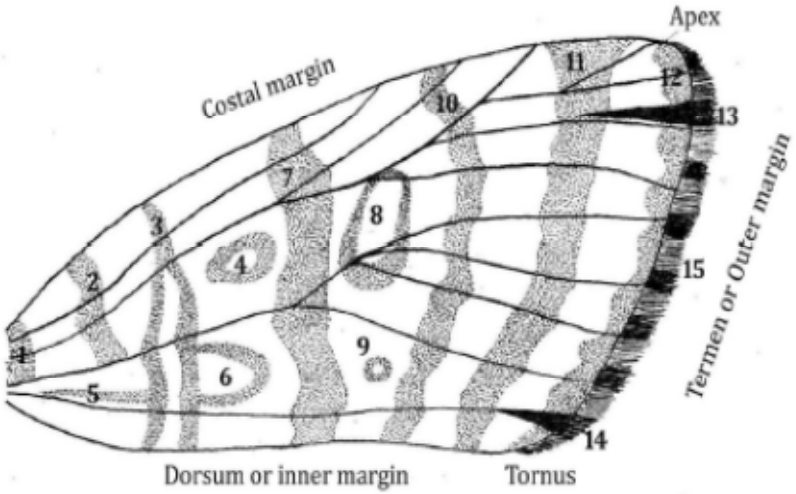


k)



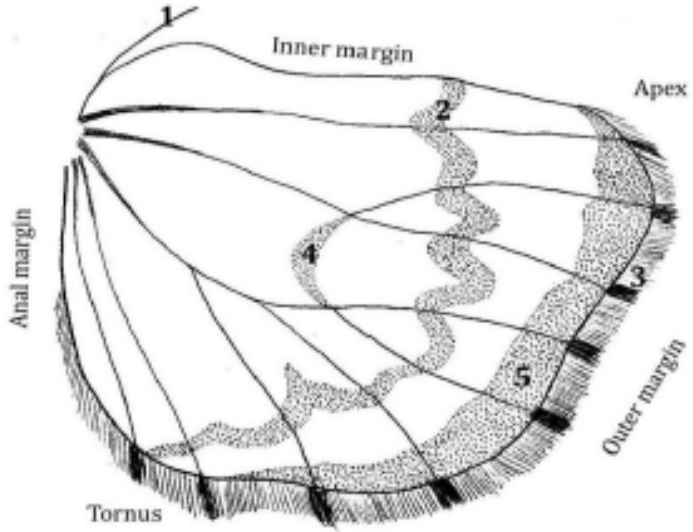
l)

Plate: Wing Venation and wing Markings of (a) Forewing & (b) Hindwing (Barlow 1982)



a)

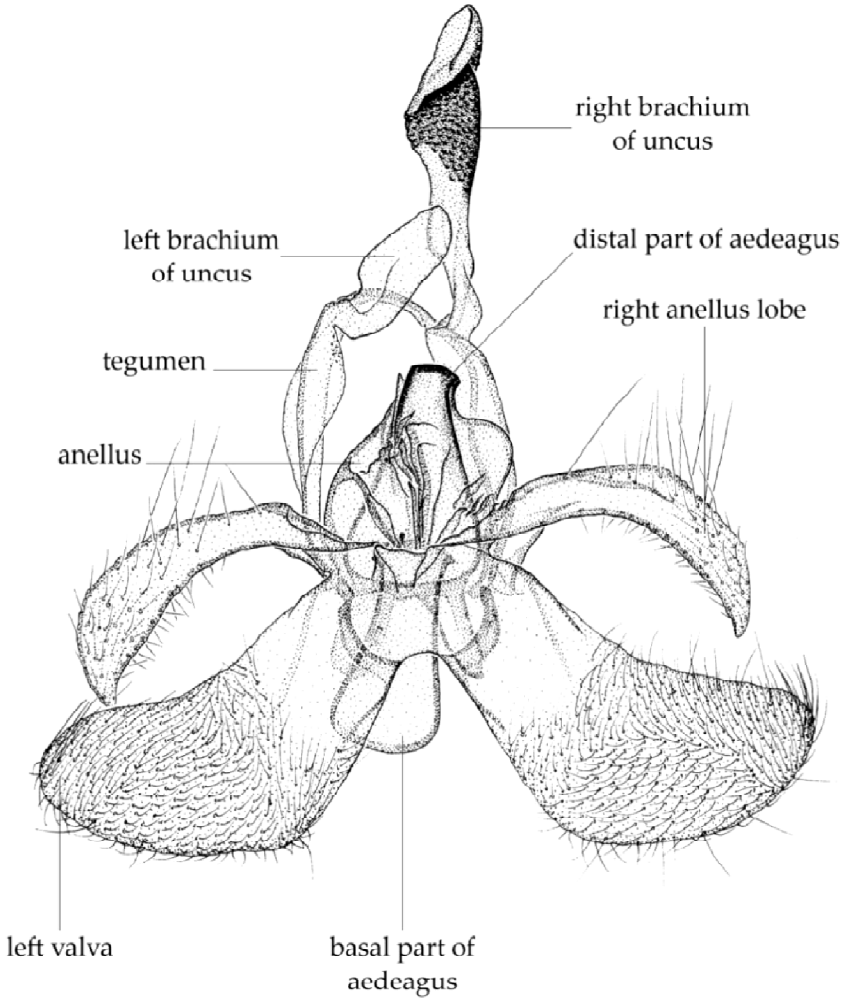
a) 1) Basal Sport, 2) Sub-basal Fascia 3) Antemedial Fascia, 4) Orbicular Stigma, 5) Basal Streak, 6) Claviform Stigma, 7) Median Fascia, 8) Reniform Stigma, 9) Sub-Reniform Stigma, 10) Post-medial Fascia, 11) Subterminal Fascia, 12) Terminal Fascia, 13) Apical Streak, 14) Tornal Streak, 15) Fringe.



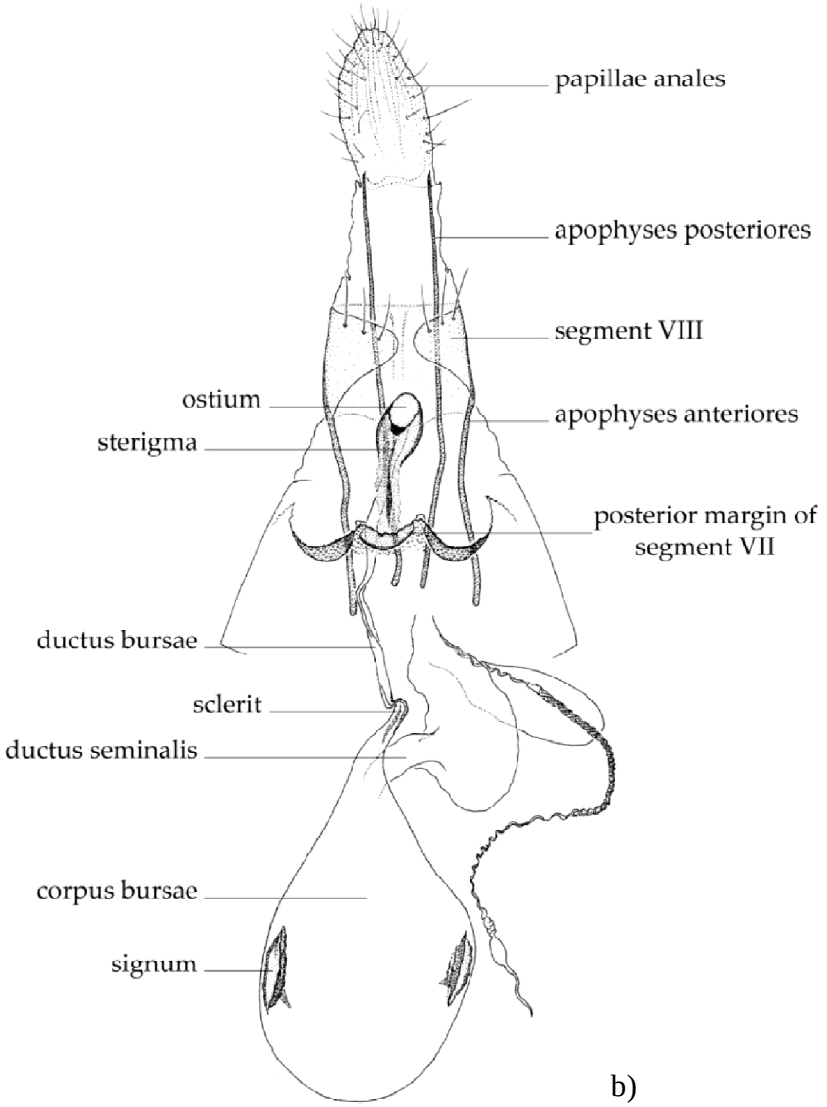
b)

b) 1) Frenulum, 2) Post-medial Fascia, 3) Fringe, 4) Discal Spot, 5) Terminal Fascia.

Plate: Anatomy of: a) Male Genitalia, b) Female Genitalia in Moth (Koster 2010)



a)



b)

Chapter III

Faunistic Inventory of Moths along Altitudinal Gradient in Gangotri Landscape

3.1 Biodiversity Conservation & Inventory

Based on their inherent ecological role as sustaining the dynamics of ecological processes, there is urgency for conservation of insects and other arthropods which has been neglected for too long. The conservation of insects and related arthropods is a overwhelming task and some of the critical factors which pose difficulty are: (1) the species diversity is large, both at global scale and local scale and our taxonomic literature is inadequate; (2) the size of populations and biomass of insects are extremely large and their functional roles, habitats and niche requirements are so diverse and variable, but ecological information about them is sparse; (3) geographical populations are highly variable and faunal and biogeographical information is inadequate; (4) the extirpation and extinction of insects are subtle and often difficult to recognize, as habitat destruction and environmental degradation are rampant throughout the world with ever-expanding human impacts; (5) the amount of taxonomic and natural history expertise is decreasing, while the need for taxonomic and biodiversity information and services has increased greatly. With these odds, insect conservation must take multiple approaches to cover all the fronts, targeted at different scales, such as specific community, assemblage, ensemble, population or species at a certain habitat.

An inventory of biodiversity is of primary importance as part of biodiversity conservation for sustainable development, particularly in threatened and fragmented landscapes such as the Western Himalaya, which harbor a unique assemblage of flora and fauna of considerable conservation importance. In comparison with higher animals, the inventory of insects in the Western Himalayan landscape is still fragmentary and incomplete due to the taxonomic complexity and lack of expertise for species-level identification. This has made the monitoring and conservation of insect biodiversity an impractical thing for protected area managers. Inventory and assessment of insect biodiversity provide the bases for developing practical, cost-effective preservation and monitoring programs.

Any faunal survey, aims at obtaining maximal information return on the distribution of all component species and their habitats, although the strategy of what and how to do a ground survey is determined by the goals of each program. There are two primary types of ground faunal surveys: (1) taxonomic survey (Kim & Knutson 1986, Vane-Wright *et al.* 1991); (2) environmental survey (Clarke 1986, Braithwaite 1991). Both types of faunal surveys contribute to developing a comprehensive description of the composition, richness and geographical distribution of constituent species and provide the inventory and assessment of biological heterogeneity.

The inventory of insects and related arthropods primarily has been made on a taxon based approach. To characterize the general profile of arthropod biodiyersity, taxonomists may undertake a quick survey of the target area for major taxa with specific collecting techniques and tools along with general collecting methods. This approach usually involves a long turn-around time, although it does produce comprehensive, authoritative catalogues and monographs for specific taxa. Taxonomic surveys must continue for systematics and evolutionary research and be integrated with environmental surveys for conservation. Considering the shortage of taxonomist specialist and limited funding support, this approach consumes too much time. Therefore, in most cases, conservation projects do not have the luxury of such time and thus require alternate approach like environmental survey which assesses the status of environmental heterogeneity including habitats and their biotic components in the local target site. Environmental surveys, however, often fail to supply sufficient information on the composition and habitats of resident species for effective conservation action because the data collected are superficial and often based on misidentification and gross taxonomy. Such surveys are often so general that the samples collected do not reflect accurately the diversity of habitats and their inhabitants, particularly for arthropods and invertebrates (Braithwaite 1991). Furthermore, because of the lack of taxonomic knowledge and expertise in environmental survey activities, frequently the materials collected are not properly prepared, preserved and accessioned for species identification and future reference. The major problems in environmental surveys are the insensitivity of investigators to accurate taxonomy and the lack of taxonomic knowledge. To establish the baseline data for monitoring, such surveys should be designed on the basis of knowledge on

ecological functional groups, e.g. guilds or assemblage (Walker 1992) or indicator species groups (Noss 1990).

The current study aimed to provide a complete inventory of the moth species assemblage along altitudinal gradients in different vegetation zones present in Gangotri Landscape Area. In this study, the taxonomic and environmental approach of site inventorying was tried to be merged for laying out a basic plan for moth conservation and future monitoring. While the taxonomy-based approach emphasized to prepare a local inventory of this highly diverse nocturnal group of insects, the environmental approach intended to explore for major climatic, topographical or vegetation aspects which govern the species diversity and composition in various habitats. Merging these two kinds of studies under one sampling framework is a daunting task and can only be managed with wise choice of sampling localities and specific sampling techniques. While the environmental and habitat association of this moth assemblage is discussed in subsequent chapters, the aim of this chapter is to provide an authenticated inventory of moth assemblage in a typical Western Himalayan altitudinal gradient.

3.2 Methods: Specimen Identiication

Obtaining accurate identifications is the foremost important stage for any study covering taxonomy or ecology of moths. Most butterflies and many macrolepidoptera are readily identified by 'picture-booking' using various internet resources (Dombroskie 2011), or visually skimming insect collections. However, this method is not practical for some macrolepidoptera and most microlepidoptera. Field guides are most useful for butterflies, but are less comprehensive, and in Indian scenario unavialable for moths due to their much larger diversity and ambiguity in classification. Even with all these resources, picture-booking can be error prone, especially for beginners, and offers no obvious starting point. Alternatively, while traditional dichotomous keys can be helpful in giving a place to start, it is difficult to see many characters due to the covering of scales. The reliable identification of specimens often requires careful examination of genitalia or wing venation. There are a few user-friendly dichotomous keys; however, they do not have a comprehensive coverage of Lepidopteran subfamilies and tribes. Consequently, relying on expert opinion has remained the best means for identifying microlepidoptera and difficult

macrolepidoptera. However, such taxonomists are already overworked and experts are often lacking for key taxa.

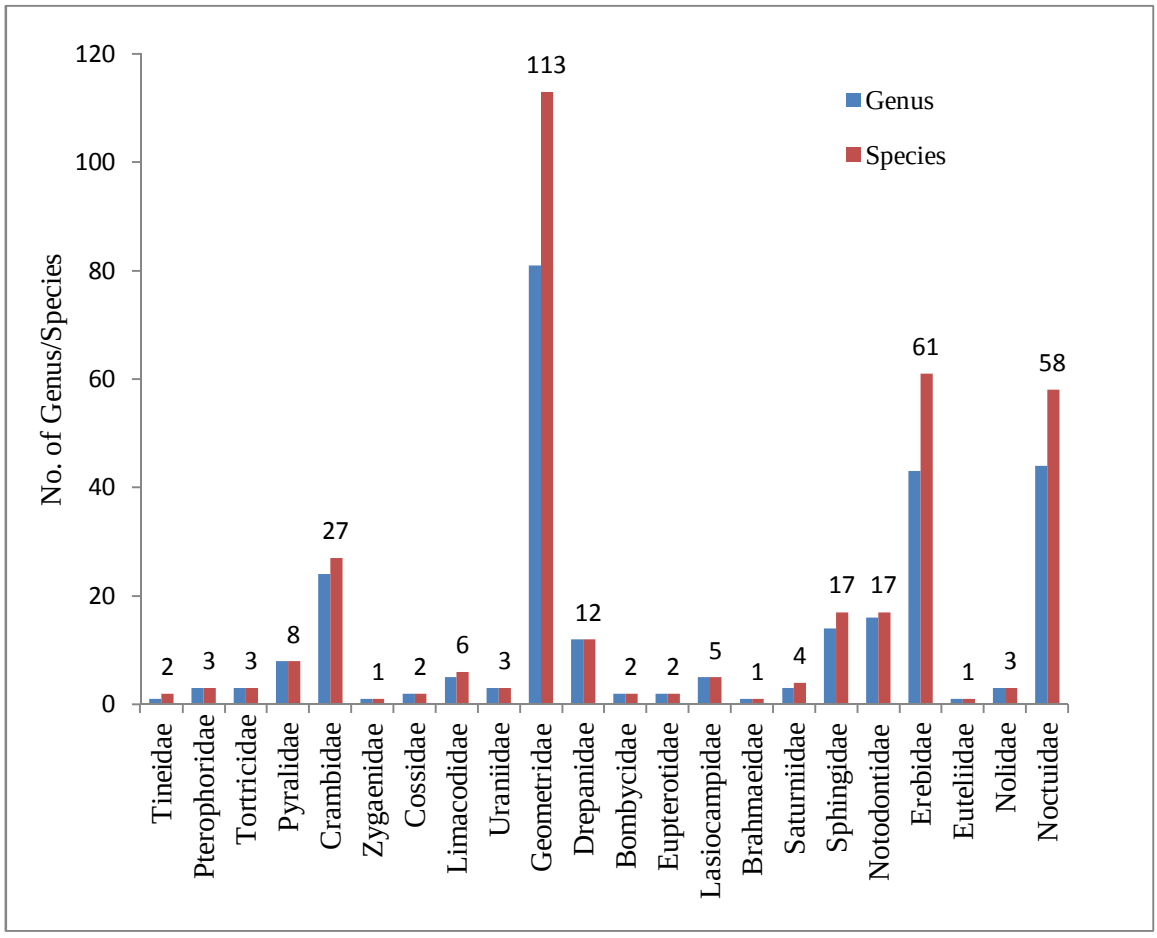
Voucher specimens were examined with help of low power stereoscopic binocular microscope for their external characters for taxonomic identification. Identification of voucher specimens were done by comparison with existing material from other reliably determined collections locally or by direct comparison with material at Zoological Survey of India, Central Regional Station at Jabalpur and National Collection at Kolkata. Where not possible, the initial determinations were made by comparing with the literature, primarily Holloway (1983-2011) and Robinson *et al.* (1994) following identification keys. The reference books used for taxonomic identifications were Hampson (1892, 1894, 1895, and 1896), Holloway (1985, 1986, 1987b, 1988, 1989, 1994, 1996, 1999, 2011), Barlow (1982), Robinson *et al.* (1994), Haruta (1994, 2002), Kendrick (2002), Srivastava (2002). The species were also identified from the current literature avialable online like Moths of India group on flickr (http://www.flickr.com/groups/mothsofindia) and on yahoo group (http://in.groups.yahoo.com/group/Indianmoths/), as well as consulting experts. Species whose identities could still not be ascertained from external morphology were studied by dissecting the genitalia under the stereoscopic binocular microscope. Current valid names of each species were consulted from "The Global Lepidoptera Name Index" (LEPINDEX) of the Natural History Museum, London (http://www.nhm.ac.uk/research-curation/research/projects/lepindex/).

3.3 Result: Inventory of Moth in Gangotri Landscape

A total of 670 morphospecies belonging to 356 genera and 22 families were collected during entire sampling periods. Of these, 351 species (48% of all species) representing 277 genera were identified at specis level. A complete species inventory is provided here of each family recorded from GLA with their current valid name, synonyms, distribution record, size, host plant record, abundance, altitude and habitat recorded from and the examined material information. Distribution record is provided from Hampson (1892-1896), LEPINDEX and other specifc literature available for each species. The host plant records were compiled from HOSTS, the Caterpillar Hostplant Database (Robinson *et al.* 2010, available at http://www.nhm.ac.uk/hosts) and other literarture avialble for specific generas. Each species was categorized into

four abundance classes: Rare (<10 individuals, found in 1 site only), Uncommon (< 20 individuals, found in 2 sites), Common (20 to 50 individuals, found in more than 5 sites) Abundant (>50 individuals, found in >10 sites). At altitude and habitat information, site code from where the species was collected is provided in parentheses. Details of every site code are already provided in second chapter (Table 2.1). Collection dates with umber of specimens studied are provided to give an idea about the seasonal activity period of the species (April-May: Premonsoon, June-August: Monsoon and September-November: Postmonsoon). General appearance, natural history and biology of the moth families and subfamilies are compiled from A Guide to Australian Moth (Zborowski & Edwards 2007), Moths of Borneo (Holloway 1985- 2011) and Hampson (1892-1896). Number of genera and species identified for all the major families are shown in Fig 3.1.

Fig.3.1: Species and Genus number identified for all the families recorded in GLA



3.3.1 Systematic Account

Order Lepidoptera

Suborder Glossata

Infraorder Heteroneura

Clade: Ditrysia

SUPERFAMILY: TINEOIDEA

I. Family Tineidae Latreille, 1810

Collectively, they are known as fungus moths or tineid moths. The family contains considerably more than 3,000 species in more than 300 genera worldwide (Robinson 2009). Most of the tineid moths are small or medium-sized, with wings held roofwise over the body when at rest. They are particularly common in the Palaearctic, but many occur elsewhere, and some are found very widely as introduced species. Tineids are unusual among Lepidoptera as the larvae of only a very small number of species feed on living plants, the majority feeding on fungi, lichens, and detritus. The most familiar members of the family are the clothes moths, which have adapted to feeding on stored fabrics. The most widespread of such species are the common clothes moth (*Tineola bisselliella*), the case-bearing clothes moth (*Tinea pellionella*), and the carpet moth (*Trichophaga tapetzella*). A single genus and two species were identified from Gangotri Landscape Area.

***1. Opogona flavofasciata* (Stainton, 1859) (Plate 1.1)**

1859. *Lozostoma flavofasciata* Stainton, *Trans. Ent. Soc. (N.S.),* 5: 124.

1864. *Cachura objectella* Walker, *List. Specs. Lep. Ins. B. M.*, 30: 918.

1906. *Opogona flavofasciata,* Peton, *Ann. R. B. G. Perad*, 3: 229.

2012. *Opogona flavofasciata,* Koçak, A.Ö. & M. Kemal, *Cesa News,* 79: 1-57

Distribution: India, World (Sri Lanka), New record to Uttarakhand; *Size:* 16mm; *Host Plant:* Mostly scavengers, some are reported pest of banana and sugarcane; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mix Forest; *Specimen studied:* 29.v.2009 (1ex.), 01.vi.2009 (3ex.).

***2. Opogona theobroma* Bradley, 1956 (Plate 1.2)**

1956. *Opogona theobroma* Bradley, *Entomologist,* 89: 155.

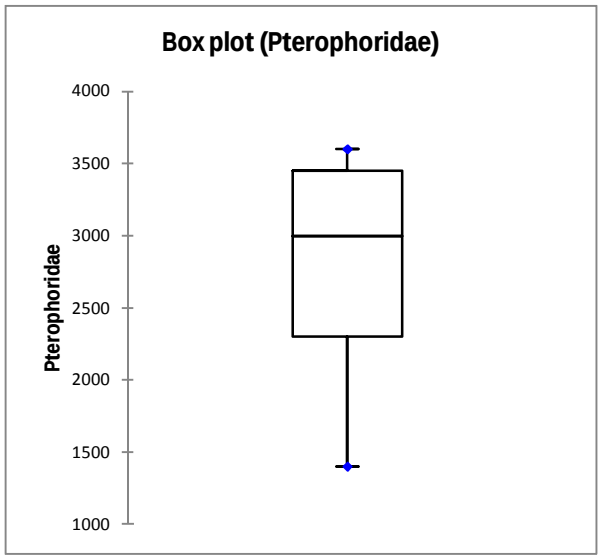
Distribution: World (Malayasia), New record to Uttarakhand; Size: 14.6mm; *Host Plant:* Mostly scavengers, feeding upon decaying remains of wide ranging plants;

Abundance: Uncommon; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mix Forest; *Specimen studied:* 01.vi.2009 (3 ex.)

II.Family Pterophoridae Zeller, 1841

The superfamily Pterophoroidea and family Pterophoridae is a unique group of slenderly built moths with long legs and narrow and fissured/clefted wings. The forewing may have one, sometimes two and rarely three clefts, whereas the hindwing is always clefted twice. They are commonly called the Plume-moths.

Figure 3.2: Altitudinal distribution of family Pterophoridae (n=15) recorded in GLA



Except from Meyrick and Fletcher in early parts of twentieth century, no concrete attempt has been made to collect and study these moths from India. The family is represented by 1238 species world over, and in India by 109 species (Sidhu *et al.* 2010). Due to their being smaller in size and difficult to handle taxonomically, this group of moth poses serious problems in collection and identification. They are extremely fragile moths sometimes active in the day or at early dusk but some also come to light at night. The larvae feed on flowers or occasionally on leaves openly during the day and have numerous small hairs on them.

Three genera and three species were identified from Gangotri Landscape Area. Mean distribution of the family is recorded around 3000m, while most of the species were recorded between 2300m to 3500m (Fig. 3.2), however species range extends from 1400m to 3500m.

***3. Buckleria paludum* (Zeller, 1841) (Plate 1.3)**

1841. *Pterophorus paludum* Zeller, *Isis von Oken*, (11-12): 866.

1907. *Trichoptilus paludicola* Fletcher, *Spolia zeylan*, 5: 20.

1931. *Pselnophorus dolichos* Matsumura, *Insects Japan Empire:* 1056.

2002. *Buckleria paludum* Zeller, *Microlepidop Palaearctica*: 2: 62.

2010. *Buckleria paludum* Zeller, Sidhu *et al., A Checklist of Microlepidoptera of India (Part-I: Pterophoridae).*

Distribution: India, World (Europe, Japan, Sri Lanka), New record to Uttarakhand; *Size:* 12mm; *Host Plant:* Recorded larval host plant is Sundew, *Drosera* sp., Cleome; *Abundance:* Common; *Altitude & Habitat:* 2600m (KK26) & 3600m (CH36), Western Mix Coniferous & Subalpine Forest; *Specimen studied:* 25.v.2012 (4 ex.), 13.v.2011 (3 ex.).

***4. Deuterocopus socotranus* Rebel, 1907 (Plate 1.4)**

1907. *Deuterocopus socotranus* Rebel, *Lep. Sokotr*.: 85: 37.

1913. *Deuterocopus triannulatus* Meyrick, *Exot. Micr*., 1: 107.

1934. *Deuterocopus socotranus*, Hori, *Mushi*., 7: 21.

2002. *Deuterocopus socotranus* Rebel, *Microlepidop Palaearctica*: 2: 24.

2010. *Deuterocopus socotranus* Rebel, Sidhu *et al., A Checklist of Microlepidoptera of India (Part-I: Pterophoridae).*

Distribution: India, World (Sri Lanka, Taiwan, Japan, South-East Asia, New Guinea, Australia, Africa), New record to Uttarakhand; *Size:* 12mm; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14) & 2600m (CH26), Subtropical Pine forest & Western Mix Coniferous forest; *Specimen studied:* 01.vi.2009 (2 ex.), 12.v.2011 (2 ex.).

***5. Diacrotricha fasciola* Zeller, 1851 (Plate 1.5)**

1851. *Diacrotricha fasciola* Zeller, *Linn. Ent.*, 6: 399.

2002. *Diacrotricha fasciola* Zeller, *Microlepidop Palaearctica*: 2: 36.

2010. *Diacrotricha fasciola* Zeller, Sidhu *et al., A Checklist of Microlepidoptera of India (Part-I: Pterophoridae).*

Distribution: India, World (Sri Lanka, Java, New Guinea, throughout South-East Asia), New record to Uttarakhand; *Size:* 14.5mm; *Host Plant:* Recorded feeding and

pest on Star fruit, *Averrhoa* sp. from peninsular Malaysia; *Abundance:* Rare; *Altitude & Habitat:* 3400m (DV34), 1400m (NT14), Alpine Scrub, Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 03.x.2008 (3 ex.), 10.xi.2009 (1 ex.).

Clade: Apoditrysia

SUPERFAMILY: TORTRICOIDEA

III.Family Tortricidae Latreille, 1803

The family Tortricidae contains the codling moth and oriental fruit moth, both serious pests, particularly of fruit. The codling moth which is considered to be the single most important group of insects that feed on apple. Most adult tortricids come readily to light but there are a small number of diurnal species. The larvae are typically 'leaf-tiers': they silk leaves together and live and feed in the shelter so formed. Some are borers in stems, cones, under bark, in seeds, and many are borers in fruit. One group feeds on dead leaves on the forest floor. Most live solitarily, a few live in large communal webs. They pupate in the larval shelters from which the pupal shell protrudes when the moth emerges. The family is found worldwide with more than 5000 species.

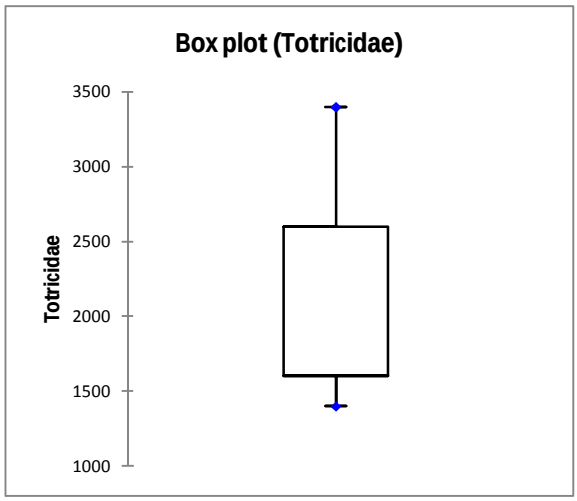
Their head is usually smooth-scaled. Wings are held flat roof-wise or rolled about body. Antennae are simple, held back along leading edge of the wing. Forewing near their base are often strongly curved. Palpi projected forward directly in front of head. Both wings are broad with short scale fringes. Hindwings are often slightly pointed near front edge.

Out of total 19 morphospecies collected from Gangotri Landscape Area, three genera and one species were identified. Mean distribution of the family is recorded around 2200m, while most of the species were recorded between 1700m to 2600m (Fig. 3.3), however species range extends from 1400m to 3400m.

***6. Clepsis* sp. (Plate 1.6)**

Genus Distribution: Worldwide; *Size:* 16mm; *Host Plant:* Recorded pest of Plum (*Prunus* sp.), apple (*Malus*), *Taxus* and *Polygonum*; *Abundance:* Common; *Altitude & Habitat:* 2400m (TK24), 2900m (KK30), Western Mix Coniferous forest, Kharsu Oak forest; *Specimen studied:* 28.v.2012 (1 ex.), 09.vi.2012 (3 ex.).

Fig. 3.3: Altitudinal Distribution of family Totricidae (n=23) recorded in GLA



***7. Homana* sp. (Plate 1.7)**

Genus Distribution: World (South-East Asia, Australia); *Size:* 15mm; *Host Plant:* Polyphagous including Tea (*Camellia* sp.); *Abundance:* Common; *Altitude & Habitat:* 2600m (KK26), 2900m (KK30), Western Mix Coniferous forest, Kharsu Oak forest; *Specimen studied:* 25.v.2012 (6 ex.), 26.v.2012 (2 ex.), 28.v.2012 (2 ex.).

***8. Dynatocephala omophaea* (Meyrick, 1926) (Plate 1.8)**

1926. *Harmologa omophaea* Meyrick, *Sarawak Mus. J.*, 3: 149.

1926. *Cacoecia cirrhocrossa* Meyrick, *Sarawak Mus. J.*, 3: 148.

1976. *Homona cruenta* Diakonoff, *Zoologische Verh. Leiden*, 144: 76.

1990. *Dynatocephala omophaea*, Tuck, *Ent. Scand.*, 21: 195.

Distribution: India (Sikkim, Northern India), World (Nepal, Thailand, Western Malaysia, Vietnam, Sumatra and Borneo), New record to Uttarakhand; *Size:* 22mm; *Abundance:* Rare; *Altitude & Habitat:* 2600m (KK26), Western Mixed Coniferous forest; *Specimen studied:* 26.v.2012 (2 ex.).

Clade Obtectomera

SUPERFAMILY PYRALOIDEA

The Pyraloidea (pyraloid moths) are a superfamily containing about 16,000 described species worldwide (Munroe & Solis 1998). They are generally fairly small moths. This superfamily used to contain the Hyblaeidae, Thyrididae, Alucitidae (plus

Tineodidae), Pterophoridae, and Pyralidae. Currently, the Crambidae are usually separated from the Pyralidae, but the first four families are now each split off as a distinct superfamily. Among all Lepidoptera, pyraloids show the most diverse life history adaptations and as a result are an ideal group for biodiversity studies (Schulze & Fiedler 2002).

IV. Family Pyralidae Latreille, 1802

This is one of the mega-diverse families of moths technically characterized by a scaled base to the proboscis (found otherwise in the gelechioid families), abdominal hearing organs, and often visible maxillary palpi. The other prominent character includes prominent labial palpi that usually protrude forward directly in front of the head, although they are sometimes large and ascending. Head is usually smooth, sometimes rough-scaled. Wings are held in many different poses, either at right angles to the body or horizontally, steep roof-wise, flattened roof-wise, sometimes rolled about body. The antennae are usually simple but sometimes pectinate, usually about half length of wing, but sometimes very short or long. Antennae are often held back over wings or body but sometimes along leading edge of forewing. The legs may be long and fragile, or short. The pupal shell is extruded from the cocoon on emergence of the adult.

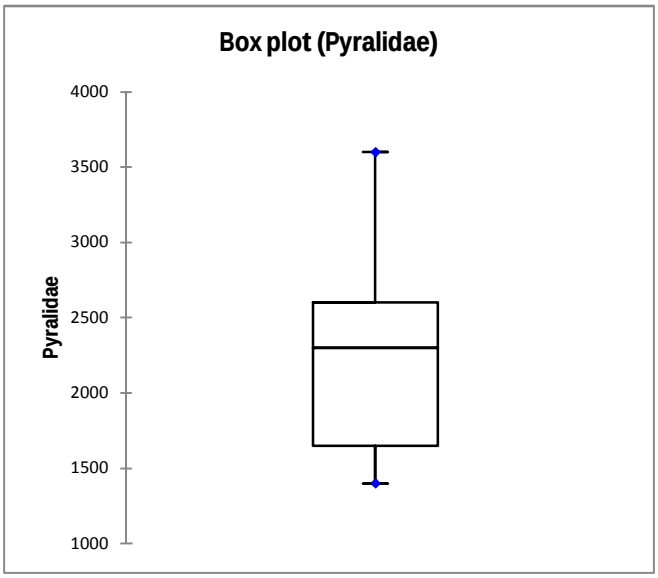
The family is globally represented by 5 subfamilies, viz. Chrysauginae, Epipaschiinae, Galleriinae, Phycitinae and Pyralinae of which three, viz. Epipaschiinae, Phycitinae and Pyraliinae were recorded from GLA.

Mean distribution of the family is recorded around 2400m, while most of the species were recorded between 1600m to 2500m (Fig. 3.4), and species range extends from 1500m to 3600m.

IVA. Subfamily Epipaschiinae

Almost 600 species are known today which are found mainly in the tropics and subtropics. Some occur in temperate regions, but the subfamily is completely absent from Europe, as native species. A few Epipaschiinae are crop pests that may occasionally become economically significant. Two species were recorded from the study area:

Fig 3.4: Altitudinal distribution of family Pyralidae (n=30) recorded in GLA



***9. Macalla* sp. (Walker, 1863) (Plate 1.9)**

Genus Distribution: India (Sikkim), World (South America, South Africa); *Size:* 34mm; *Host Plant:* The genus is sometimes recorded as serious defoliator of woody plants, like Mahogony in South America; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine forest; *Specimen studied:* 21.v.2010 (4 ex.).

***10. Lista haraldusalis* (Walker, 1858) (Plate 1.10)**

1858. *Locastra haraldusalis* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 16: 160.

1859. *Lista genisusalis* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 19: 877.

1992. *Lista haraldusalis*, Solis, *J. Lepid. Soc.*, 46 (4): 283.

Distribution: India (Himachal Pradesh, Sikkim), World (Malaysia), New record to Uttarakhand; *Size:* 25mm; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 09.vi.2009 (1 ex.).

IV B. Subfamily Phycitinae

This subfamily contains 600 genera considered valid and more than 4000 species described. They are apparently the most advanced lineage of snout moths.

***11. Epicrocis hilarella* Ragonot, 1888 (Plate 1.11)**

1888. *Epicrocis hilarella* Ragonot, *Nouv. Phycitidae* : 22.

1998. *Epicrocis hilarella* Ragonot, Mathew, Rugmini & Sudheendrakumar, *KFRI Research Report* 135: 101.

Distribution: India (Himachal Pradesh), World (Sri Lanka, China, Taiwan), New record to Uttarakhand; *Size:* 20mm; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 31.v.2009 (4 ex.), 03.v.2010 (4 ex.).

IV C. Subfamily Pyralinae

This is the typical subfamily of snout moth and occurs essentially worldwide with 900 described species (Solis & Shaffer 1999). The systematics and taxonomy of this subfamily is somewhat provisional. No quantitative phylogenetic analysis had been done, though in the mid-late 1990s M. Shaffer of the London Natural History Museum and M.A.Solis of the NMNH prepared the groundwork for further studies by their comprehensive qualitative reviews of Pyralinae morphology. They are polyphagous leaf-feeder as well as pest of stored goods. I recorded five species from the study area:

***12. Diloxia fimbriata* Hampson, 1896 (Plate 1.12)**

1896. *Diloxia fimbriata* Hampson, *Fauna of Brit. India*, 4: 180.

Distribution: India (Nilgiri Hills), New record to Uttarakhand; *Size:* 26mm; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Pine Broadleaved mix forest; *Specimen studied:* 10.xi.2009 (3 ex.), 13.xi.2010 (2 ex.).

***13. Endotricha olivacealis* (Bremer, 1864) (Plate 2.1)**

1864. *Rhodaria olivacealis* Bremer, *Mem. Acad. St. Petersb.*, 8: 66.

1891. *Endotricha flavifimbrialis* Warren, *Ann. Mus. Nat. Hist.*, 8(6): 69.

1963. *Endotricha olivacealis*, Whalley, *Bull. Brit. Mus. Nat. Hist. Ent.*, 13(11): 422.

1995. *Endotricha olivacealis* Bremer, *In* Haruta*: Moths of Nepal*, 4: 169.

Distribution: India, World (Russia, China, Korea, Japan, Taiwan, Malaysia, Java), New record to Uttarakhand; *Size:* 24mm; *Abundance:* Common; *Altitude & Habitat:* 1400m, (NT14), Subtropical Pine forest; *Specimen studied:* 03.v.2010 (4 ex.), 29.v.2009 (2 ex.).

***14. Orybina flaviplaga* Walker, 1863 (Plate 2.2)**

1863. *Orybina flaviplaga* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 27: 11.

2006. *Orybina flaviplaga* Walker, Mathew, *Zoos' Print Journal*, 21(5):2245-2258.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim), World (China, Thailand, Taiwan); *Size:* 38mm; *Abundance:* Rare; *Altitude & Habitat:* 1800m (CH18), Riverine Forest; *Specimen studied:* 24.vii.2012 (2 ex.).

***15. Sacada discinota* (Moore, 1866) (Plate 2.3)**

1866. *Paravetta discinota* Moore, *Proc. Zool. Soc. London* 814.

2006. *Sacada discinota* Moore, Mathew, *Zoos' Print Journal*, 21(5):2245-2258.

Distribution: India (Sikkim, Nagaland), World (Taiwan), New record to Uttarakhand; *Size:* 34mm; *Host Plant:* The genus is recorded to feed on different species of *Quercus*; *Abundance:* Rare; *Altitude & Habitat:* 2200m (CH22), 2600m (CH26), Western Mixed Coniferous forest; *Specimen studied:* 19.vii.2012 (2 ex.), 23.vii.2012 (3 ex.).

***16. Orthopygia igniflualis* (Walker, 1859) (Plate 2.4)**

1859. *Pyralis igniflualis* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 17: 268.

1859. *Pyralis dorcasalis* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 17: 271.

1980. *Orthopygia glauculalis* Yamanaka, *Tinea*, 10(34): 326.

1985. *Orthopygia igniflualis*, Inoue, *Akitu*, 72: 4.

Distribution: India (Nilgiri Hills), World (Borneo, Sri Lanka, China, Nepal, Japan), New record to Uttarakhand; *Size:* 24mm; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), Subtropical Broadleaved forest; *Specimen studied:* 29.v.2009 (3 ex.), 09.vi.2009 (2 ex.), 12.vi.2009 (2 ex.), 22.vi.2011 (2 ex.).

V. Family Crambidae Latreille, 1810

In many classifications, the Crambidae have been treated as a subfamily of the Pyralidae or snout-moths. The principal difference lies in the structure in the ears called the praecinctorium, which joins two tympanic membranes in the Crambidae, and is absent from the Pyralidae. The latest review by Munroe and Solis, in Kristensen (1999) retains the Crambidae as a full family. They are quite variable in appearance, the nominal subfamily Crambinae (grass moths) taking up closely folded

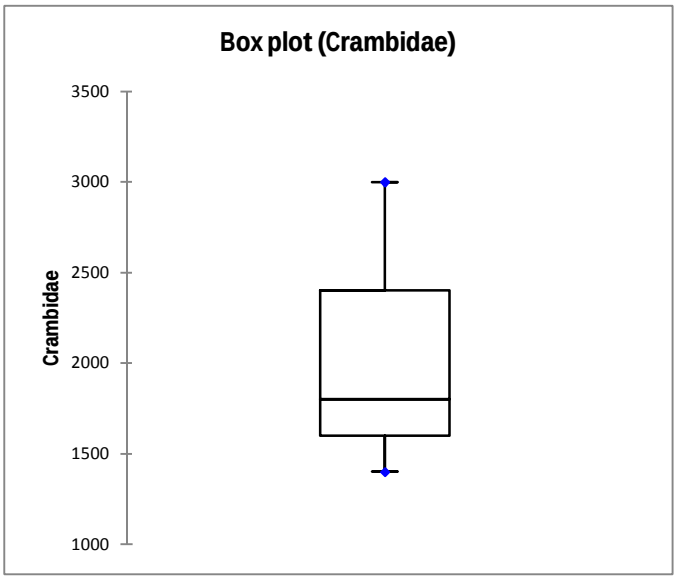
postures on grass stems where they are inconspicuous, while other subfamilies include brightly coloured and patterned moths which rest in wing-spread attitudes. The proboscis is with scales at base. Tympanal organs are at base of the abdomen ventrally and open anteriomedially. The larvae are stem borers, root feeders, leaf tiers and leaf miners.

There are about 11,630 described species in 15 subfamilies in the world (Solis 2007). From GLA, I recorded 5 subfamilies, 18 genera and 21 species. Mean distribution of the family is recorded around 1800m, while most of the species were recorded between 1600m to 2400m (Fig. 3.5), and species range extends from 1400m to 3000m.

V A. Subfamily Musotiminae

A rare subfamily of Crambidae, Musotiminae is comprised of 18 genera and 200 species worldwide (Regier *et al.* 2012). Musotimines are defined by their laterally compressed antennae with flattened segments, R2 stalked with R3+R4, a reduced coecum in the aedeagus of the male genitalia, and enlarged tympanal cases (Yen 1996). Larvae are reported to feed on Pteridophytes. A single species was recorded from the study area:

Fig 3.5: Altitudinal distribution of family Crambidae (n=104) recorded in GLA



***17. Cymoriza ustalis* Walker, 1865 (Plate 2.5)**

1865. *Cymoriza ustalis* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 34: 1529.

1896. *Cymoriza fascialis* Warren, *Ann. Mus. Nat. Hist.*, 18: 223.

2006. *Cymoriza ustalis* Walker, Mathew, *Zoos' Print Journal*, 21(5):2245-2258.

Distribution: India (Himachal Pradesh, Sikkim), World (Java), New record to Uttarakhand; *Size:* 36mm; *Abundance:* Common; *Altitude & Habitat:* 1800m (CH18), 2200m (CH22), Riverine forest, Montane Temperate Deciduous forest; *Specimen studied:* 20.vii.2012 (7 ex.), 23.vii.2012 (4 ex.), 25.vii.2012 (7 ex.).

V B. Subfamily Nymphulinae

The subfamily Nymphulinae has aquatic larvae with tracheal gills for living in still or running fresh water. This small and rare subfamily was represented by single species from the study area:

***18. Eoophyla peribocalis* (Walker, 1859) (Plate 2.6)**

1859. *Cataclyota peribocalis* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 17: 446.

1859. *Cataclysta halialis* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 17: 447.

1890. *Oligostigma papulalis* Snellen, *Trans. Ent. Soc. London* : 640.

1999. *Eoophyla peribocalis*, Speidel & May, *Tijdschr. Ent.*, 142: 129.

Distribution: India (North West Himalayas, Nilgiri Hills), World (China, Burma); *Size:* 26mm; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 1800m (CH18), Subtropical Pine Broadleaved mix forest, Riverine forest; *Specimen studied:* 23.v.2010 (6 ex.), 24.vii.2012 (3 ex.), 25.vii.2012 (2 ex.).

V C. Subfamily Pyraustinae

Pyraustinae is a large subfamily containing over 1400 species worldwide (Regier *et al.* 2012) distributed mainly in the tropics and few in temperate North Americas and Europe. They are characterized by atrophied spinula and venulae in the tympanal organs. Many species have larvae that bore into stems and fruit of plants, and several are serious agricultural pests. I recorded two species from the study area:

***19. Herpetogramma luctuosalis* (Guenée, 1854) (Plate 2.7)**

1854. *Sylepta luctuosalis* Guenee, *Delt. & Pyr.*, : 290.

1859. *Botys oemealis* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 18: 671.

1877. *Coptobasis andamanalis* Moore, *Proc. Zool. Soc. London*, : 615.

1916. *Lygropea nictoalis* Swinhoe, *Ann. Mus. Nat. Hist.*, 18: 489.

1995. *Herpetogramma luctuosalis* Guenée, *In* Haruta*: Moths of Nepal*, 4: 171.

Distribution: India (North Western and Eastern Himalayas, Andamans), World (Siberia, China, Japan, Borneo); *Size:* 28mm; *Host Plant:* Various herbaceous plants including Amaranthus, Cucurbits, Lantana and Lichens; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16) and 1800m (CH18), Subtropical Pine Broadleaved mix forest and Riverine forest; *Specimen studied:* 22.vi.2011 (4 ex.), 26.vi.2011 (5 ex.), 24.vii.2012 (5 ex.).

***20. Hyaloplaga pulchralis* Moore, 1867 (Plate 2.8)**

1867. *Hyaloplaga pulchralis* Moore, *Proc. Zool. Soc.*: 90.

2006. *Hyaloplaga pulchralis* Moore, Mathew, *Zoos' Print Journal*, 21(5):2245-2258.

Distribution: India (Uttarakhand, Sikkim); *Size:* 24mm; *Abundance:* Abundant, one of the most abundant Pyraloidea in GLA; *Altitude & Habitat:* 1400m (NT14), 2200m (CH22) and 2400m (CH24), Subtropical Pine Broadleaved Mix forest and Moist Temperate Deciduous forest; *Specimen studied:* 03.v.2010 (7 ex.), 22.vi.2011 (8 ex.), 23.vii.2012 (5 ex.), 19.vii.2012 (11 ex.).

V D. Subfamily Crambinae

This large subfamily includes over 1,800 species worldwide (Regier *et al.* 2012) and the monophyly of this group is supported by the structure of the tympanal organ and the phallus attached medially to juxta. The larvae are root feeders or stem borers, mostly on grasses. A few species are pests of grasses, maize, sugar cane, rice, and other Poaceae. I recorded two species from the study area:

***21. Euchromius ocellea* (Haworth, 1811) (Plate 2.9)**

1811. *Palparia ocellea* Haworth, *Lepid. Britannica*, (3): 486.

1829. *Crambus cyrilli* Costa, *Dizion. Univ. Agric.* : 11.

1915. *Eromene ocellea*, Rothschild, *Novit. Zool.*, 22 (2): 237.

1966. *Euchromius ocellea*, Capps, *Proc. U. S. Nat. Mus.*, 119 (3551): 3.

2006. *Euchromius ocellea* Haworth, Mathew, *Zoos' Print Journal*, 21(5):2245-2258.

Distribution: India (Maharashtra), World (Algeria, Persia, Japan, England), New record to Uttarakhand; *Size:* 22mm; *Host Plant:* Maize and Sorghum; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved mix forest; *Specimen studied:* 18.v.2010 (2 ex.).

22. Ancylolomia sp. **(Plate 2.10)**

Genus Distribution: The genus is widespread, occurring in all the biogeographic regions of the world; *Size:* 24mm; *Host Plant:* The genus is reported as minor pest to Poaceae including rice; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 12.xi.2011.

V E. Subfamily Spilomelinae

Spilomelinae is a very large subfamily which was formerly included in the Pyraustinae as tribe Spilomelini. They are believed to be polyphyletic; many genera are only tentatively placed here even currently. With nearly 3,800 described species worldwide (Regier *et al.* 2012), this is the most speciose group among Pyraloids. The moths are characterized by the absence of chaetosemata, a bilobed praecinctorium, projecting fornix tympani, pointed spinula, absence of a gnathos, and the female genitalia have no rhomboidal signum on the bursa copulatrix. 20 species were identified from GLA:

23. Cirrhochrista brizoalis **(Walker, 1859) (Plate 2.11)**

1859. *Margaronia brizoalis* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 19: 976.

1863. *Cirrhochrista aetherialis* Lederer, *Wien. ent. Monats.,* 7(12): 441.

1891. *Cirrhochrista brizoalis*, Ragonot, *Ann. Soc. ent. Fr.*, 10(6): 542.

2006. *Cirrhochrista brizoalis* Walker, Mathew, *Zoos' Print Journal,* 21(5):2245-2258.

Distribution: India (North West Himalaya, Maharashtra, Nilgiri Hills), World (Taiwan, Japan, China, Formosa, Borneo, New Guinea, Australia); *Size:* 26mm; *Host Plant:* Common fig (*Ficus carica*); *Abundance:* Uncommon; *Altitude & Habitat:* 1400 (NT14), 1600m (NT16), 1800m (CH18), Pine forest and Riverine forest; *Specimen studied:* 10.xi.2009 (6 ex.), 30.xi.2011 (4 ex.), 25.vii.2012 (1 ex.).

***24. Cotachena histricalis* (Walker, 1859) (Plate 2.12)**

1859. *Botys histricalis* Walker, *List. Specimens Lepid. Insects Colln. Br. Mus.*, 18: 655.

1896. *Cotachena peractalis* Warren, *Ann. Nat. Hist.*, 17 (6): 465.

1961. *Cotachena histricalis*, Whalley, *Bull. Br. Mus. Nat. Hist. Ent.*, 10: 99.

2006. *Cotachena histricalis* Walker, Mathew, *Zoos' Print Journal*, 21(5):2245-2258.

Distribution: India (Himachal Padesh, Sikkim, Nagaland, Nilgiri Hills), World (Sri Lanka, Australia, Africa), New record to Uttarakhand; *Size:* 23mm; *Host Plant:* Reported from China to feed on Hackberry (*Celtis sinensis*); *Abundance:* Common; *Altitude & Habitat:* 2200m (CH22), 2400m (CH24), Mixed Coniferous forest; *Specimen studied:* 10.vi.2012 (4 ex.), 10.vii.2012 (2 ex.), 20.vii.2012 (1 ex.).

***25. Dichocrocis definita* (Butler, 1889) (Plate 3.1)**

1889. *Haritala definita* Butler, *Ill. Het.*, 7: 97.

2006. *Dichocrocis definita* Butler, Mathew, *Zoos' Print Journal*, 21(5):2245-2258.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Assam, Arunachal Pradesh); *Size:* 30mm; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), 1800m (CH18), Pine Broadleaved Mix forest, Riverine Forest; *Specimen studied:* 10.xi.2009 (3 ex.), 24.vii.2012 (7 ex.).

***26. Dysallacta negatalis* (Walker, 1859) (Plate 3.2)**

1859. *Phalangiodes negatalis* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 17: 468.

1859. *Botys monesusalis* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 18: 653.

2006. *Dysallacta negatalis* Walker, Mathew, *Zoos' Print Journal*, 21(5):2245-2258.

Distribution: India, World (South Africa, Hong Kong, Japan, Australia), New record to Uttarakhand; *Size:* 28mm; *Host Plant:* Elephant apple (*Dillenia indica*), Indian Laurel (*Ficus microcarpa*), Peepal (*Ficus religiosa*). Serious defoliator of Indian Beech (*Millettia pinnata*); Abundance: Rare; *Altitude & Habitat:* 1400m (NT14), Pine Broadleaved Mix forest; *Specimen studied:* 17.vi.2009 (3 ex.).

***27. Endocrossis flavibasalis* (Moore, 1867) (Plate 3.3)**

1867. *Botyodes flavibasalis* Moore, *Proc. Zool. Soc. Lond.* : 96.

2001. *Endocrossis flavibasalis* Moore, Kirti & Sodhi, *Zoos' Print*, 16(10):607-614.

Distribution: India (Sikkim, Assam, West Bengal, Arunachal Pradesh), World (Myanmar, Sumatra, New Guinea), New record to Uttarakhand; *Size:* 36mm; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Pine Broadleaved mix forest; *Specimen studied:* 06.v.2010 (1 ex.).

***28. Glyphodes crithealis* (Walker, 1859) (Plate 3.4)**

1859. *Desmia crithealis*, Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 17: 344.

1888. *Glyphodes chilka* Moore, *Lep. Atk.* : 216.

1925. *Glyphodes minoralis* Caradja, *Acad. Romana, Mem. Sect. Stiint. Ser. Iii*, 3, 7: 352.

2006. *Glyphodes crithealis* Walker, Mathew, *Zoos' Print Journal*, 21(5):2245-2258.

Distribution: India (North West and Eastern Himalaya), World (Nepal, Taiwan, China); *Size:* 33mm; *Host Plant:* Different species of *Ficus*; *Abundance:* Abundant; *Altitude & Habitat:* 1400m (NT14), 1800m (CH18), 2200m (CH22), 2400m (CH24), 2600m (CH26) and 3000m (CH30), Pine forest, Riverine forest, Mixed Coniferous forest, Upper Oak forest and Subalpine forest; *Specimen studied:* 03.v.2010 (5 ex.), 24.vi.2011 (4 ex.), 10.vii.2012 (11 ex.), 13.vii.2012 (3 ex.), 19.vii.2012 (2 ex.).

***29. Glyphodes bivitralis* Guenée, 1854 (Plate 3.5)**

1854. *Glyphodes bivitralis* Guenee, *In* Boisduval & Guenée: *Hist. nat. Ins., Spec. gén. Lépid.*, 8: 293.

1886. *Glyphodes alitalis* Hulst, *Trans. Amer. Ent. Soc.*, 13: 158.

1996. *Glyphodes bivitralis*, Nielsen & Rangsi, *Checklist of the Lepidoptera of Australia; CSIRO.*

2006. *Glyphodes bivitralis* Walker, Mathew, *Zoos' Print Journal*, 21(5):2245-2258.

Distribution: India (Uttarakhand, Sikkim, Assam, Western India, South India, Andamans), World (Sri Lanka, Borneo, Taiwan, Hong Kong, Japan, Thailand, Australia, Hawaiian Island); *Size:* 34mm; *Host Plant: Erythrina speciosa*, *Ficus variolosa*; Abundance: Rare; *Altitude & Habitat:* 2600m (CH26), Mixed Coniferous forest; *Specimen studied:* 19.vii.2012 (1 ex.).

***30. Goniorhynchus signatalis* (Walker, 1866) (Plate 3.6)**

1866. *Pyrausta signatalis* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 34: 1444.

1995. *Goniorhynchus signatalis, In* Haruta: *Moths of Nepal*, 4: 185.

2013. *Goniorhynchus signatalis*, Sanyal *et al., Jour. Threat. Taxa*, 5(2):3646-3653.

Distribution: India (North West Himalayas, Nilgiri Hills), World (Sri Lanka, Java); *Size:* 26mm; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Pine forest; *Specimen studied:* 10.xi.2009 (4 ex.), 12.xi.2009 (3 ex.).

***31. Lamprosema commixta* (Butler, 1879) (Plate 3.7)**

1979. *Samea commmixta* Butler, *Ann. Mus. Nat. Hist.*, 4(5): 453.

2001. *Lamprosema commixta* Butler, Kirti & Sodhi, *Zoos' Print*, 16(10):607-614.

Distribution: India (Himachal Pradesh, Nagaland, Assam, Tamil Nadu, Meghalaya), World (Japan, China, Sri Lanka), New record to Uttarakhand; *Size:* 18mm; *Abundance:* Uncommon; *Altitude & Habitat:* 1600m (NT16), Pine Mix Forest; *Specimen studied:* 01.vi.2009 (5 ex.), 03.vi.2009 (3 ex.), 26.vi.2011 (2 ex.).

***32. Nomophila noctuella* (Denis & Schiffermüller, 1775) (Plate 3.8)**

1775. *Botys noctuella* Denis & Schiffermüller, *Ankündung eines systematischen Werkes von den Schmetterlingen der Wienergegend* : 136.

1796. *Pyralis hybridalis* Hübner, *Samml. eur. Schmett.* [6] : f. 114, : 184.

1863. *Nephopteryx indistinctalis* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 27: 59.

1890. *Botys helvolalis* Maassen, *In* Reiss & Stübel: *Reisen Süd-Am. Lep.* : 170.

2006. *Nomophila noctuella*, Mathew, *Zoos' Print Journal*, 21(5):2245-2258.

Distribution: India, World (Cosmopolitan); *Size:* 28mm; *Host Plant:* Larvae feed on Clover, Medicago, *Polygonum*, Wheat and *Vaccinium*; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), 2100m (TK21), 2200m (CH22), Pine Mix Forest, Montane Temperate Deciduous, Western Mix Coniferous forest; *Specimen studied:* 01.vi.2009 (4 ex.), 03.vi.2009 (3 ex.), 08.vi.2009 (9 ex.), 03.v.2010 (2 ex.), 25.x.2011 (1 ex.), 23.vii.2012 (2 ex.).

***33. Omiodes noctescens* (Moore, 1888) (Plate 3.9)**

1888. *Charema noctescens* Moore, *Lep. Atk.* : 218.

1982. *Omiodes noctescensi*, Inoue, *Moths of Japan*, 1: 340, 2: 233, 454.

2006. *Omiodes noctescens* Moore, Mathew, *Zoos' Print Journal*, 21(5):2245-2258.

Distribution: India (Sikkim, Assam, Meghalaya), World (China, Indonesia, Japan, Korea, Nepal, Philippines), New record to Uttarakhand; *Size:* 38mm; *Abundance:*

Rare; *Altitude & Habitat:* 1400m (NT14), Pine mix Forest; *Specimen studied:* 31.v.2009 (4 ex.)

***34. Pleuroptya balteata* (Fabricius, 1798) (Plate 3.10)**

1798. *Phalaena balteata* Fabricius, *Suppl. Ent. Syst*. : 457.

1865. *Botys accipitralis* Walker, *Cat. Lep.*, 34: 1422.

1879. *Botys aurea* Butler, *Ill. Het.*, 3: 76.

1915. *Sylepta irregularis* Rothschild, *Rep. B. O. U. exp.*, 2(15): 136.

2001. *Pleuroptya balteata*, Kovacs & Kovacs, *Entomol. Rom.* 6:53-54

Distribution: India (Uttarakhand-First time record from India), World (Nepal, Europe, Africa, Madagascar, Japan, Korea, Taiwan, Thailand, Australia); *Size:* 32mm; *Host Plant:* Cashew (*Anacardium occidentale*), *Quercus serrata* and Chestnut (*Castanea* sp.); *Abundance:* Uncommon; *Altitude & Habitat:* 1600m (NT16), 2200m (CH22) and 2500m (HS26); Pine Broadleaved mix Forest and Western Mix Coniferous forest; *Specimen studied:* 24.x.2008 (3 ex.), 01.vi.2009 (4 ex.), 23.vii.2012 (4 ex.).

***35. Pleuroptya quadrimaculalis* (Kollar, 1844) (Plate 3.11)**

1844. *Scopula quadrimaculalis* Kollar, *Hugel's Kschm.*, 4: 492.

1863. *Sylepta quadrimaculalis* Led., *Wien. Ent. Mon.* pl. 16, f. 12.

1982. *Pleuroptya quadrimaculalis*, Inoue, *Moths of Japan.*, 1: 234, 454.

Distribution: India (North West Himalayas, Sikkim, Meghalaya, Assam, Arunachal Pradesh, Nagaland), World (Africa, Japan, Borneo); *Size:* 35mm; *Abundance:* Abundant; *Altitude & Habitat:* 1400m (NT14), 1800m (CH18), 2400m (CH24), 2600m (CH26), 3000m (CH30); Pine Mix forest, Riverine forest, Western mixed Coniferous forest and Subalpine forest; *Specimen studied:* 22.vi.2011 (5 ex.), 13.vii.2012 (9 ex.), 19.vii.2012 (7 ex.), 24.vii.2012 (2 ex.).

***36. Pleuroptya ruralis* (Scopoli, 1763) (Plate 3.12)**

1763. *Phalaena ruralis* Scopoli, *Ent. Carn.* : 242.

1891. *Notarcha dubia* Hampson, *Ill. Het.*, 8: 136.

1960. *Lypotigris pallid* Dufrane, *Bull. Inst. Sci. nat. Belg.*, 36(29): 5.

2006. *Pleuroptya ruralis* Scopoli, Mathew, *Zoos' Print Journal*, 21(5):2245-2258.

Distribution: India, World (Europe), New record to Uttarakhand; *Size:* 32mm; *Host Plant:* Stinging Nettle (*Urtica dioica*); *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 2400m (CH24), Pine Broadleaved mix forest, Mixed Coniferous forest; *Specimen studied:* 31.v.2009 (9 ex.), 12.vi.2009 (2 ex.), 24.vii.2012 (8 ex.).

***37. Polygrammodes sabelialis* Guenée, 1854 (Plate 4.1)**

1854. *Polygrammodes sabelialis* Guenée, *Delt. & Pyr.* : 326.

1865. *Pachynoa obstructalis* Walker, *Cat. Lep.*, 34: 1481.

1918. *Pachynoa melanopyga* Strand, *D. ent. Zeitschr. Iris.*, 32: 69.

2006. *Polygrammodes sabelialis* Guenée, Mathew, *Zoos' Print*, 21(5):2245-2258.

Distribution: India (Himachal Pradesh, West Bengal, Maharashtra, Andamans), World (Africa), New record to Uttarakhand; *Size:* 32mm; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), 1800m (NT18), Pine Broadleaved Mix forest; *Specimen studied:* 01.vi.2009 (1 ex.), 03.vi.2009 (2 ex.), 07.xi.2012 (1 ex.).

***38. Sameodes cancellalis* (Zeller, 1852) (Plate 4.2)**

1852. *Botys cancellalis* Zeller, *Lepid. micr. Caff.* : 34.

1859. *Stenia pipleisalis* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 17: 420.

1880. *Sameodes trithyralis* Snellen, *Tijdschr. Ent.*, 23: 218, 26.

1996. *Sameodes cancellalis,* Nielsen & Rangsi, *Checklist of the Lepidoptera of Australia; CSIRO.*

2006. *Sameodes cancellalis* Zeller, Mathew, *Zoos' Print*, 21(5):2245-2258.

Distribution: India (Chhattisgarh, Madhya Pradesh, Maharashtra), World (Sri Lanka, Nepal, Thailand, China, Indonesia, Malaysia, Myanmar, Java, Phillipines, New Guinea, Australia), New record to Uttarakhand; *Size:* 22mm; *Host Plant:* Rice (*Oryza sativa*), *Stylosanthes erecta*, Teak (*Tectona grandis*); *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 2400m (TK24), Pine mix forest, Temperate Deciduous forest; *Specimen studied:* 15.v.2010, 21.v.2010.

***39. Spoladea recurvalis* (Fabricius, 1775) (Plate 4.3)**

1775. *Phalaena recurvalis* Fabricius, *Syst. Ent.* : 644.

1833. *Hydrocampa albifacialis* Boisduval, *Ann. Mus. Nat. Paris.*, 2: 267.

1854. *Spoladea animalis* Guenee, *Delt. & Pyr.* : 226.

1904. *Hymena exodias* Meyrick, *Ent. Mag.*, 40: 130.

1958. *Hymena recurvalis* Zimmermann, *Ins. Hawaii*., 8: 52.

1983. *Spoladea recurvalis*, Hodges, *Check List of the Lepidoptera of America North of Mexico*.

Distribution: India (Uttarakhand, Chattisgarh, Madhya Pradesh, Maharashtra, Karnataka, Andamans), World (Sri Lanka, China, Vietnam, Phillipines, Australia, Japan, Syria) *Size:* 22mm; *Host Plant:* Larval food plant reported as Spinach, Beet, Cotton, Maize and Soybean; *Abundance:* Common; *Altitude & Habitat:* 1600m (NT16), 2100m (TK22), 2400m (JK24), Pine Mix forest, Montane Temperate Deciduous forest and Western Mix Coniferous forest; *Specimen studied:* 13.v.2010 (4 ex.), 25.x.2010 (3 ex.), 11.xi.2011 (4 ex.).

***40. Syllepte verecunda* (Warren, 1896) (Plate 4.4)**

1896. *Loxoscia verecunda* Warren, *Ann. Nat. Hist.*, 18(6): 167.

2006. *Syllepte verecunda* Warren, Mathew, *Zoos' Print*, 21(5):2245-2258.

Distribution: India (North West Himalayas, Sikkim, Meghalaya, Tamil Nadu), World (Sri Lanka); *Size:* 32mm; *Host Plant:* Reported pest of Cotton; *Abundance:* Uncommon; *Altitude & Habitat:* 2600m (CH26, TK26), Western Mix Coniferous forest; *Specimen studied:* 12.vi.2012 (4 ex.), 19.vii.2012 (6 ex.).

***41. Syngamia falsidicalis* (Walker, 1859) (Plate 4.5)**

1859. *Asopia falsidicalis* Walker, *Cat. Lep.*, 17: 370.

1918. *Pyrausta suisharyonalis* Strand, *D. ent. Zeitschr. Iris.*, 32: 82.

2001. *Syngamia falsidicalis* Walker, Kirti & Sodhi, *Zoos' Print*, 16(10):607-614.

2006. *Syngamia falsidicalis* Walker, Mathew, *Zoos' Print*, 21(5):2245-2258.

Distribution: India (North West Himalayas, Assam, Meghalaya, Arunachal Pradesh, Mizoram, Nilgiri Hills), World (Sri Lanka); *Size:* 21mm; *Host Plant:* Various food plants including *Ficus*; *Abundance:* Uncommon; *Altitude & Habitat:* 2200m (CH22, KK22), 2600m (CH26), Montane Temperate Deciduous forest, Western Mix Coniferous forest; *Specimen studied:* 11.v.2010 (3 ex.), 19.vii.2012 (3 ex.), 20.vii.2012 (5 ex.).

***42. Terastia egialealis* (Walker, 1859) (Plate 4.6)**

1859. *Megaphysa egialealis* Walker, *Cat. Lep.*, 17: 383.

1863. *Terastia procelalis* Lederer, *Wien. Ent. Mon.*: 416.

1865. *Agathodes diversalis* Walker, *Cat. Lep.,* 34: 1307.

2006. *Terastia egialealis* Walker, Mathew, *Zoos' Print*, 21(5):2245-2258.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Karnataka, Maharashtra, Meghalaya), World (Java, Australia); *Size:* 45mm; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Pine Broadleaved mix forest; *Specimen studied:* 03.v.2010 (2 ex.).

***43. Dichocrocis punctiferalis* (Guenée, 1854) (Plate 4.7)**

1854. *Astura punctiferalis* Guenée, 1854, *Delt. & Pyr.* : 320.

1866. *Astura guttatalis* Walker, *Cat. Lep.*, 34: 1381.

1896. *Conogethes nigralis* Warren, *Ann. Mus. Nat. Hist.*, 18(6): 168.

2006. *Dichocrocis punctiferalis* Guenée, Mathew, *Zoos' Print*, 21(5):2245-2258.

Distribution: India (Throughout), World (Sri Lanka, China, Japan, Myanmar, Australia); *Size:* 24mm; *Host Plant:* Recorded as pests from different part of the world mainly associated with *Zea mays, Livistona humilis, Helianthus annuus, Durio zibethinus, Carica papaya, Ricinus communis, Sorghum bicolor, Prunus persica, Nephelium lappaceum, Solanum melongena, Brachychiton acerifolium* and *Elettaria cardamomum; Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), 2400m (CH24) from Pine forest, Mix Coniferous forest; *Specimen studied:* 03.vi.2009 (3ex.), 21.v.2010 (2 ex.), 10.vi.2012 (5 ex.).

SUPERFAMILY ZYGAENOIDEA

VI. Family Zygaenidae Latreille, 1809

Zygaenoidea is the superfamily of moths that includes burnet moths, forester moths, and relatives. This superfamily in many respects appears to stand astride the gap between butterflies and moths - they are brightly coloured, fly in sunshine, and have clubbed antennae; but they rest with the wings folded down, and they pupate in silk cocoons. The superfamily is divided into 13 families. Some of these, e.g. Dalceridae & Megalopygidae, are comprised of mostly nocturnal species - these are usually drab in colour, and have feathered antennae. Others including Zygaenidae are day-flying, brightly coloured, with unfeathered antennae that are swollen at the tips like those of

butterflies. The Zygaenidae comprises of about 1,000 species (Epstein 1996), found mainly in the tropics. The moths generally have a metallic blue or green sheen, and many of the species have prominent red spots on the forewings, and red hindwings. These bright colours are a warning to predators that they are poisonous, their bodies contain levels of Hydrogen Cyanide that are lethal to small birds. I recorded a single day flying species from Govind Wildlife Sanctuary:

***44. Chalcosia suffusa* Leech, 1898 (Plate 4.8)**

1898. *Chalcosia suffusa* Leech, *Trans. Ent. Soc. London*. : 343.

2005. *Chalcosia suffusa* Leech, *Zool. Journ. of Linn. Soc*.: 143, 161–341

Distribution: India, World (Hong Kong, Taiwan), New record to Uttarakhand; *Size:* 52mm; *Host Plant:* The genus feeds on *Symplocos*; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 24.vi.2011 (2 ex.), 26.vi.2011 (1 ex.).

SUPERFAMILY COSSOIDEA

Cossoidea is the superfamily of moths that includes carpenter moths (Family Cossidae), Dudgeoneidae – dudgeon moths and relatives. They are internal feeders and have spiny pupae with moveable segments to allow them to extrude out of their exit holes in stems and trunks during emergence of the adult. The Limacodidae are sometimes included here as a third family.

VII. Family Cossidae Leach, 1815

The Cossidae are a relatively small family that is most diverse in the tropics and subtropics. The adult moths are usually large with elongate, slender forewings and much shorter hindwings. The wing markings are usually cryptic, bark-like, involving fine dark striae or reticulation. The abdomen is long, reflecting the length of the forewings. The larvae bore in the twigs and trunks of bushes and trees and thus a number of species come into conflict with man, attacking timber and fruit trees as well as bush crops such as tea and coffee. The two subfamilies have been recognized in the oriental region, the Cossinae and Zeuzerinae. The two subfamilies differ in the character of hind tibiae. These are dilated in Cossinae and bear two pairs of spurs, but are slender in Zeuzerinae and have only one pair of spurs. I recorded two species from the study area both from subfamily Zeuzerinae:

***45. Xyleutes strix* (Linnaeus, 1758) (Plate 4.9)**

1758. *Phalaena strix* Linnaeus, *Syst. Nat. ed.*, 10a: 508.

1882. *Zeuzera bubo* Butler, *Ann. Mag. Nat. Hist.*, 10(5): 228.

1856. *Zeuzera signata* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 7: 1537.

1915. *Xyleutes formosicola* Strand. *Arch. F. Naturg. A.*, 8: 42.

1986. *Xyleutes strix* Linnaeus, Holloway, *Malay. Nat. J.*, 40: 1-166

Distribution: India (Uttarakhand, Sikkim), World (South-East Asia, Sundaland, Philippines, Sulawesi, Moluccas, New Guinea); *Size:* 178mm; *Host Plant:* The genus is reported as borers in different plantation species like coffee, cocoa etc.; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Pine Broadleaved Mix forest; *Specimen studied:* 22.vi.2011 (2 ex.).

***46. Zeuzera multistrigata* Moore, 1881 (Plate 4.10)**

1881. *Zeuzera multistrigata* Moore, *Proc. Zool. Soc. London.* : 327.

2008. *Zeuzera multistrigata* Moore, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Nagaland), World (China, Japan, Taiwan); *Size:* 59mm; *Host Plant:* From India recorded host plants are Japanese Cedar (*Cryptomeria japonica*), Mussaenda tree (*Mussaenda frondosa*), *Prunus,* Blue oak (*Quercus glauca*), Sandalwood (*Santalum album*); *Abundance:* Rare; *Altitude & Habitat:* 1800m (CH18), Riverine forest; *Specimen studied:* 24.vii.2012 (ex.).

VIII. Family Limacodidae Duponchel 1845

The Limacodidae are a moderately diverse, essentially tropical and subtropical family. Their place in the higher classification of Lepidoptera is yet to be ascertained properly. They were placed in the Cossoidea by Brock (1971) on the ground of thoracic structure, but Common (1975) included them in the Zygaenoidea on the basis of early stage characteristics.

The adults are characterized by relatively stout bodies which are usually covered with a dense pile of scales, and the forewings are also coarsely scaled, the scales arranged haphazardly rather than in rows. Head is rough-scaled. Wings are held steeply roof-wise over body. Antennae in male are short, pectinate, with pectinations shortening rapidly towards tip and are held back along leading edge of wing at rest. These moths

usually have no proboscis; their labial palpi are small and directed forwards. The larvae are well known for their bright colours, flattened slug-like shape and the ability of some to sting if handled.

They feed on a wide range of foodplants. They pupate in impressively neat cocoons, almost spherical in shape, and spun on twigs. Some pupate in the litter. To emerge, the pupa pushes up a cap prepared by the larva, and the pupal shell is protruded on emergence. The unique cup shape of the cocoon gave rise to the common name "Cup Moths". There are over 100 species recorded worldwide so far. I recorded 6 species from study area, most of which were recorded between 1600m and 1800m (Fig 3.6) with a single record below 1500m.

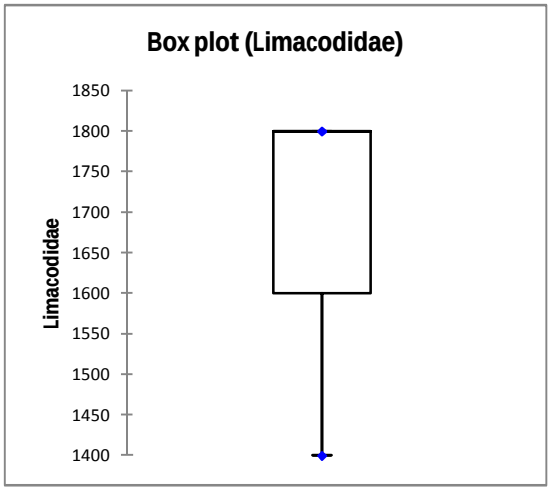
***47. Altha subnotata* (Walker, 1865) (Plate 4.11)**

1865. *Belgoraea subnotata* Walker, *List. Lep. Ins. Br. Mus.*, 32: 497.

2008. *Altha subnotata* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Assam, Jharkhand, Orissa, South India), World (Sri Lanka); *Size:* 26mm; *Host Plant:* Variety of woody plants like Red Cotton tree (*Bombax ceiba*), *Polyalthia longifolia*, Castor oil plant (*Ricinus communis*), Sal (*Shorea robusta*), *Terminalia myriocarpa*; *Abundance:* Rare; *Altitude & Habitat:* 1600m (BH16), Subtropical Broadleaved forest; *Specimen studied:* 12.vi.2009 (1 ex.).

Fig 3.6: Altitudinal distribution of family Limacodidae (n=17) in GLA



***48. Chalcoscelides castaneipars* (Moore, 1865) (Plate 4.12)**

1865. *Miresa castaneipars* Moore, *Proc. Zool. Soc. Lond.* : 819.

2008. *Chalcoscelides castaneipars* Moore, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Sikkim, Uttarakhand, Nagaland), World (Myanmar, Taiwan, Borneo); *Size:* 40mm; *Host Plant:* Recorded food plant from India includes *Spondias* sp, *Trevesia* sp., *Theobroma* sp., *Mangifera indica*; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Mix Broadleaved Forest; *Specimen studied:* 31.x.2012 (1 ex.).

***49. Miresa albipuncta* (Herrich-Schäffer, 1854) (Plate 5.1)**

1854. *Nyassi albipuncta* Herrich-Schaffer, *Aussereurop. Schmett.*, 1(10): 179.

1855. *Miresa guttifera* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 5: 1124.

2011. *Miresa albipuncta* Herrich-Schäffer, Smetacek & Smetacek, *J. of Threat. Taxa.* 3(12):2272–2276.

Distribution: India (Uttarakhand), World (Sri Lanka, Myanmar); *Size:* 30mm; *Host Plant:* Pest to Cottonwood Poplar (*Populus deltoids*), *Butea monosperma*, *Terminalia* etc.; *Abundance:* Rare; *Altitude & Habitat:* 1800m (CH18), Riverine forest; *Specimen studied:* 24.vii.2012 (2 ex.).

***50. Phocoderma velutina* (Kollar, 1844) (Plate 5.2)**

1844. *Gastropacha velutina* Kollar, *Hugel's Kaschmir.*, 4: 473.

1855. *Natada rugosa* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 5: 1109.

2008. *Phocoderma velutina* Kollar, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himalayas, Maharashtra, West Bengal, Assam, Punjab, Uttarakhand), World (Myanmar, Sundaland, Borneo); *Size:* 76mm; *Host Plant: Aleurites*, *Bombax ceiba*, *Butea monosperma*, *Lannea coromandelica*, *Camellia sinensis*, *Mangifera indica*, *Terminalia*; *Abundance:* Rare; *Altitude & Habitat:* 1800m (CH18), Riverine forest; *Specimen studied:* 25.v.2012 (2 ex.).

***51. Scopelodes unicolor* Westwood 1841 (Plate 5.3)**

1841. *Scopelodes unicolor* Westwood, *Nat. Libr. Exot. Moths.* : 222.

1862. *Bethura minax* Walker, *Journ. Linn. Soc. Lond.*, 6: 207.

2008. *Scopelodes unicolor* Westwood, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand, Sikkim, Assam), World (Java, Borneo, Myanmar, Sundaland); *Size:* 45mm; *Host Plant: Nephelium*, *Phaseolus*, *Eugenia*, *Ricinus*; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Subtropical Broadleaved forest; *Specimen studied:* 12.xi.2011 (1 ex.).

***52. Scopelodes venosa* Walker, 1855 (Plate 5.4)**

1855. *Scopelodes venosa* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 5: 1105.

1883. *Scopelodes aurogrisea* Moore, *Lep. Cey.*, 2: 126.

2008. *Scopelodes venosa* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand, Sikkim, North Eastern Himalaya), World (Sri Lanka, China); *Size:* 54mm; *Host Plant:* Polyphagous including *Camellia sinensis*, Coffee, *Rosa*; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 1800m (CH18), Pine Mix Forest, Riverine forest; *Specimen studied:* 22.vi.2011 (3 ex.), 24.vii.2012 (4 ex.).

SUPERFAMILY URANIOIDEA

IX. Family Uraniidae Blanchard, 1845

The superfamily Uraniodea contains one family, Uraniidae, with three subfamilies, Uraniinae, Microniinae and Epipleminae. The Epipleminae have been treated by most authors as a separate family and with Uraniidae, were referred either to the Geometroidea or to the Uranioidea. However Minet (1983) distinguished the Uraniodea from Geometroidea and assigned the Uraniinae, Microniinae and Epiplemiinae to one family, the Uraniidae, basing his conclusions on the structural features of the tympanal organ of the adults. The Uraniidae are distinguished from other families with abdominal tympanal organs and by the sexual dimorphism of these organs; they are present at the base of the abdomen in the female and at the junction of the second and third abdominal segments in the male.

The moths are generally of delicate build with deep triangular forewings without a basal area of wing-locking microtrichia and with tailed or angled hindwing. The head is small and smooth-scaled, without ocelli and with a pair of large chaetosemata. The antennae are filiform in females, but thickened, dentate and pectinate in males. Proboscis is present and unscaled. The family is widely distributed on a world basis, but is mainly tropical and subtropical. The family includes more than 650 species in

some 40 genera. I recorded two subfamilies, Microninae and Epipleminae from GLA:

IX A. Subfamily Microninae

The species in this subfamily all have white, creamy white or grayish white wings, the hindwing usually tailed or angled at vein M3, often with black spots associated. One species was recorded:

***53. Micronia aculeata* Guenée, 1857 (Plate 5.5)**

1857. *Micronia aculeata* Guenée, *Hist. Nat. Ins. (Spec. gén. Lépid.).* 10: 26.

1858. *Micronia aculeata* Guenée, *Hist. Nat. Ins. (Spec. gén. Lépid.).* 10: 13.

2013. *Micronia aculeata* Guenée, Gurule & Nikam, *J. Threat. Taxa.* 5(12): 4693–4713.

Distribution: India (Uttarakhand, Maharashtra, Andamans), World (Sri Lanka, Java, Borneo, China); *Size:* 48mm; *Host Plant:* Green Milkweed climber (*Wattakaka volubilis*); *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Broadleaved forest; *Specimen studied:* 19.v.2010 (2 ex.).

IX B. Subfamily Epipleminae

The Epiplemines are very much smaller than most members of other subfamilies. The majority have hidwings with tails at R3 and M3, the fasciation is often sharply angled, the angle more or less in line with the more posterior tail. The submarginal zone of the forewing is often darker. Two species were recorded:

***54. Orudiza protheclaria* Walker, 1861 (Plate 5.6)**

1861. *Orudiza protheclaria* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 23: 858.

1880. *Orudiza luctiferata* Snellen, *Midden Sumatra*. : 55.

1998. *Orudiza protheclaria*, Holloway, *The Moths of Borneo*, 8: 94.

Distribution: India (Uttarakhand, Sikkim, Meghalaya, Maharashtra, South India), World (Myanmar, Java, Borneo); *Size:* 36mm; *Host Plant:* The host-plants are *Bajanella, Sajanella* and other Bignoniaceae; *Abundance:* Rare; *Altitude & Habitat:* 1600m (BH16), Subtropical Broadleaved forest; *Specimen studied:* 04.xi.2008 (1 ex.).

***55. Epiplema bicaudata* Moore, 1867 (Plate 5.7)**

1867. *Epiplema bicaudata* Moore, *Proc. Zool. Soc. London*. : 643.

1896. *Epiplema fuscifrons* Warren, *Novit. Zool.*, 3: 348.

2005. *Epiplema bicaudata* Moore, Sohn & Yen, *Zoological Studies,* 44(1): 44-70.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Meghalaya, Kashmir), World (Korea, Japan); *Size:* 24mm; *Host Plant:* The genus is dependent on different species of Rubiaceae; *Abundance:* Abundant; *Altitude & Habitat:* 2200m (CH22), 2400m (CH24, KK24) in low abundance and in high abundance at 3000m (CH30), Western Mixed Coniferous forest and Subalpine Forest; *Specimen studied:* 22.vi.2010 (4 ex.), 10.vii.2012 (2 ex.), 13.vii.2012 (8 ex.), 24.vii.2012 (2 ex.).

SUPERFAMILY GEOMETROIDEA

X. Family Geometridae Leach, 1815

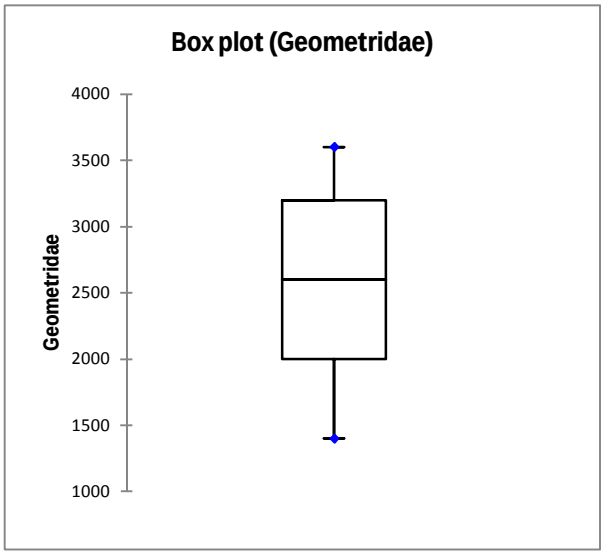
Only one family, Geometridae, is referred to the superfamily Geometroidea following Minet (1983), who based his decision on the structure of tympanal organ. Many authors have included several other families, such as the Drepanidae and Uraniidae, which have tympanal organs at the base of the abdomen. Geometridae is one of the largest families of Lepidoptera and are distributed throughout the world. According to some estimation 20,000 species, referred to at least 1,500 genera, belong to this family (Scoble 1999).

The geometridae are a varied group, but most have broad, rather triangular forewings and rather light, slender bodies, enabling low-energy flight rather than power and speed. Many species fly at dusk, before light traps are fully effective, and are best searched for with a net, or by trapping vegetation to disturb them by day. Wings usually outstretched from body pressed flat against the substrate, but sometimes back along body roof-wise or rolled about body, and a few with wings held upright together like butterflies Many Geometrids have functional tounges and can drink moisture, but relatively few can be found reliably by searching flowers or by trying to attract them to sugary baits, probably because low energy flighty requires less frequent refuelling. Another distinguishing feature of the family is that the caterpillars have only two pairs of hind legs, or prolegs, situated at the rear end. The central

region of the body has no legs and is looped up when the caterpillar moves, drawing the hind end up to the three pairs of legs at the head end.

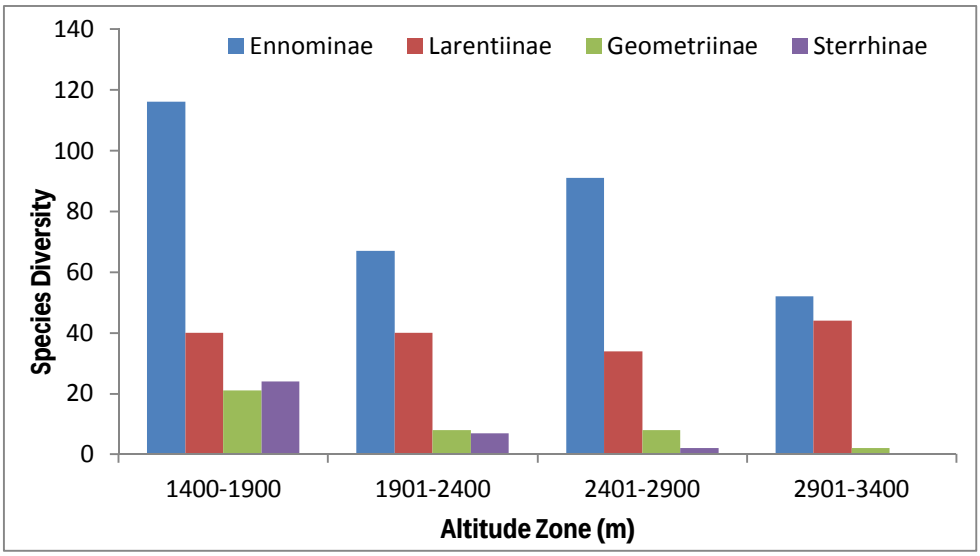
The mean species abundance of the family is around 2600m, while most of the species were recorded between 2000m and 3200m (Fig.3.7). However species range extends from 1400m to 3600m. This is the most diverse family recorded in the Gangotri Landscape with maximum number of species and individual observed. There are six main subfamilies: Ennominae, Geometrinae, Larentiinae, Sterrhinae and Oenochrominae and Desmobathrinae. Except Oenochrominae, all the five subfamilies were recorded from Gangotri Landscape Area.

Fig. 3.7: Altitudinal distribution of Family Geometridae (n=705) recorded in GLA



Ennominae was the most diverse group of insects in all the altitude zones examined with highest species diversity in lower altitude region (1400m-1900m) with another peak in 2400m-2900m and lowest in 2900m-3400m (Fig. 3.8). The highest diversity of Larentiinae was recorded in highest altitude zone (2900m-3400m). While the other two subfamilies show identical trend with highest diversity in lower region and zero or negligible presence in highest altitude zones.

Fig. 3.8: Altitudinal distribution of four subfamilies of Geometridae, Ennominae (n=326), Larentiinae (n=158), Geometrinae (n=38) & Sterrhinae (n=33) in GLA



X A. Subfamily Ennominae

The subfamily Ennominae is the largest subfamily with some 9,700 described species in 1,100 genera (Scoble 1999). The group has a wide ecological range, diverse everywhere except very high latitudes and, in the tropics, altitudes. The subfamily also includes several species that appear to fly predominantly in the forest understory. Ennominae are therefore highly suitable as an environmental indicator group except for poor representation in open habitats. This subfamily has a global distribution. It includes some species that are notorious defoliating pests.

This subfamily was represented by 71 morphospecies from Gangotri Landscape Area but many of them can't be identified reliably up to species level which requires the help of molecular taxonomy to ascertain many of the cryptic species present within a species/genus group complex.

The identified species from the study area are:

56. Abraxas peregrina Inoue, 1995 (Plate 5.8)

1995. *Abraxas peregrina* Inoue, Tinea, 14(2): 119-139.

Distribution: India, World (Nepal, Bhutan, Vietnam), New record to Uttarakhand; *Size:* 42mm; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Broadleaved forest; *Specimen studied:* 30.v.2009 (5 ex.).

***57. Abraxas irrorata* Moore, 1867 (Plate 5.9)**

1867. *Abraxas irrorata* Moore, *Proc. Zool. Soc. London* : 6526.

1893. *Abraxas diaphana* Warren, *Proc. Zool. Soc. London* : 393.

1895. *Abraxas irrorata*, Hampson, *Fauna of Brit. India*, 3: 302.

1995. *Abraxas irrorata* Moore, *In* Haruta: *Moths of Nepal*, 4: 119.

Distribution: India (Uttarakhand, Sikkim, West Bengal), World (Nepal); *Size:* 42mm; *Abundance:* Rare; *Altutude & Habitat:* 3400m (CH34), Subalpine Forest; *Specimen studied:* 16.vii.2012 (3 ex.).

***58. Abraxas sylvata* (Scopoli, 1763) (Plate 5.10)**

1763. *Phalaena sylvata* Scopoli, *Ent. Carniolica* : 220.

1775. *Phalaena ulmata* Fabricius, *Syst. Ent.* : 632.

1915. *Abraxas sylvata*, Seitz, *Macro Lep.*, 4: 311.

2008. *Abraxas sylvata* Scopoli, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalayas, Uttarakhand, Sikkim, Assam, Nilgiri Hills), World (Europe, North Asia, Japan, China); *Size:* 55mm; *Host Plant:* Larva feeds on *Betula*, *Corylus*, *Fagus*, *Ulmus*, *Prunus*, and *Frangula*; *Abundance:* Abundant; *Altitude & Habitat:* 2800m (TK28),3200m (CH32), 3400m (CH34), Western Himalayan Upper Oak forest, Subalpine forest; *Specimen studied:* 29.v.2012 (15 ex.), 15.vi.2012 (21 ex.), 16.vii.2012 (7 ex.).

***59. Abraxas picaria* Moore, 1868 (Plate 5.11)**

1868. *Abraxas picaria* Moore, *Proc. Zool. Soc. Lond.* 1867: 652.

1893. *Abraxas semilugens* Warren, *Proc. Zool. Soc. Lond.* 1893: 393.

1995. *Abraxas picaria* Moore, *In* Haruta: *Moths of Nepal*, 4: 119.

2015. *Abraxas picaria* Moore, Thakur & Kumar, *Int. J. Sci. Res.* 4 (1).

Distribution: India (Uttarakhand, Sikkim, Himachal Pradesh), World (Nepal); *Size:* 40mm; *Abundance:* Abundant; *Altitude & Distribution:* 2400m (TK24), 3000m

(CH30), Western Mixed Coniferous forest & Subalpine forest; *Specimen studied:* 10.vi.2012 (2 ex.), 13.vii.2012 (3 ex.)

***60. Anonychia lativitta* (Moore, 1888) (Plate 5.12)**

1888. *C. lativitta* Moore, *Lep. Atk.* : 279.

1895. *Anonychia lativitta*, Hampson, *Fauna of Brit. India*, 3: 179.

1994. *Anonychia lativitta* Moore, *In* Haruta*: Moths of Nepal*, 3: 22.

2003. *Anonychia lativitta* Moore, Ghosh, *Fauna of Sikkim*, 4: 217-342.

Distribution: India (Sikkim, North West Himalayas, Himachal Pradesh, West Bengal); *Size:* 39mm; *Abundance:* Rare; *Altitude & Habitat:* 3000m (HD30), Alpine scrubland; *Specimen studied:* 26.vi.2012 (1 ex.).

***61. Anonychia violacea* Moore, 1888 (Plate 6.1)**

1888. *Anonychia violacea* Moore, *Lep. Ack.*: 279.

1997. *Anonychia violacea* Moore, Mandal & Ghosh, *Fauna of West Bengal,* 7:491-532.

Distribution: India (West Bengal), New record to Uttarakhand; *Size:* 32mm; *Abundance:* Abundant; *Altitude & Habitat:* 2000m (KK20), 2600m (KK26, CH26, TK26, HS26), 2800m (TK28, KK28), 3000m (HD30), 3200m (HD32, TK32), Montane Temperate Deciduous forest, Western Mix Coniferous forest, Upper Oak forest, Subalpine forest, Deciduous Alpine scrubland; *Specimen studied:* 12.v.2010 (12 ex.), 09.vi.2011 (7 ex.), 25.v.2012 (4 ex.), 11.vi.2012 (11 ex.), 12.vi.2012 (3 ex.), 14.vi.2012 (2 ex.), 16.vi.2012 (9 ex.), 26.vi.2012 (12 ex.), 28.vi.2012 (2 ex.).

***62. Biston bengaliaria* (Guenée, 1857) (Plate 6.2)**

1857. *Amphidasys bengaliaria* Guenée, *Hist. nat. Ins., Spec. gén. Lépid*., 9: 210.

1895. *Biston bengaliaria*, Hampson, *Fauna of Brit. India*, 3: 247.

2011. *Biston bengaliaria* Guenée, Jiang *et al*., Zookeys 139: 45-96.

Distribution: India (Uttarakhand, Sikkim, Meghalaya, Meghalaya, Arunachal Pradesh, West Bengal, Central India), World (China, Thailand); *Size:* 56mm; *Host Plant: Camellia sinensis; Abundance:* Rare; *Altitude & Habitat:* 2100m (TK22), Montane Temperate Deciduous Forest; *Specimen studied:* 25.x.2011 (2 ex.).

***63. Biston falcata* (Warren, 1893) (Plate 6.3)**

1893. *Eubyjodonta falcata* Warren, *Proc. zool. Soc. Lond.*, (2): 416.

1895. *Biston falcata*, Hampson, *Fauna of Brit. India*, 3: 246.

1915. *Biston falcata*, Seitz, *Macro Lep.*, 4: 359.

2011. *Biston falcata* Warren, Jiang *et al.*, Zookeys 139: 45-96.

Distribution: India (Sikkim), World (China), New record to Uttarakhand; *Size:* 60mm; *Host Plant:* Polyphagous; *Abundance:* Rare; *Altitude & Habitat:* 3000m (HD30), 3200m (KK32), Subalpine Forest, Deciduous Alpine Scrubland; *Specimen studied:* 29.v.2012 (2 ex.), 24.vi.2012 (2 ex.).

***64. Buzura suppressaria* (Guenée, 1858) (Plate 6.4)**

1858. *Amphidasys suppressaria* Guenée, *Hist. nat. Ins., Spec. gén. Lépid.*, 9: 210.

1863. *Buzura multipunctaria* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 26: 1531.

1895. *Biston suppressaria*, Hampson, *Fauna of Brit. India*, 3: 247.

1900. *Buzura suppressaria*, Swinhoe, *Cat. East Lep. Ext. Mus.*, 2: 277.

2010. *Buzura suppressaria* Guenée, Mukhopadhyay *et al.*, *J. of Biopest.* 3(1):117-120.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Assam, West Bengal, Maharashtra), World (Sri Lanka, Japan, China); *Size:* 68mm; *Host Plant: Carissa carandas, Cassia auriculata, Cassia fistula, Lagerstroemia indica, Litsea monopetala, Acacia catechu, Aleurites Montana, Bauhinia variegate, Bombax ceiba, Camellia sinensis, Dodonaea viscose, Eugenia cumini* etc.; *Abundance:* Rare; *Altitude & Habitat:* 2400m (KK24, TK24), Western Mixed Coniferous forest; *Specimen studied:* 13.v.2010 (1 ex.), 10.vi.2012 (1 ex.).

***65. Psilalcis inceptaria* (Walker, 1866) (Plate 6.5)**

1866. *Tephrosia inceptaria* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 35: 1590.

1892. *Psilalcis inceptaria, Warren, Proc. Zool. Soc. London* : 430.

1895. *Boarmia inceptaria*, Hampson, *Fauna of Brit. India* 3: 262.

1953. *Psilalcis inceptaria*: Singh, *Ind. For. Rec.*, 8(7): 105.

2008. *Psilalcis inceptaria*, Kirti *et al., Journ. Ent. Res.*, 2: 161-169.

Distribution: India (Sikkim, Nilgiri Hills), World (Sri Lanka, Myanmar, Korea), New record to Uttarakhand; *Size:* 35mm; *Host Plant:* Recorded as of polyphagous habit; *Abundance:* Abundant; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), 1800m (NT18), 2000m (CH20), 2400m (CH24, JK24), 3000m (CH30), Subtropical Pine Broadeaved Mix forest, Montane Temperate Deciduous forest, Western Mixed Coniferous forest and Subalpine forest; *Specimen studied:* 29.v.2009 (11 ex.), 01.vi.2009 (14 ex.), 09.v.2010 (4 ex.), 13.v.2011 (4 ex.), 10.vii.2012 (16 ex.), 13.vii.2012 (9 ex.), 04.xi.2012 (9 ex.), 07.xi.2012 (2 ex.).

***66. Phthonandria atrilineata* (Butler, 1881) (Plate 6.6)**

1881. *Hemerophila atrilineata* Butler, *Trans. Ent. Soc. London,* (3): 405.

1894. *Phthonandria atrilineata*, Warren, *Nov. Zool.*, 1: 438.

1895. *Boarmia atrilineata*, Hampson, *Fauna of Brit. India*, 3: 279.

1900. *Phthonandria atrilineata*, Swinhoe, *Cat. East Lep. Ext. Mus.*, 2: 299.

2010. *Phthonandria atrilineata* Butler, Liao *et al.*, Int. J. Biol. Sci. 6(2):172-186.

Distribution: India (Sikkim, Uttarakhand, Himachal Pradesh), World (Japan, Korea, China); *Size:* 60mm; *Host Plant:* Recorded as pest of Mulberry (*Morus* sp.); *Abundance:* Rare; *Altitude & Habitat:* 2000m (CH20), Montane Temperate Deciduous forest; *Specimen studied:* 08.v.2011 (3 ex.).

***67. Menophra bicornuta* Inoue, 1990 (Plate 6.7)**

1990. *Menophra bicornuta* Inoue, *Tinea,* 13(2): 15.

Distribution: India (West Bengal), World (Nepal), New record to Uttarakhand; *Size:* 33mm; *Host Plant:* Polyphagous; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 26.vi.2011 (1 ex.).

***68. Menophra subplagiata* (Walker, 1860) (Plate 6.8)**

1860. *Hemerophila subplagiata* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 21: 319.

1888. *Menophra subplagiata*, Warren, *Proc. Zool. Soc. London* : 320.

1895. *Boarmia subplagiata*, Hampson, *Fauna of Brit. India,* 3: 275.

1915. *Menophra subplagiata*, Seitz, *Macro Lep.*, 4: 362.

1984. *Menophra subplagiata* Walker, Sato, *Tinea* 11:189-198.

2005. *Menophra subplagiata* Walker, Walia, *Fauna of West. Himalaya*, 2: 181-190.

Distribution: India (North West Himalayas, Himachal Pradesh, Uttarakhand, Sikkim), World (Japan, Korea); *Size:* 42mm; *Host Plant:* Chestnut (*Castanea crenata*), *Quercus serrata; Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), 2400m (CH24), Subtropical Pine Broadleaved Mix forest, Western Mixed Coniferous forest; *Specimen studied:* 29.v.2009 (5 ex.), 06.v.2010 (4 ex.), 15.v.2010 (5 ex.),15.v.2010 (6 ex.), 21.v.2010 (5 ex.), 18.v.2011 (2 ex.), 10.vii.2012 (1 ex.).

***69. Medasina interruptaria* (Moore, 1867) (Plate 6.9)**

1867. *Hemerophila interruptaria* Moore, *Proc. Zool. Soc. London* : 626.

1895. *Medasina interruptaria*, Hampson, *Fauna of Brit. India*, 3: 287.

2003. *Medasina interruptaria* Moore, Ghosh, *Fauna of Sikkim*, 4: 217-342.

Distribution: India (Sikkim, West Bengal), New record to Uttarakhand; *Size:* 65mm; *Host Plant:* Unknown; *Abundance:* Common; *Altitude & Habitat:* 2400m (CH24), 2600m (CH26), 3000m (CH30), Western Mixed Coniferous forest, Subalpine forest; *Specimen studied:* 10.vii.2012 (5 ex.), 13.vii.2012 (4 ex.), 19.vii.2012 (2 ex.).

***70. Medasina albidaria* (Walker, 1866) (Plate 6.10)**

1866. *Boarmia albidaria* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 26: 1582.

1867. *Boarmia albidaria*, Moore, *Proc. Zool. Soc. London* : 630.

1895. *Medasina albidaria*, Hampson, *Fauna of Brit. India*, 3: 289.

2008. *Medasina albidaria* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himachal Pradesh, Sikkim, Uttarakhand, Meghalaya), World (China); *Size:* 68mm; *Host Plant: Pinus wallichiana*, *Prunus*, *Rosa*; *Abundance:* One of the most abundant species in the landscape, Abundant; *Altitude & Habitat:* 1400m (NT14), 1600m (BH16, NT16), 1800m (NT18, CH18), 2400m (TK24), 2600m (CH26, KK26, TK26), 2800m (TK28), 3000m (KK30) and 3200m (TK32), Subtropical Pine Broadleaved mix forest, Montane Temperate Deciduous forest, Western Mixed Coniferous forest, Upper Oak forest and Subalpine forest; *Specimen studied:* 04.xi.2008 (3 ex.), 29.v.2009 (2 ex.), 01.vi.2009 (2 ex.), 04.v.2010 (9 ex.), 12.v.2010 (7 ex.), 18.v.2011 (3 ex.), 26.v.2012 (11 ex.), 28.vi.2012 (5 ex.), 09.vi.2012

(2 ex.), 11.vi.2012 (7 ex.), 14.vi.2012 (5 ex.), 16.vi.2012 (1 ex.), 24.vii.2012(3 ex.), 25.vii.2012 (9 ex.), 4.xi.2012 (2 ex.).

***71. Medasina cervina* (Warren, 1893) (Plate 6.11)**

1893. *Deinotrichia cervina* Warren, *Proc. Zool. Soc. London* : 419.

1905. *Medasina pallidimargo* Swinhoe, *Ann. Mus. Nat. Hist.*, 16: 627.

1994. *Deinotrichia cervina* Warren, *In* Haruta*: Moths of Nepal*, 3: 52.

Distribution: India (Kashmir, Sikkim), World (Nepal), New record to Uttarakhand; *Size:* 62mm; *Abundance:* Abundant; *Altitude & Habitat:* 2200m (KK22), 2400m (TK24), 2600m (CH26, TK26), 2800m (TK28), 3000m (CH30) and 3200m (CH32, TK32), Western Mix Coniferous forest, Upper Oak Forest, Subalpine Forest; *Specimen studied:* 12.v.2010 (1 ex.), 09.vi.2011 (3 ex.), 09.vi.2012 (7 ex.), 12.vi.2012 (5 ex.), 14.vi.2012 (6 ex.), 16.vi.2012 (2 ex.), 13.vii.2012 (1 ex.), 15.vii.2012 (7 ex.).

***72. Thinopteryx crocoptera* Kollar, 1844 (Plate 6.12)**

1844. *Thinopteryx crocoptera* Kollar, *Hugel's Kaschmir*, 4: 483.

1895. *Thinopteryx crocoptera*, Hampson, *Fauna of Brit. India*, 3: 148.

2008. *Thinopteryx crocoptera* Kollar, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Throughout including Uttarakhand, Andamans), World (Sri Lanka, China, Java, Japan); *Size:* 76mm; *Host Plant:* Ivy (*Parthenocissus quinquefolia*), Vine (*Vitis* sp.); *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Broadleaved Forest; *Specimen studied:* 23.v.2010 (1 ex.).

***73. Elphos pardicelata* Walker, 1862 (Plate 7.1)**

1862. *Elphos pardicelata* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 26: 1544.

1867. *Elphos pardicelata*, Moore, *Proc. Zool. Soc. London* : 635.

1894. *Elphos megaspilata* Warren, *Nov. Zool.*, 1: 430.

1895. *Elphos pardicelata*, Hampson, *Fauna of Brit. India*, 3: 250.

2008. *Elphos pardicelata* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalayas, Uttarakhand, Sikkim, Meghalaya); *Size:* 96mm; *Host Plant:* The genus *Elphos* is reported to feeds on plant family Lauraceae; *Abundance:* Uncommon; *Altitude & Habitat:* 1800m (CH18), 2200m (CH22), 2400m

(CH24), Riverine forest, Western Mix Coniferous forest; *Specimen studied:* 22.v.2010, 10.vii.2012 (3 ex.), 23.vii.2012 (3 ex.), 25.vii.2012 (2 ex.).

***74. Erebomorpha fulguraria* Walker, 1860 (Plate 7.2)**

1860. *Erebomorpha fulguraria* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 21: 495.

1895. *Erebomorpha fulguraria*, Hampson, *Fauna of Brit. India*, 3: 296..

2003. *Erebomorpha fulguraria* Walker, Ghosh, *Fauna of Sikkim*, 4: 217-342.

2011. *Erebomorpha fulguraria* Walker, *Folia Ent. Hung.* 72, 79-107.

Distribution: India (Sikkim, West Bengal, Meghalaya), New record to Uttarakhand; *Size:* 96mm; *Host Plant: Camellia sinensis; Abundance:* Rare; *Altitude & Habitat:* 2600m (TK26), 2800m (TK28), Mixed Coniferous forest, Upper Oak forest; *Specimen studied:* 12.vi.2012 (1 ex.), 14.vi.2012 (1 ex.).

***75. Fascellina plagiata* (Walker, 1866) (Plate 7.3)**

1866. *Geometra plagiata* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 35: 1601.

1867. *Fascellina viridis* Moore, *Proc. zool. Soc. Lond*. : 79.

1936. *Fascellina plagiata*, icteria Wehrli, *Ent. Rdsch.*, 54: 126.

1976. *Fascellina plagiata*, Holloway, *Moths of Borneo reference to Mt. Kinabalu* : 77.

2008. *Fascellina plagiata* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Assam, West Bengal, Himalayas), World (China, Taiwan, Malaysia); *Size:* 41mm; *Host Plant:* Species of Lauraceae family, *Alseodaphne* sp., *Beilschmiedia* sp., *Cinnamomum* sp.; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Broadleaved forest; *Specimen studied:* 26.vi.2011 (1 ex.).

***76. Hirasa muscosaria* (Walker, 1866) (Plate 7.4)**

1866. *Gnophos muscosaria* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 35: 1596.

1895. *Gnophos muscosarius*, Hampson, *Fuana of Brit. India*, 3: 251.

1915. *Gnophos muscosaria*, Seitz, *Macro Lep.*, 4: 385.

1998. *Hirasa muscosaria* Walker, *In* Haruta*: Moths of Nepal*, 5: 25.

Distribution: India (North West Himalayas, Sikkim, West Bengal); *Size:* 52mm; *Host Plant:* The genus *Hirasa* feeds on different species of *Quercus*; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 1800m (NT18), 2100m (TK22), 2400m (TK24), 2600m (TK26), 2800m (TK28), Subtropical Broadleaved Mix forest, Montane Temperate Deciduous forest, Mixed Coniferous forest, Upper Oak forest; *Specimen studied:* 03.v.2010 (2 ex.), 04.v.2010 (2 ex.), 27.x.2011 (3 ex.), 09.vi.2012 (3 ex.), 12.vi.2012 (2 ex.), 14.vi.2012 (1 ex.), 04.xi.2012 (3 ex.).

***77. Ourapteryx convergens* Warren 1897 (Plate 7.5)**

1897. *Ourapteryx convergens* Warren, *Novit. Zool.*, 4: 75.

2005. *Ourapteryx convergens* Warren, Walia, *Fauna of West. Himalaya* 2: 181-190.

Distribution: India (Himachal Pradesh), World (Nepal), New record to Uttarakhand; *Size:* 54mm; *Host Plant:* Unknown; *Abundance:* Rare; *Altitude & Habitat:* 2600m (TK26), Western Mixed Coniferous forest; *Specimen studied:* 11.vi.2012 (1 ex.), 12.vi.2012 (1 ex.).

***78. Ourapteryx sciticaudaria* Walker 1862 (Plate 7.6)**

1862. *Ourapteryx sciticaudaria* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 26: 1480.

1895. *Urapteryx sciticaudaria*, Hampson, *Fauna of Brit. India*, 3: 145.

1900. *Ourapteryx sciticaudaria*, Swinhoe, *Cat. Lep. Oxf. Mus.* : 2319.

1995. *Ourapteryx sciticaudaria* Walker, *In* Haruta*: Moths of Nepal*, 4:130.

2003. *Ourapteryx sciticaudaria* Walker, Ghosh, *Fauna of Sikkim*, 4: 217-342.

Distribution: India (Uttarakhand, Sikkim, Meghalaya), World (Sri Lanka, Taiwan, China, Thailand, Bhutan); *Size:* 60mm; *Abundance:* Rare; *Altitude & Habitat:* 2600m (CH26), Western Mixed Coniferous Forest; *Specimen studied:* 19.vii.2012 (1 ex.).

***79. Ourapteryx ebuleata* (Guenée, 1858) (Plate 7.7)**

1858. *Urapteryx ebuleata* Guenée, *Spec. Gen.* 9: 32.

1895. *Urapteryx ebuleata*, Hampson, *Fauna of Brit. India*, 3: 145.

1900. *Ourapteryx ebuleata*, Swinhoe, *Cat. Lep. Pxf. Mus.*: 2318.

1995. *Ourapteryx ebuleata* Guenée, *In* Haruta*: Moths of Nepal*, 4:128.

2008. *Ourapteryx ebuleata* Guenée, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalayas, Sikkim, Uttarakhand, West Bengal, Meghalaya); *Size:* 82mm; *Host Plant: Symplocos* sp.; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 2500m (HS26), 3400m (DV34), Subtropical Pine Broadleaved mix forest, Western Mix Coniferous forest, Subalpine Forest; *Specimen studied:* 07.x.2008 (3 ex.), 23.x.2008 (3 ex.), 29.v.2009 (2 ex.).

Note: There were six more specimens of *Ourapteryx* collected from 2400m, 2600m, 2800m, 3050m and 3200m altitudes which are very close in appearance to each other and could not be ascertained to specific levels.

***80. Arichanna tenebraria* (Moore, 1867) (Plate 7.8)**

1867. *Charaxas tenebraria*, Moore, *Proc. Zool. Soc.*: 652.

1895. *Arichanna tenebraria*, Hampson, *Fauna of Brit India*, 3: 293.

1994. *Arichana (Paricterodes) tenebraria*, *In* Haruta, *Moths of Nepal*, 3: 42.

2003. *Arichanna tenebraria* Moore, Ghosh, *Fauna of Sikkim*, 4: 217-342.

Distribution: India (Sikkim, Meghalaya), World (Nepal), New record to Uttarakhand; *Size:* 58mm; *Host Plant:* Different species of *Arichana* are known to feed on *Rhododendron* sp.; *Abundance:* Common; *Altitude & Habitat:* 3000m (CH30), 3200m (CH32), 3400m (CH34), 3600m (CH36), Subalpine Forest; *Specimen studied:* 13.vii.2012 (1 ex.), 15.vii.2012 (7 ex.), 16.vii.2012 (5 ex.), 17.vii.2012 (5 ex.).

***81. Gnophos albidior* (Hampson, 1895) (Plate 7.9)**

1895. *Medasina albidior* Hampson, *Fauna of Brit. India*, 3: 290.

1995. *Gnophos albidior* Hampson, *In* Haruta*: Moths of Nepal*, 4: 32.

Distribution: India (Nagaland), World (Nepal), New record to Uttarakhand; *Size:* 78mm; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), 1800m (NT18), Pine Broadleaved Mix forest; *Specimen studied:* 18.v.2011 (3 ex.), 07.11.2012 (3 ex.).

***82. Heterolocha phoenicotaeniata* (Kollar, 1844) (Plate 7.10)**

1844. *Aspilates phoenicotaeniata* Kollar, *In* Hugel: *Kaschmir*, 4: 487.

1874. *Heterolocha phoenicotaeniata*, Felder, *Resc. Nov.*, 33: 6.

1886. *Pyrinia phoenicotaeniata*, Butler, *Proc. Zool. Soc. London* : 388.

1915. *Heterolocha phoenicotaeniata*, Seitz, *Macro Lep.*, 4: 171.

2005. *Heterolocha phoenicotaeniata* Kollar, Walia, *Fauna of West. Himalaya* 2: 181-190.

2008. *Heterolocha phoenicotaeniata* Kollar, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalaya, Himachal Pradesh, Uttarakhand); *Size:* 32mm; *Host Plant:* Plumbagos (*Plumbago auriculata*); *Abundance:* Abundant; *Altitude & Habitat:* 2000m (CH20), 2400m (TK24), 2600m (CH26, KK26, TK26), 2800m (TK28), 3200m (KK32), Montane Temperate Deciduous Forest, Western Mixed Coniferous forest, Western Himalayan Upper Oak Fotrest; *Specimen studied:* 08.v.2010 (7 ex.), 12.v.2010 (14 ex.), 26.v.2012 (4 ex.), 27.v.2012 (2ex.), 10.vi.2012 (7 ex.), 11.vi.2012 (4 ex.), 12.vi.2012 (11 ex.), 14.vi.2012 (4 ex.), 15.vi.2012 (2 ex.).

***83. Hypomecis ratotaria* (Swinhoe, 1894) (Plate 7.11)**

1894. *Boarmia ratotaria* Swinhoe, *Ent. Soc. London*, 18: 216.

1993. *Hypomecis ratotaria*, Holloway, *The Moths of Borneo*, 11: 242.

1994. *Hypomecis ratotaria* Swinhoe, *In* Haruta*: Moths of Nepal*, 3: 46.

Distribution: India (Sikkim, Assam, Meghalaya, Nilgiri Hills), World (Bhutan, Sri Lanka, Java, Myanmar), New record to Uttarakhand; *Size:* 44mm; *Host Plant:* Different species Betulaceae, Rosaceae and Fagaceae; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), 2000m (CH20), 2400m (JK24), Subtropical Pine Broadleaved Mix forest, Montane Temperate Deciduous forest and Western Mixed Coniferous forest; *Specimen studied:* 29.v.2009 (11 ex.), 21.v.2010 (1 ex.), 08.viii.2010 (4 ex.), 02.v.2011 (6 ex.), 13.v.2011 (1 ex.).

***84. Loxaspilates hastigera* Butler, 1889 (Plate 7.12)**

1889. *Aspilates hastigera* Butler, *Ill. Het.*7:112.

1895. *Loxaspilates hastigera*, Hampson, *Fauna of Brit. India,* 3:182.

1920. *Loxaspilates hastigera,* Prout, *In* Seitz *Macrolep.* 4:410.

Distribution: India (Himachal Pradesh, Sikkim), India (Nepal, Tibet), New record to Uttarakhand; *Size:* 35mm; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), Subtropical Broadleaved forest; *Specimen studied:* 29.xi.2011 (2 ex.), 30.xi.2011 (2 ex.).

***85. Semiothisa nora* (Walker, 1861) (Plate 8.1)**

1861. *Macaria nora* Walker, *List. Spec. Lepid. Ins. Colln. Brit. Mus.* 23:934.

1976. *Semiothisa nora*, Holloway, *Moths of Borneo with special reference to Mt. Kinabalu*: 78

Distribution: India (Uttarakhand, North India, Maharashtra), World (Borneo, South East Asia); *Size:* 38mm; *Host Plant: Juniperus* sp.; *Abundance:* Rare; *Altitude & Habitat:* 2400m (TK24), Western Mixed Coniferous Forest; *Specimen studied:* 09.vi.2012 (3 ex.).

***86. Semiothisa sufflata* (Guenée, 1858) (Plate 8.2)**

1858. *Macaria sufflata* Guenée, *Spec. Gen.*, 10: 88.

1887. *Gonodela sufflata*, Moore, *Lep. Ceylon*, 3: 467.

1895. *Macaria sufflata*, Macaria, *Fauna of Brit. India*, 3: 204.

1950. *Semiothisa sufflata*, Viette, *Bull. mem. Soc. Linn. Lyon.*, 19: 204.

Distribution: India (Throughout), World (Sri Lanka, China, Myanmar); *Size:* 32mm; *Host Plant: Alnus*, *Salix*; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 29.v.2009 (3 ex.), 03.v.2010 (5 ex.), 21.v.2010 (1 ex.), 09.v.2011 (1 ex.).

***87. Xandrames latiferaria* (Walker, 1860) (Plate 8.3)**

1860. *Pachyodes latiferaria* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 21: 445.

1895. *Xandrames latiferaria*, Hampson, *Fauna of Brit. India*, 3: 250.

2013. *Xandrames latiferaria* Walker, Chandra & Sambath, *Jour. of Threat. Taxa*, 5(1): 3565-3570.

Distribution: India (North West Himalayas, Sikkim, Meghalaya, Arunachal Pradesh), World (Japan, China); *Size:* 76mm; *Host Plant:* From Japan recorded host plant is *Lindera praecox; Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), 1800m (CH18), Riverine Forest; *Specimen studied:* 26.vi.2011 (4 ex.), 24.vii.2012 (5 ex.), 25.vii.2012 (2 ex.).

***88. Odontopera heydena* (Swinhoe, 1894) (Plate 8.4)**

1894. *Brozullis heydena* Swinhoe, *Trans. Ent. Soc. London* : 203.

1900. *Odontopera heydena*, Swinhoe, *Cat. East Lep. Oxf. Mus.*, 2: 255.

1994. *Odontopera heydena* Swinhoe, *In* Haruta*: Moths of Nepal*, 3:27.

Distribution: India (Meghalaya), World (Nepal, Japan), New record to Uttarakhand; *Size:* 44mm; *Host Plant: Camellia sinensis*; *Abundance:* Uncommon; *Altitude &*

Habitat: 2100m (TK22), 3200m (TK32), Montane Temperate Deciduous forest, Upper Oak Forest; *Specimen studied:* 27.x.2011 (1 ex.), 30.x.2011 (1ex.), 16.vi.2012 (2 ex.).

***89. Odontopera lentiginosaria* (Moore, 1867) (Plate 8.5)**

1867. *Crocalis lentiginosaria* Moore, *Proc. Zool. Soc. London* : 622.

1895. *Odontopera lentiginosaria*, Hampson, *Fauna of Brit. India*, 3: 231.

2005. *Odontopera lentiginosaria* Moore, Walia, *Fauna of West. Himalaya* 2: 181-190.

Distribution: India (Himachal Pradesh, Sikkim, West Bengal), New record to Uttarakhand; *Size:* 48mm; *Abundance:* Common; *Altitude & Habitat:* 2400m (TK24), 2800m (TK28), 3000m (KK30, HD30), 3200m (HD32, TK32), 3400m (HD34), Western Mixed Coniferous forest, Upper Oak forest, Subalpine Forest and Alpine Scrubland; *Specimen studied:* 27.v.2012 (3 ex.), 09.vi.2012(3 ex.), 10.vi.2012 (2 ex.), 14.vi.2012 (5 ex.), 15.vi.2012 (4 ex.), 22.vi.2012 (2 ex.), 26.vi.2012 (1 ex.).

***90. Odontopera obliquaria* (Moore, 1867) (Plate 8.6)**

1867. *Crocalis obliquaria* Moore, *Proc. Zool.Soc. London* : 622.

1888. *Crocalis obliquaria*, Cotes & Swinhoe, *Cat. Moths India* : 3170.

1895. *Odontopera obliquaria*, Hampson, *Fauna of Brit. India*, 3: 232.

2005. *Odontopera obliquaria* Moore, Walia, *Fauna of West. Himalaya* 2: 181-190.

Distribution: India (North West Himalayas, Himachal Pradesh, West Bengal); *Size:* 46mm; *Host Plant: Camellia sinensis*; *Abundance:* Rare; *Altitude & Habitat:* 3400m (CH34), Subalpine Forest; *Specimen studied:* 16.vii.2012 (1 ex.).

***91. Odontopera kametaria* (Felder, 1873) (Plate 8.7)**

1893. *Crocallis kametaria* Felder, *Reis Nov.*, 23: 28.

1895. *Crocallis kametaria*, Hampson, *Fauna of Brit. India*, 3: 233.

1998. *Odontopera kametaria* Felder & Rogenhofer, *In* Haruta*: Moths of Nepal*, 5: 14.

Distribution: India (Uttar Pradesh, Himalaya), World (Nepal); Size: 36mm; Host Plant: *Bauhinia variegate*, *Jasminum*; Abundance: Uncommon; *Altitude & Habitat:* 2000m (KK20), 2200m (KK22, TK22), 2600m (KK26), Montane Temperate

Deciduous forest, Western Mix Coniferous forest; *Specimen studied:* 10.vi.2011 (3 ex.), 26.v.2012 (2 ex.).

***92. Heterocallia temeraria* (Swinhoe, 1891) (Plate 8.8)**

1891. *Macaria temeraria* Swinhoe, *Trans. Ent. Soc.* : 492.

1895. *Macaria temeraria*, Hampson, Fauna of Brit. *India*, 3: 207.

1896. *Semeothisa fumosa* Warren, *Nov. Zool*., 3: 320.

1915. *Macaria temeraria*, Prout, *In* Seitz: *Macro Lep.*, 4: 347.

2013. *Heterocallia temeraria* Swinhoe, Chandra & Sambath, *Jour. of Threat. Taxa*, 5(1): 3565-3570.

Distribution: India (Himachal Pradesh, Uttarakhand, Meghalaya, Nagaland, Arunachal Pradesh), World (China, Borneo, Java); *Size:* 30mm; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), 2000m (KK20), Subtropical Pine Broadleaved Mix forest, Montane Temperate Deciduous forest; *Specimen studied:* 31.v.2009 (1 ex.), 03.v.2010 (3 ex.) , 09.vi.2011 (3 ex.).

***93. Peratophyga hyalinata* (Kollar, 1844) (Plate 8.9)**

1844. *Idaea hyalinata* Kollar, *Hügel's Kaschmir und das Reich der Siek.*, 4: 491.

1868. *Acidalia aerata* Moore, *Proc. zool. Soc. Lond.* : 643.

1993. *Peratophyga hyalinata*, Holloway, *The Moths of Borneo*, 11: 131.

2005. *Peratophyga hyalinata* Kollar, Walia, *Fauna of West. Himalaya* 2: 181-190.

Distribution: India (Himachal Pradesh, Uttarakhand, West Bengal), World (China, Japan); Size: 26mm; *Host Plant: Hypericum* sp.; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), 2000m (CH20), Subtropical Pine Mix forest, Montane Temperate Deciduous forest; *Specimen studied:* 02.v.2011 (4 ex.), 22.v.2011 (6 ex.).

***94. Percnia belluaria* Guenée, 1858 (Plate 8.10)**

1858. *Percnia belluaria* Guenee, *Spec. Gen.*, 10: 217.

1874. *Percnia guttata* Felder & Rogenhofer, *Reis Nov.*, 30: 15.

1895. *Percnia belluaria*, Hampson, *Fauna of Brit. India*, 3: 308.

2003. *Percnia belluaria* Guenée, Ghosh, *Fauna of Sikkim*, 4: 217-342.

Distribution: India (Uttarakhand, West Bengal, North India, Sikkim, Meghalaya), World (China); *Size:* 74mm; *Host Plant:* Different species of family Lauraceae;

Abundance: Common; *Altitude & Habitat:* 1400m (NT14), 2200m (CH22), 3200m (TK32), Subtropical Pine Mix forest, Western Mixed Coniferous forest and Subalpine Forest; *Specimen studied:* 22.vi.2011 (1 ex.), 29.v.2009 (4 ex.), 17.vi.2012 (1 ex.), 23.vii.2012 (6 ex.).

***95. Plagodis inustaria* (Moore, 1867) (Plate 8.11)**

1867. *Eurymene inustaria* Moore, *Proc. Zool. Soc. London,* : 620.

1895. *Eurymene inustaria*, Hampson, *Fauna of Brit. India*, 3: 177.

1998. *Plagodis inustaria* Moore, *In* Haruta*: Moths of Nepal,* 5: 15.

Distribution: India (Sikkim, Meghalaya, West Bengal), World (Nepal), New record to Uttarakhand; *Size:* 33mm; *Host Plant:* Recorded food plant for the genus are *Acer*, *Betula*, *Picea*, *Salix* etc; *Abundance:* Rare; *Altitude & Habitat:* 2900m (KK30), Kharsu Oak forest; *Specimen studied:* 27.v.2012 (3 ex.).

***96. Plagodis reticulata* Warren, 1893 (Plate 8.12)**

1893. *Plagodes reticulata* Warren, *Proc. Zool. Soc. London* : 408.

1895. *Plagodis reticulata*, Hampson, *Fauna of Brit. India,* 3: 178.

2008. *Plagodis reticulata* Warren, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim), World (Nepal); *Size:* 36mm; *Host Plant:* Recorded food plants for the genus are *Acer*, *Betula*, *Picea*, *Salix* etc.; *Abundance:* Common; *Altitude & Habitat:* 2600m (TK26), 2800m(TK28), 2900m(KK30), Western Mix coniferous forest, Upper Oak forest; *Specimen studied:* 11.vi.2012(3 ex.), 12.vi.2012(5 ex.), 14.vi.2012 (1 ex.), 27.vi.2012 (6 ex.).

***97. Pseudomiza cruentaria* (Moore, 1867) (Plate 9.1)**

1867. *Cimicodes cruentaria* Moore, *Proc. Zool. Soc. London* : 616.

1906. *Mimomiza flavescens* Swinhoe, *Ann. Mus. Nat. Hist.*, 17(7): 284.

1915. *Pseudomiza cruentaria*, Seitz, *Macro Lep.*, 4: 328.

2001. *Pseudomiza cruentaria* Moore, Sato, *Insecta Matsumurana*, 58: 115-138.

Distribution: India (Himachal Pradesh, Uttarakhand, West Bengal, Meghalaya); *Size:* 32mm; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), 2200m (CH22), Subtropical Pine Broadleaved Mix forest, Western Mix Coniferous forest; *Specimen studied:* 29.v.2009 (3 ex.), 22.vi.2011(1 ex.), 20.vii.2012 (2 ex.).

***98. Pseudopanthera himaleyica* (Kollar, 1848) (Plate 9.2)**

1848. *E. himaleyica* Kollar, *In*: Hugel: *Kaschmir*, 4: 455.

1858. *Venilia himalayata* Guennee, *Spec. Ger. Lep.*, 9: 113.

2005. *Pseudopanthera himaleyica* Kollar, Walia, *Fauna of West. Himalaya,* 2: 181-190.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim); *Size:* 28mm; *Host Plant:* The genus is reported to feeds on different species of family Labiatae; *Abundance:* Abundant; *Altitude & habitat:* 1800m (CH18), 2200m (CH22), 2400m (CH24), 2600m (CH26); Montane Temperate Deciduous forest, Western Mixed Coniferous forest; *Specimen studied:* 10.vii.2012 (2 ex.), 19.vii.2012 (6 ex.), 20.vii.2012 (4 ex.), 23.vii.2012 (5 ex.), 24.vii.2012 (1 ex.).

***99. Psyra similaria* Walker, 1866 (Plate 9.3)**

1867. *Psyra similaria* Moore, *Proc. Zool, Soc. London,* 33: 659.

1994. *Psyra similaria* Moore, *In* Haruta*: Moths of Nepal,* 3: 26.

Distribution: India (North West Himalayas, Sikkim, Meghalaya, West Bengal), World (Nepal); *Size:* 45mm; *Host Plant:* The Genus *Psyra* is recorded as of polyphagous habit; *Abundance:* Common; *Altitude & Habitat:* 2400m (CH24,TK24), 2800m (TK28), 3000m (HD30), Western Mixed Coniferous forest, Subalpine Forest; *Specimen studied:* 09.vi.2012 (2 ex.), 10.vi.2012 (6 ex.), 14.vi.2012 (4 ex.), 10.vii.2012 (7 ex.), 22.vi.2012 (2 ex.).

***100. Psyra debilis* Warren, 1888 (Plate 9.4)**

1888. *Psyra debilis* Warren, *Proc. Zool. Soc. London* : 319.

1889. *Psyra indica* Butler, *Ill. Het.,* 7: 99.

1897. *Psyra debilis*, Hampson, *Fauna of Brit. India*, 3: 222.

Distribution: India (Punjab), World (Nepal), New record to Uttarakhand; *Size:* 44mm; *Host Plant:* Polyphagous; *Abundance:* Common; *Altitude & Habitat:* 1800m (NT18), 2400m (TK24), 2600m (CH26, TK24), 2800m (TK28), 3400m (HD34), Subtropical Chir Pine Forest, Mixed Coniferous forest, Kharsu Oak forest and Birch-Rhododendron Scrub forest; *Specimen studied:* 12.v.2010 (1 ex.), 10.vi.2012 (7 ex.), 12.vi.2012 (1 ex.), 15.vi.2012 (3 ex.), 22.vi.2012 (1 ex.), 07.xi.2012 (5 ex.).

***101. Psyra falcipennis* Yazaki, 1994 (Plate 9.5)**

1994. *Psyra falcipennis, In* Haruta*: Moths of Nepal,* 3: 32

Distribution: India (Uttarakhand-First time record from India), World (Nepal); *Size:* 44mm; *Host Plant:* Polyphagous, Family Rosaceae; *Abundance:* Rare; *Altitude & Habitat:* 2400m (CH24), 2600m (CH26), Mixed Coniferous forest; *Specimen studied:* 10.vii.2012 (2 ex.), 19.vii.2012 (7 ex.).

***102. Psyra angulifera* Walker, 1866 (Plate 9.6)**

1866. *Psyra angulifera* Walker, *List Spec. Lepid. Insects Colln Br. Mus.,* 35: 1687.

1895. *Psyra angulifera*, Hampson, *Fauna of Brit. India,* 3: 222.

2003. *Psyra angulifera* Walker, Ghosh, *Fauna of Sikkim*, 4: 217-342.

2008. *Psyra angulifera* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, West Bengal); *Size:* 44mm; *Host Plant:* Polyphagous; *Abundance:* Rare; *Altitude & Habitat:* 2200m (CH22), 2600m (CH26), 2800m (TK28), Mohru Oak forest, Mixed Coniferous forest and Kharsu Oak forest; *Specimen studied:* 11.v.2010 (1 ex.), 12.xi.2010 (3 ex.), 15.vi.2012 (3 ex.), 19.vii.2012 (1 ex.).

***103. Hyperythra lutea* (Stoll 1781) (Plate 9.7)**

1781. *Phalaena lutea* Stoll, *In* Cramer: *Uitl. Kapellen*, 4 (29-31): 157.

1787. *Phaleana flavaria* Fabricius, *Mant. Ins.* 2: 187.

1857. *Hyperythra limbolaria* Guenée, *In* Boisduval & Guenée: *Hist. nat. Ins., Spec. gén. Lépid.,* 9 : 101.

1896. *Hyperythra rufifimbria* Warren, *Novit. zool.,* 3 : 140.

1993. *Hyperythra lutea*, Holloway, *The Moths of Borneo*, 11: 99.

2008. *Hyperythra lutea* Stoll, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Throughout including Himachal Pradesh, Uttarakhand, Andamans), World (Sri Lanka, China, Myanmar, Sumatra, Java, New Guinea); *Size:* 38mm; *Host Plant:* Gouania (*Gouania leptostachya*), Wild Jujube (*Ziziphus oenoplia*); *Abundance:* Rare; *Altitude & Habitat:* 2600m (CH26), Mixed Coniferous forest; *Specimen studied:* 12.v.2011 (1 ex.).

***104. Ophthalmitis herbidaria* (Guenée, 1858) (Plate 9.8)**

1858. *Ophthalmodes herbidaria* Guenée, *Hist. nat. Ins., Spec. gén. Lépid.*, 9: 283.

1891. *Opthalmodes pulsaria* Swinhoe, *Trans. Ent. Soc.* : 489.

1993. *Ophthalmitis herbidaria*, Holloway, *The Moths of Borneo.*, 11: 227.

2005. *Ophthalmitis herbidaria* Guenée, Walia, *Fauna of West. Himalaya* 2: 181-190.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Assam, Central India), World (Sri Lanka); *Size:* 58mm; *Host Plant: Casearia elliptica* (Family Flacourtiaceae); *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mixed Forest; *Specimen studied:* 18.v.2011 (1 ex.), 22.vi.2011 (1 ex.).

***105. Opisthograptis sulphurea* (Butler, 1880) (Plate 9.9)**

1880. *Rumia sulphurea* Butler, *Ann. Mus. Nat. Hist.*, 6: 123.

1895. *Rumia sulphurea*, Hampson, *Fauna of Brit. India.*, 3: 184.

1915. *Opisthograptis sulphurea*, Seitz, *Macro Lep.*, 4: 339.

1997. *Opisthograptis sulphurea* Butler, Mandal & Ghosh, *Fauna of West Bengal*, 7:491-532.

Distribution: India (West Bengal, Sikkim), World (Nepal), New record to Uttarakhand; *Size:* 48mm; *Host Plant:* The Genus is dependent mainly on the plant families Rosaceae and Betulaceae; *Abundnce:* Abundant; *Altitude & Habitat:* 2600m (CH26), 2800m (TK28), 3200m (CH32, TK32), 3400m (CH34), 3600m (CH36), Mixed Coniferous forest, Kharsu Oak forest, Western Himalayan Birch-Fir forest, Deciduous Alpine Scrub; *Specimen studied:* 14.vi.2012 (3 ex.), 16.vi.2012 (5 ex.), 15.vii.2012 (3 ex.), 16.vii.2012 (2 ex.), 17.vii.2012 (1 ex.), 19.vii.2012 (1 ex.).

***106. Opisthograptis tridentifera* (Moore, 1888) (Plate 9.10)**

1888. *Rumia tridentifera* Moore, *Lep. Auk.* : 230.

1895. *Rumia tridentifera*, Hampson, *Fauna of Brit. India.*, 3: 184.

1915. *Opisthograptis tridentifera*, Seitz, *Macro Lep.*, 4: 339.

1997. *Opisthograptis tridentifera* Moore, Mandal & Ghosh, *Fauna of West Bengal*, 7:491-532.

Distribution: India (West Bengal, Sikkim), World (Nepal, Bhutan), New record to Uttarakhand; *Size:* 46mm; *Host Plant:* Plant families Rosaceae and Betulaceae;

Abundance: Abundant; *Altitude & Habitat:* 2000m (CH20), 3000m (CH30), 3200m (CH32, TK32), 3400m (CH34), Riverine forest, Western Himalayan Birch Fir Forest, Deciduous Alpine Scrub; *Specimen studied:* 02.v.2011 (1 ex.), 16.vi.2012 (11 ex.), 13.vii.2012 (7 ex.), 15.vii.2012 (2 ex.), 16.vii.2012 (5 ex.), 17.vii.2012 (2 ex.).

***107. Sirinopteryx rufivinctata* (Walker, 1862) (Plate 9.11)**

1862. *Urapteryx rufivinctata* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 26: 1747.

1867. *Urapteryx rufivinctata*, Moore, *Proc. Zool. Soc. London.* : 613.

1895. *Sirinopteryx rufivinctata*, Hampson, *Fauna of Brit. India.* 3: 147.

2013. *Sirinopteryx rufivinctata* Walker, Chandra & Sambath, *Jour. of Threat. Taxa*, 5(1): 3565-3570.

Distribution: India (West Bengal, Sikkim, Meghalaya, Nagaland, Arunachal Pradesh), World (Nepal), New record to Uttarakhand; *Size:* 46mm; *Abundance:* Common; *Altitude & Habitat:* 1800m (NT18), 2200m (KK22, TK22), Moist Temperate Deciduous forest, Riverine Forest; *Specimen studied:* 10.vi.2011 (5 ex.), 25.x.2011 (6 ex.), 4.xi.2012 (6 ex.).

***108. Stenorumia* sp. (Plate 9.12)**

Genus Distribution: India, World (Nepal); *Size:* 38mm; *Host Plant:* Unknown; *Abundance:* Uncommon; *Altitude & Habitat:* 3200m (TK32), Himalayan Temperate Parkland; *Specimen studied:* 17.vi.2012 (4 ex.).

***109. Tanaoctenia haliaria* (Walker, 1861) (Plate 10.1)**

1861. *Geometra haliaria* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 35: 518.

1866. *Geometra decoraria* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 35: 1601.

1895. *Heterocampa haliaria*, Hampson, *Fauna of Brit. India*, 3: 157.

1926. *Tanaoctenia haliaria*, P.T. *J. Bombay Nat. Hist. Soc.*, 31: 786.

2003. *Tanaoctenia haliaria* Walker, Ghosh, *Fauna of Sikkim*, 4: 217-342.

Distribution: India (Sikkim, Meghalaya), World (Nepal, China, Myanmar), New record to Uttarakhand; *Size:* 44mm; *Host Plant:* The Genus *Tanaoctenia* has a preference for plant family Fagaceae; *Abundance:* Common; *Altitude & Habitat:* 2400m (KK24, CH24), 2600m (CH26, TK26), 2800m (TK28), Western Mix Coniferous Forest and Upper Oak Forest; *Specimen studied:* 12.v.2010 (2 ex.),

22.vi.2011 (2 ex.), 12.vi.2012 (4 ex.), 15.vi.2012 (8 ex.),, 10.vii.2012 (6 ex.), 19.vii.2012 (2ex.).

***110. Luxiaria* sp. (Plate 10.2)**

Genus Distribution: India (Himalaya, Nilgiri Hills), World (Sri Lanka, South East Asia, Japan); *Size:* 40mm; *Host Plant:* From India the larval food plants reportedly belong to family Melastomataceae; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Mix forest; *Specimen studied:* 03.v.2010 (1 ex.), 04.v.2010 (2 ex.), 22.vi.2011 (1 ex.).

***111. Zeheba* sp. (Plate 10.3)**

Genus Distribution: India (Sikkim, Meghalaya, Nilgiri Hills), World (Sri Lanka, South East Asia); *Size:* 42mm; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Pine Mix Forest; *Specimen studied:* 08.xi.2010 (1 ex.), 11.xi.2010 (1 ex.), 29.v.2009 (1 ex.).

***112. Krananda* sp. (Plate 10.4)**

Genus Distribution: India (Himalayas, Meghalaya); *Size:* 34mm; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Pine Mix forest; *Specimen studied:* 22.vi.2011 (1 ex.).

***113. Lomographa* sp. (Plate 10.5)**

Genus Distribution: World (Holarctic, Tropical, South East Asia); *Size:* 30mm; *Host Plant:* Plant families Leguminosae, Rosaceae; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 2400m (TK24), 3000m (CH30), 3600m (CH36), Pine Mix Forest, Mixed Coniferous forest, Birch-Fir forest, Deciduous Alpine Scrub; *Specimen studied:* 03.v.2010 (6 ex.), 10.vii.2012 (2 ex.), 13.vii.2012 (4 ex.), 17.vii.2012 (2 ex.).

***114. Heterostegane subtessellata* Walker 1862 (Plate 10.6)**

1862. *Macaria subtessellata* Walker, *List. Specimens Lepid. Insects. Colln. Br. Mus.*, 26: 1648.

1886. *Terpnomicta quadrilineata* Snellen, *Tijdschr. Ent*., 29: 49.

2005. *Heterostegane subtessellata* Walker, Walia, *Fauna of West. Himalaya* 2: 181-190.

2013. *Heterostegane subtessellata* Walker, Gurule & Nikam, *Jour. of Threat. Taxa,* 5(12): 4693-4713.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Meghalaya, Maharashtra), World (Bhutan, Java, Borneo); *Size:* 28mm; *Host Plant:* Mainly Leguminosae, *Acacia, Mimosa*; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Pine Broadleaved Mix Forest; *Specimen studied:* 03.vi.2009 (1 ex.), 21.v.2010 (1 ex.).

X B. Subfamily Geometrinae

The subfamily Geometrinae is strongly split, containing a considerable number of tribes of which most are presently very small or monotypic however. These small moths are often a light bluish green, leading to the common name of emerald moths. There are about 2,300 described species, mostly from the tropics. This subfamily was mainly present in lower altitude zone (1400m-1900m) in very low abundance compared to other subfamilies of Geometridae. 18 species were identified from Gangotri Landscape Area:

***115. Agathia hemithearia* Guenée, 1857 (Plate 10.7)**

1857. *Agathia hemithearia* Guenée, *Spec. Gen.*, 9: 381.

1895. *Agathia hemithearia*, Hampson, *Fauna of Brit. India*, 3: 486.

1932. *Agathia hemithearia*, Seitz, *Macro Lep.* : 71.

2008. *Agathia hemithearia* Guenée, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand, Sikkim, Assam, Nilgiri Hills), World (Sri Lanka); *Size:* 35mm; *Host Plant: Carissa* sp., *Holarrhena* sp., *Nerium* sp., *Tabernaemontana* sp. from plant family Apocynaceae; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Pine Broadleaved Mix Forest; *Specimen studied:* 15.xi.2010 (1 ex.), 12.xi.2011 (2 ex.).

***116. Chlorissa gelida* (Butler, 1889) (Plate 10.8)**

1889. *Nemoria gelida* Butler, *Ill. Het.*, 7: 21.

1895. *Nemoria gelida*, Hampson, *Fauna of Brit. India*, 3: 502.

1935. *Chlorissa gelida*, Seitz, *Macro Lep. Supl.*, 4: 15.

2013. *Chlorissa gelida* Butler, Chandra & Sambath, *Jour. of Threat. Taxa*, 5(1): 3565-3570.

Distribution: India (Himachal Pradesh, Uttarakhand, Arunachal Pradesh); *Size:* 28mm; *Host Plant: Carissa* sp., *Acacia* sp.; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), 2000m (KK20), Pine Mix forest, Moist Temperate Deciduous forest; *Specimen studied:* 03.v.2010 (1 ex.), 09.vi.2011 (1 ex.).

***117. Hemithea tritonaria* (Walker, 1863) (Plate 10.9)**

1863. *Thalassodes tritonaria* Walker, *List Lep. Ins. B.M.*, 26: 1560

1887. *Thalassodes leucospilota* Moore, *Lep. Ceyl. Iii.* : 427.

1895. *Hemithea tritonaria* Walker, Hampson, *Moths of Brit. India*, 3: 491

2008. *Hemithea tritonaria* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand, Sikkim, Meghalaya, Nilgiri Hills), World (Sri Lanka, Borneo, Java, Hong Kong); *Size:* 26mm; *Host Plant: Acacia* sp.; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Pine Broadleaved Mix forest; *Specimen studied:* 09.vii.2011 (4 ex.).

***118. Chlorissa distinctaria* (Walker, 1866) (Plate 10.10)**

1866. *Hemithea distinctaria* Walker, *Cat. Lep.*, 35: 1607

1894. *Hemithea rubrifrons* Warren, *Nov. Zool.*: 393.

2008. *Hemithea distinctaria* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North India, Uttarakhand, Sikkim), World (Bhutan); *Size:* 35mm; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 1600m (BH16), Pine Broadleaved Mix Forest; *Specimen studied:* 12.xi.2011 (4 ex.), 30.xi.2011 (3 ex.).

***119. Chlorochaeta inductaria* (Guenée, 1857) (Plate 10.11)**

1857. *Phorodesma inductaria* Guenee, *Spec. Gen.*, 9: 370.

1895. *Phorodesma inductaria*, Hampson, *Fauna of Brit. India.*, 3: 504.

1933. *Chlorochaeta inductaria*, Seitz, *Macro Lep.*, 12: 91.

Distribution: India (Himachal Pradesh, Nagaland), World (Borneo), New record to Uttarakhand; *Size:* 36mm; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Pine Mix forest; *Specimen studied:* 03.v.2009 (1 ex.), 01.vi.2009 (1 ex.).

***120. Chlorochaeta quadrinotata* Butler, 1889 (Plate 10.12)**

1889. *Comibaena quadrinotata, Ill. Het. Brit. Mus.* 7:107.

1895. *Comibaena quadrinotata,* Hampson, *Fauna of Brit. India* 3:503.

1912. *Chlorochaeta quadrinotata fuscidorsata* Prout, *Gen. Ins.*, 129: 101.

Distribution: India (Himachal Pradesh, Uttarakhand, Assam); *Size:* 26mm; *Host Plant: Quercus, Juglans, Malus, Rhus, Betula* sp.; *Abundance:* Rare; *Altitude & Habitat:* 2800m (BG28), Upper Oak Forest; *Specimen studied:* 21.x.2008 (2 ex.).

***121. Chlorochaeta pictipennis* (Butler, 1880) (Plate 11.1)**

1880. *Geometra pictipennis* Butler, *Ann. Mag. Nat. Hist.*, 6(5): 215.

1895. *Geometra pictipennis*, Hampson, *Fauna of Brit. India,* 3: 496.

1935. *Chlorochaeta pictipennis*, Prout, *In* Seitz *Macro Lep. Suppl.*, 4: 11.

2013. *Chlorochaeta pictipennis* Butler, Chandra & Sambath, *Jour. of Threat. Taxa,* 5(1): 3565-3570.

Distribution: India (Sikkim, North India, Arunachal Pradesh), New record to Uttarakhand; *Size:* 36mm; *Host Plant: Quercus*, *Syzygium* sp.; *Abundance:* Rare; *Altitude & Habitat:* 2600m (CH26), Western Mixed Coniferous forest; *Specimen studied:* 12.vi.2012 (1 ex.).

***122. Comostola subtiliaria* (Bremer, 1864) (Plate 11.2)**

1864. *Euchloris subtiliaria* Bremer, *Mém. Acad. Sci. St. Pétersb.*, (7) 8 (1): 76.

1917. *Comostola demeritaria* Prout, *Novit. Zool.*, 24: 304.

1996. *Cosmostola subtiliaria*, Holloway, *The Moths of Borneo*, 9: 293.

2013. *Comostola subtiliaria* Bremer, Chandra & Sambath, *Jour. of Threat. Taxa,* 5(1): 3565-3570.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Nilgiri Hills), World (Sri Lanka, Siberia, China, Korea, Japan, Australia); *Size:* 18mm; *Host Plant: Eurya, Malus, Viburnum* sp., *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), 2000m (CH20), Subtropical Pine Forest, Riverine Forest; *Specimen studied:* 03.v.2010 (3 ex.), 04.v.2010 (1 ex.), 09.v.2010 (6 ex.), 21.v.2010 (2 ex.).

***123. Anisozyga gavissima* (Walker, 1861) (Plate 11.3)**

1861. *Comibaena gavissima* Walker, *List. Lep. Ins. Brit. Mus.,* 22: 575.

1935. *Anisozyga gavissima*, Seitz, *Macro Lep. Supl.*, 4: 10.

2003. *Anisozyga gavissima* Walker, Ghosh, *Fauna of Sikkim*, 4: 217-342.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim), World (Sri Lanka, Borneo); *Size:* 36mm; Abundance: Rare; *Altitude & Habitat:* 1600m (NT16), Pine Broadleaved Mix Forest; *Specimen studied:* 26.vi.2011 (1 ex.).

***124. Herochroma cristata* (Warren, 1894) (Plate 11.4)**

1894. *Actenochroma cristata* Warren, *Novit. zool.*, 1 (2): 381.

1894. *Actenochroma subopalina* Warren, *Novit. zool.*, 1 (2): 382.

1996. *Herochroma cristata*, Holloway, *The Moths of Borneo*, 9: 199.

2005. *Herochroma cristata* Warren, Walia, *Fauna of West. Himalaya* 2: 181-190.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Meghalaya), World (Bhutan, Sri Lanka, Borneo, Hong Kong); *Size:* 44mm; *Host Plant:* From Hong Kong the recorded host plant is *Schefflera* for the genus; *Abundance:* Uncommon; *Altitude & Habitat:* 2200m (KK22), 2400m (JK24), Moist Temperate Deciduous forest, Mohru Oak forest; *Specimen studied:* 01.vi.2009 (1 ex.), 23.v.2010 (2 ex.).

125. Aporandria specularia (Guenée, 1857)

1857. *Geometra specularia* Guenee, *List. Nat. Ins. Spec. Gen. Lapid.* 9: 342.

1976. *Aporandria specularia* Guenée, Holloway, *Moths of Borneo*, 9: 248.

2008. *Aporandria specularia* Guenée, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand, Assam, Chhattisgarh, Kerala, Madhya Pradesh), World (Borneo, Malaysia, Phillipines, Sri Lanka, Sumatra, Vietnam, Thailand); *Size:* 38mm; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Forest; *Specimen studied:* 30.v.2009 (2 ex.).

***126. Mixochlora vittata* (Moore, 1867) (Plate 11.6)**

1867. *Geometra vittata* Moore, *Proc. zool. Soc. London* : 636.

1976. *Mixochlora vittata*, Holloway, *Moths of Borneo with Mt. Kinabalu*, 9: 217.

2005. *Mixochlora vittata vittata*, Walia, *Fauna of West. Himalaya* 2: 181-190.

Distribution: India (Himachal Pradesh, North West Himalaya, Uttarakhand, Sikkim, Meghalya), World (Japan, China, Sumatra, Borneo, Java); *Size:* 44mm; *Host Plant:* From India different Quercus species, especially *Quercus incana* is recorded; *Abundance:* Rare; *Altitude & Habitat:* 3400m (CH34), Subalpine forest; *Specimen studied:* 17.vii.2012 (1 ex.).

***127. Ornithospila avicularia* (Guenée, 1857) (Plate 11.7)**

1857. *Geometra avicularia* Guenée, *Hist. nat. Ins., Spec. gén. Lépid.* 9: 342.

1861. *Geometra pennisignata* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 22: 516.

1996. *Ornithospila avicularia*, Holloway, *Moths of Borneo*, 9: 233.

2003. *Ornithospila avicularia*, Ghosh, *Fauna of Sikkim*, 4: 217-342.

2005. *Ornithospila avicularia avicularia*, Walia, *Fauna of West. Himalaya* 2: 181-190.

Distribution: India (Himachal Pradesh, Uttarakhand, Punjab, Sikkim, Meghalaya), World (Bhutan, Sumatra, Borneo, Philippines); *Size:* 46mm; *Abundance:* Rare; *Altitude & Habitat:* 2600m (TK26), Mixed Coniferous forest; *Specimen studied:* 11.vi.2012 (1 ex.).

***128. Pingasa rubicunda* Warren, 1894 (Plate 11.8)**

1894. *Pingasa rubicunda* Warren, *Novit. Zool.*, 1: 383.

1932. *Pingasa rubicunda*, Seitz, *Macro Lep.*, 12: 48.

2005. *Pingasa rubicunda* Warren, Kendrik, *Fauna Conserv. Dept. Project Report*, 1-28.

Distribution: India (Meghalaya), World (Africa, Hong Kong), New record to Uttarakhand; *Size:* 46mm; *Host Plant:* From Malysia different species of *Shorea* are recorded as food plant; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Mix forest; *Specimen studied:* 31.xi.2009 (2 ex.).

***129. Pingasa alba* Swinhoe, 1891 (Plate 11.9)**

1891. *Pingasa alba* Swinhoe, *Trans. R. Ent. Soc. London*, 24: 492.

1895. *Pingasa alba*, Hampson, *Fauna of Brit. India*, 3: 474.

1917. *Pingasa alba*, Seitz, *Macro Lep.*, 12: 49.

2008. *Pingasa alba* Swinhoe, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand, Meghalaya), World (China, Taiwan, Japan); *Size:* 48mm; *Host Plant: Dalbergia, Litsea, Sterculia* are recorded from India as host plant; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Broadleaved forest; *Specimen studied:* 02.xi.2011 (2 ex.).

***130. Pingasa ruginaria* Guenée, 1857 (Plate 11.10)**

1857. *Hypochroma ruginaria* Guenée, *Hist. nat. Insectes, Spec. gen. Lep.*, 9: 278.

1860. *Hypochroma perfectaria* Walker, 1860, List Specimens lepid. Insects Colln Br. Mus., 21: 434.

1916. *Pingasa ruginaria andamanica* Prout, *Novit. zool.*, 23: 194.

1964. *Pingasa ruginaria pacifica* Inoue, 1964, *Kontyû*, 32: 335.

1976. *Pingasa ruginaria* Guenée; Holloway, *The Moths of Borneo,* 9: 60.

2003. *Pingasa ruginaria,* Ghosh, *Fauna of Sikkim*, 4: 217-342.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Chhattisgarh, Andamans), World (Borneo, Philippines, Africa); *Size:* 46mm; *Host Plant: Dalbergia monetaria, Litsea elongata, Sterculia villosa, Xylia xylocarpa, Wendlandia notoniana* etc.; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), 1800m (CH18); Subtropical Pine Broadleaved Mix forest, Riverine forest; *Specimen studied:* 30.x.2011 (3 ex.), 12.xi.2011 (2 ex.), 25.vii.2012 (2 ex.).

***131. Tanaorhinus reciprocata* (Walker, 1861) (Plate 11.11)**

1861. *Geometra reciprocata* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 22: 515.

1895. *Geometra reciprocata*, Hampson, *Fauna of Brit. India,* 3: 493.

1934. *Tanaorhinus reciprocata*, Seitz, *Macro Lep. Supl.*, 12: 76.

2003. *Tanaorhinus reciprocata* Walker, Ghosh, *Fauna of Sikkim*, 4: 217-342.

2005. *Tanaorhinus reciprocate reciprocate* Walker, Walia, *Fauna of West. Himalaya* 2: 181-190.

2008. *Tanaorhinus reciprocata* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Meghalaya), World (Japan, China); *Size:* 65mm; *Host Plant:* From Japan different species of *Quercus* like *Quercus cerris, Quercus serrata* are recorded as host plant; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine forest; *Specimen studied:* 20.v.2012 (1 ex.).

***132. Thalassodes veraria* Guenée, 1857 (Plate 11.12)**

1857. *Thalassodes veraria* Guenée, *Spec. Gen.*, 9: 360.

1895. *Thalassodes veraria*, Hampson, *Fauna of Brit. India,* 3: 508.

1933. *Thalassodes veraria*, Seitz, *Macro Lep.*, 12: 100.

2008. *Thalassodes veraria* Guenée, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himalayas, Uttarakhand, Meghalaya, Nagaland, Nilgiri Hills), World (Sri Lanka, Java); *Size:* 38mm; *Host Plant: Xylia* specis of family Fabaceae is recorded as genus host plant; *Abundance:* Common; *Altitude & Habitat:* 2400m (CH24), 2600m (CH26, TK26), 2800m (TK28), 3000m (CH30), Western Mix Coniferous forest, Upper Oak forest, Birch-Fir forest; *Specimen studied:* 14.vi.2012 (2 ex.), 19.vii.2012 (1 ex.), 21.vii.2012 (2 ex.).

X C. Subfamily Larentiinae

Larentiinae moths contain roughly 5,800 species and occur mostly in the temperate regions of the world. They are generally divided into a few large or good-sized tribes, and numerous very small or even monotypic ones which might not always be valid. Well-known members are the "pug moths" and the "carpets". This subfamily tends to predominate over other subfamilies of geometridae with increasing latitude. In the tropical region, and also in my study area, in a typical Western Himalayan landscape, this same trend is observed with increasing altitude. I recorded following species from GLA:

***133. Photoscotosia miniosata* (Walker, 1862) (Plate12.1)**

1862. *Scotosia miniosata* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 25: 1354.

1895. *Photoscotosia miniosata*, Hampson, *Fauna of Brit. India.*, 3: 380.

1914. *Photoscotosia miniosota*, Seitz, *Macro Lep.*, 4: 202.

2003. *Photoscotosia miniosata* Walker, Ghosh, *Fauna of Sikkim*, 4: 217-342.

Distribution: India (North West Himalayas, Himachal Pradesh, Uttarakhand, Eastern Himalayas, West Bengal, Sikkim), World (Nepal, Bhutan); *Size:* 52mm; *Host Plant: Rubus* sp. and *Rubus ellipticus* of family Rosacea are recorded as host plant fom India; *Abundance:* Abundant, one of the most abundant species recorded in the study area; *Altitude & Habitat:* 1800m (NT18), 2000m (CH20), 2200m (KK22,TK22), 2400m (TK24), 2600m (HS26,CH26,TK24), 2800m (TK28), 3000m (HD30), 3200m (CH32,KK32), 3400m (HD34), 3600m (CH36), Moist Temperate Deciduous, Riverine forest, Mohru Oak forest, Mixed Coniferous forest, Upper Oak forest, Birch-Fir forest, Birch-Rhododendron Scrub, Deciduous Alpine Scrub; *Specimen studied:* 24.x.2008 (4 ex.), 12.v.2010 (2 ex.), 27.x.2010 (2 ex.), 10.v.2011 (4 ex.), 29.x.2011

(7 ex.), 11.vi.2012 (4 ex.), 15.vii.2012 (6 ex.), 16.vii.2012 (6 ex.), 22.vi.2012 (8 ex.), 26.vi.2012 (11 ex.), 04.xi.2012 (4 ex.).

***134. Photoscotosia multilinea* Warren, 1893 (Plate 12.2)**

1893. *Photoscotosia multilinea* Warren, Proc. Zool. Soc. London. 25: 369.

2003. *Photoscotosia multilinea* Warren, Ghosh, *Fauna of Sikkim*, 4: 217-342.

Distribution: India (Sikkim), World (Nepal, China, Tibet), New record to Uttarakhand; *Size:* 54mm; *Abundance:* Rare; *Altitude & Habitat:* 3200m (CH32), 3400m (CH34), 3600m (CH36), Western Himalayan Birch-Fir forest, Deciduous Alpine Scrub; *Specimen studied:* 15.vii.2012 (1 ex.), 16.vii.2012 (2 ex.), 17.vii.2012 (2 ex.).

***135. Photoscotosia amplicata* (Walker, 1862) (Plate 12.3)**

1862. *Cidaria amplicata* Walker, *Cat. Het.*, 25: 1404.

1895. *Photoscotosia amplicata*, Hampson, *Fauna of Brit. India*, 3: 382.

1914. *Photoscotosia amplicata*, Seitz, *Macro Lep.*, 4: 203.

2014. *Photoscotosia amplicata* Walker, Xiong *et al*., *Chinese Journ. of Ecology*,33(11):3033-3042

Distribution: India (North West Himalayas, Sikkim), World (Tibet, China); *Size:* 52mm; *Host Plant:* Species of plant family Rosaceae and Fagaceae; *Abundance:* Abundant; *Altitude & Habitat:* 2400m (TK24), 2600m (TK26), 3000m (HD30), 3200m (CH32), 3400m (CH34, HD34), 3600m (CH36), Weatern Mixed Coniferous forest, Birch-Fir forest, Birch-Rhododendron Scrub forest, Deciduous Alpine scrub; *Specimen studied:* 09.vi.2012 (11 ex.), 11.vi.2011 (2 ex.), 22.vi.2012 (4 ex.) , 26.vi.2012 (2 ex.), 15.vii.2012 (3 ex.), 16.vii.2012 (1 ex.), 17.vii.2012 (3 ex.).

***136. Photoscotosia metachryseis* Hampson, 1896 (Plate 12.4)**

1896. *Photoscotosia metachriseis* Hampson, *Fauna of Brit. India*, 4: 557.

2003. *Photoscotosia metachriseis* Hampson, Ghosh, *Fauna of Sikkim*, 4: 217-342.

Distribution: India (Sikkim), World (Nepal, China), New record to Uttarakhand*; Size:* 48mm; *Abundance:* Rare; *Altitude & Habitat:* 3000m (CH30), Western Himalayan Birch-Fir forest; *Specimen studied:* 13.vii.2012 (1 ex.).

***137. Laciniodes plurilinearia* (Moore, 1867) (Plate 12.5)**

1867. *Somatina plurilinearia* Moore, *Proc. zool. Soc. Lond.* : 645.

1895. *Laciniodes plurilinearia*, Hampson, *Fauna Brit. India*, 3: 417.

1914. *Laciniodes plurilinearia*, Seitz, *Macro Lep.*, 4: 273.

2005. *Laciniodes plurilinearia* Moore, Walia, *Fauna of West. Himalaya* 2: 181-190.

Distribution: India (North West Himalayas, Himachal Pradesh, Sikkim, West Bengal, Meghalaya); *Size:* 34mm; *Host Plant:* Plant families Rubiaceae, Rosaceae, Oleaceae are recorded as host plant for the Genus; *Abundance:* Uncommon; *Altitude & Habitat:* 2200m (CH22), 2400m (CH24,KK24), 3200m (HD32, TK32), Mohru Oak forest, Mixed Coniferous forest, Birch-Fir forest; *Specimen studied:* 22.vi.2011 (4 ex.), 16.vi.2012 (7 ex.), 22.vi.2012 (2 ex.), 10.vii.2012 (3 ex.), 20.vii.2012 (2 ex.).

***138. Cidaria aurata* Moore, 1867 (Plate 12.6)**

1886. *Cidaria prpulchra* Butler, *Proc. zool. Soc.*: 393.

1893. *Cidaria tsermosaria*, Oberthur, *Et. Ent.* 18: 39.

2003. *Cidaria aurata* Moore, Ghosh, *Fauna of Sikkim*, 4: 217-342.

Distribution: India (Himachal Pradesh, West Bengal, Sikkim, Meghalaya), World (Nepal, Bhutan, Tibet), New record to Uttarakhand; *Size:* 30mm; *Host Plant:* Species of plant family Rosaceae; *Abundance:* Uncommon; *Altitude & Habitat:* 1600m (NT16), 2400m (CH24), 3400m (CH34), Subtropical Pine forest, Mix Coniferous forest, Deciduous Alpine scrub; *Specimen studied:* 01.vi.2009 (1 ex.), 10.vii.2012 (3 ex.), 16.vii.2012 (4 ex.).

***139. Docirava aequilineata* (Walker, 1863) (Plate 12.7)**

1863. *Anaitis aequilineata* Walker, *Cat. Lep.* 26: 1635.

2005. *Docirava aequilineata* Walker, Walia, *Fauna of West. Himalaya* 2: 181-190.

Distribution: India (North West Himalayas, Himachal Pradesh); *Size:* 40mm; *Host Plant:* Species of families Rosaceae, Labiatae; *Abundance:* Rare; *Altitude & Habitat:* 2600m (KK26), 3400m (DV34), Western Mix Coniferous forest, Deciduous Alpine scrub; *Specimen Studied:* 07.x.2008 (2 ex.), 26.v.2012 (3 ex.).

***140. Docirava pudicata* (Guenée, 1858) (Plate 12.8)**

1858. *Anaitis pudicata* Guenée, *Spec. Gen.*, 10: 497.

1863. *Aspilates uvaria* Walker, *Cat. Lep.* 26: 1681

1895. *Anaitis pudicata*, Hampson, *Fauna of Brit. India*, 3: 341.

1994. *Docirava pudicata* Guenée, *In* Haruta*: Moths of Nepal,* 3:13.

Distribution: India (North West Himalayas, Sikkim), World (Afghanistan); *Size:* 33mm; *Host Plant:* Species of families Rosaceae, Labiatae; *Abundance:* Rare; *Altitude & Habitat:* 2000m (KK20), 2600m (KK26), Moist Temperate Deciduous forest, Mixed Coniferous forest; *Specimen studied:* 09.vi.2011 (2 ex.), 25.v.2012 (2 ex.).

***141. Ecliptopera postpallida* Prout, 1940 (Plate 12.9)**

1940. *Ecliptopera postpallida* Prout, *Macro Lep.*, 12: 305.

Distribution: India (Uttarakhand-First time record from India), World (Nepal, China); *Size:* 28mm; *Host Plant: Impatiens* is recorded as host plant for the genus; *Abundance:* Abundant; *Altitude & Habitat:* 1600m (BH16), 2400m (CH24, JK24, TK24), 3000m (HD30, KK30) , 3200m (CH32, HD32), 3400m (HD34), 3600m (CH36), Subtropical Pine Broadleaved Mix forest, Mixed Coniferous forest, Upper Oak forest, Birch-Fir forest; *Specimen studied:* 04.xi.2008 (2 ex.), 13.v.2011 (1 ex.), 28.v.2012 (4 ex.), 09.vi.2012 (7 ex.), 10.vi.2012 (11 ex.), 22.vi.2012 (1 ex.), 26.vi.2012 (2 ex.), 10.vii.2012 (5 ex.), 15.vii.2012 (1 ex.), 17.vii.2012 (1 ex.).

***142. Electrophaes recta* Yazaki, 1994 (Plate 12.10)**

1994. *Electrophaes recta* Yazaki, *In* Haruta: *Moths of Nepal*, 3: 15.

Distribution: India (North West Himalaya),World (Nepal), New record to Uttarakhand; *Size:* 34mm; *Host Plant:* Different species of Betulaceae, Rosaceae and Fagaceae; *Abundance:* Common; *Altitude & Habitat:* 1800m (N18), 2200m (CH22), 2400m (CH24), 2800m (TK28), Moist Temperate Deciduous forest, Western Mixed Conifrous forest, Mohru Oak and Kharsu Oak forest; *Specimen studied:* 14.vi.2012 (2 ex.), 15.vi.2012 (6 ex.), 10.vii.2012 (3 ex.), 16.vii.2012 (4 ex.), 23.vii.2012 (3 ex.), 04.xi.2012 (4 ex.).

***143. Euphyia coangulata* Prout, 1914 (Plate 12.11)**

1914. *Euphyia coangulata* Prout, *Macro Lep.*, 4: 247.

Distribution: India (Uttarakhand-First time record from India), World (Nepal, Mongolia); *Size:* 27mm; *Host Plant: Betula*, *Rubus*, *Salix*, *Stellaria*, *Ulmus* sp.;

Abundance: Common; *Altitude & Habitat:* 1600m (BH16), 1800m (NT18), 2000m (KK20), 2200m (CH22, KK22), 2400m (TK24), 2600m (CH26, TK26), 2800m (TK28), 3000m (HD30), 3200 (TK32), 3400m (CH34), Subtropical Pine Broadleaved mix forest, Moist Temperate Deciduous forest, Mixed Coniferous forest, Mohru Oak forest, Kharsu Oak forest, Deciduous Alpine scrub; *Specimen studied:* 04.xi.2008 (3 ex.), 10.v.2011 (2ex.) , 09.vi.2011 (8 ex.), 12.vi.2012 (7 ex.), 15.vi.2012 (7 ex.), 07.xi.2012 (2 ex.), 16.vii.2012 (3 ex.). 23. vii.2012 (2 ex.), 22.vi.2012 (1 ex.).

***144. Eupithecia rajata* Guenée, 1858 (Plate 12.12)**

1858. *Eupithecia rajata* Guenee, *Spec. Gen.*, 10: 328.

1895. *Eupithecia rajata*, Hampson, *Fauna of Brit. India*, 3: 399.

2005. *Eupithecia rajata* Guenée, Walia, *Fauna of West. Himalaya* 2: 181-190.

2008. *Eupithecia rajata* Guenée, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himachal Pradesh, Uttarakhand, Meghalaya, Nagaland, Nilgiri Hills, Madhya Pradesh), World (Sri Lanka); *Size:* 22mm; *Host Plant: Abies*, *Alnus* sp.; *Abundance:* Uncommon; *Altitude & Habitat:* 1600m (BH16), 2600m (HS26), Subtropical Broadleaved Mix forest, Mohru Oak forest; *Specimen studied:* 23.x.2008 (7 ex.), 30.x.2008 (3 ex.).

***145. Eustroma chalcoptera* (Hampson, 1895) (13.1)**

1895. *Cidaria chalcoptera* Hampson, *Fauna of Brit. India*, 3: 360.

1940. *Eustroma chalcoptera*, Hampson, *Macro Lep. Supl.*, 12: 308.

1995. *Eustroma chalcoptera* (Hampson), *In* Haruta*: Moths of Nepal*, 4:6.

Distribution: India (Sikkim), World (Nepal), New record to Uttarakhand; *Size:* 28mm; *Host Plant: Impatiens* sp.; *Abundance:* Common; *Altitude & Habitat:* 2200m (CH22), 3400m (CH34), 3600m (CH36), Mohru Oak forest, Upper Oak forest, Birch-Rhododendron Scub forest, Deciduous Alpine scrub; *Specimen Studied:*14.vi.2012 (3 ex.), 28.vi.2012 (2 ex.), 16.vii.2012 (1 ex.), 17.vii.2012 (1 ex.), 23.vii.2012 (5 ex.).

***146. Hydrelia bicolorata* (Moore, 1867) (Plate 13.2)**

1867. *Hyria bicolorata* Moore, *Proc. Zool. Soc. Lond.* : 642.

1895. *Hydrelia bicolorata*, Hampson, *Fauna of Brit. India*, 3: 413.

1914. *Hydrelia bicolorata*, Seitz, *Macro Lep.*, 4: 269.

1997. *Hydrelia bicolorata* Moore, Mandal & Ghosh, *Fauna of West Bengal*, 7:491-532.

Distribution: India (Himachal Pradesh, Sikkim, West Bengal, Meghalaya, Nagaland), New record to Uttarakhand; *Size:* 21mm; *Host Plant: Betula*, *Ulmus* sp.; *Abundance:* Uncommon; *Altitude & Habitat:* 2000m (CH22), 2200m (CH22), 2400m (CH24), Riverine Forest, Mohru Oak Forest, Western Mixed Coniferous forest; *Specimen studied:* 02.v.2011 (1 ex.), 10.vii.2012 (3 ex.), 20.vii.2012 (4 ex.), 23.vii.2012 (4 ex.).

***147. Stamnodes pamphilata* Felder, 1875 (Plate 13.3)**

1875. *Stamnodes pamphilata*, Feld. *Reis. Nov*.: 132.

2003. *Stamnodes pamphilata* Felder, Ghosh, *Fauna of Sikkim*, 4: 217-342.

Distribution: India (Himachal Pradesh, Sikkim), World (Nepal), New record to Uttarakhand; *Size:* 35mm; Host Plant: Different spcies of family Rosaceae; *Abundance:* Common; *Altitude & Habitat:* 2600m (TK26), 2800m (TK28), 3200m (TK32), 3400m (CH34), Western Mixed Coniferou forest, Western Himalayan Birch-Fir forest, Deciduous Alpine Scrub; *Specimen studied:* 11.vi.2012 (2 ex.), 12.xi.2012 (1 ex.), 16.vi.2012 (1 ex.), 14.vi.2012 (2 ex.), 16.vii.2012 (4 ex.).

***148. Trichopterigia rufinotata* (Butler, 1889) (Plate 13.4)**

1889. *Lobophora rufinotata* Butler, *Ill. Het.*, 7: 116.

1895. *Trichopterigia rufinotata*, Hampson, *Fauna of Brit. India*, 3: 404.

1914. *Trichopterigia rufinotata*, Seitz, *Macro Lep.*, 4: 187.

1994. *Trichopterigia rufinotata* Butler, *In* Haruta*: Moths of Nepal*, 3: 12.

Distribution: India (Himachal Pradesh), World (Nepal), New record to Uttarakhand; *Size:* 38mm; *Host Plant:* Different species of *Quercus*; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine forest; *Specimen studied:* 01.xi.2010 (1 ex.), 11.xi.2010 (1 ex.).

***149. Triphosa rubrodotata* (Walker, 1862) (Plate 13.5)**

1862. *Scotosia rubrodotata* Walker, *List. Spec. Lepid. Ins. Coll. Brit. Mus.*, 25: 1353.

1895. *Triphosa rubrodotata*, Hampson, *Fauna of Brit. India*, 3: 345.

1914. *Triphosa rubrodotata*, Seitz, *Macro Lep.*, 4: 198.

2003. *Triphosa rubrodotata* Walker, Ghosh, *Fauna of Sikkim*, 4: 217-342.

Distribution: India (Punjab, Sikkim), World (Nepal), New record to Uttarakhand; *Size:* 64mm; *Host Plant: Pyrus*, *Rhamnus*, *Prunus* sp.; *Abundance:* Abundant; *Altitude & Habitat:* 1600m (BH16), 2600m (CH26), 2800m (TK28), 3200m (HD32), 3400m (HD34), Subtropical Broadleaved Forest, Mixed Coniferous forest, Upper Oak Forest, Birch-Rhododendron Scrub Forest; *Specimen studied:* 04.xi.2008 (3 ex.), 12.v.2010 (4 ex.), 14.vi.2012 (2 ex.), 22.vi.2012 (2 ex.), 26.vi.2012 (6 ex.), 28.vi.2012 (2 ex.).

***150. Colostygia albigirata* (Kollar, 1844) (Plate 13.6)**

1844. *Cidaria albigirata* Kollar, *Hugel's Kashmir*, 4: 489.

1895. *Colostygia albigirata*, Hampson, *Fauna of Brit. India*, 3: 367.

1914. *Colostygia albigirata*, Seitz, *Macro Lep.*, 4: 229.

1995. *Lampropteryx albigirata* Kollar, *In* Haruta*: Moths of Nepal*, 4: 6.

Distribution: India (Uttarakhand, North West Himalayas), World (Nepal); *Size:* 36mm; *Host Plant:* Different species of *Galium* of family Rubiaceae are recorded from Europe; *Abundance:* Abundant; *Altitude & Habitat:* 1600m (BH16), 1800m (NT18), 2200m (TK22), 2400m (CH24,TK24), 2600m (HS26,KK26), 2800m (TK28), 3000m (CH30,HD30,KK30), 3200m (CH32), 3400m (CH34), 3600m (CH36), Subtropical Pine Mix Forest, Moist Temperate Deciduous forest, Mixed Coniferous Forest, Upper Oak forest, Birch-Fir-Rhododendron forest, Subalpine and Alpine Scrub; *Specimen studied:* 24.x.2008 (8 ex.), 30.x.2008 (5 ex.), 25.x.2011 (6 ex.), 25.v.2012 (7 ex.), 28.v.2012 (11 ex.), 10.vi.2012 (2 ex.), 15.vi.2012 (6 ex.), 22.vi.2012 (4 ex.), 10.vii.2012 (9 ex.), 13.vii.2012 (6 ex.), 16.vii.2012 (3 ex.).

***151. Perizoma albofasciata* (Moore, 1888) (Plate 13.7)**

1888. *Cidaria albofasciata* Moore, *Lep. Atk.* : 277.

1895. *Perizoma albofasciata*, Hampson, *Fauna of Brit. India*, 3: 374.

1914. *Perizoma albofasciata*, Seitz, *Macro Lep.*, 4: 259.

1994. *Perizoma albofasciata* Moore, *In* Haruta*: Moths of Nepal*, 3:17.

Distribution: India (Himachal Pradesh, Sikkim, West Bengal), New record to Uttarakhand; *Size:* 28mm; *Abundance:* Abundant; *Altitude & Habitat:* 1600m (BH16, NT16), 2000m (KK20), 2200m (CH22), 2400m (TK24), 2600m (TK26), 3000m (HD30), Subtropical Chir Pine Forest, Moist Temperate Deciduous forest, Mohru Oak

forest, Western Mixed Coniferous forest, Deciduous Alpine Scrub; *Specimen studied:* 30.xi.2008 (7 ex.), 01.vi.2009 (5 ex.), 09.vi.2011 (3 ex.), 09.vi.2012 (4 ex.), 11.vi.2012 (1 ex.), 22.vi.2012 (2 ex.), 23.vii.2012 (5 ex.).

***152. Perizoma seriata* (Moore, 1888) (Plate 13.8)**

1888. *Cidaria seriata* Moore, *Lep. Ack.*: 278.

1914. *Perizoma seriata*, Seitz, *Macro Lep.*, 4: 259.

1994. *Perizoma seriata* Moore, *In* Haruta*: Moths of Nepal,* 3:17.

Distribution: India (North West Himalayas, West Bengal); Size: 24mm; *Abundance:* Abundant; *Altitude & Habitat:* 1600m (BH16), 2400m (TK24), 2600m (HS26, KK26), 3000m (KK30), 3200m (HD32, KK32, TK32), 3500m (CH36), Subtropical Broadleaved forest, Mohru Oak forest, Mixed Coniferous forest, Upper Oak Forest, Birch-Rhododendron Scrub Forest, Deciduous Alpine Scrub; *Specimen studied:* 24.x.2008 (14 ex.), 30.x.2008 (12 ex.), 04.xi.2008 (3 ex.), 17.vii.2012 (5 ex.), 28.v.2012 (5 ex.), 29.v.2012 (4 ex.), 09.vi.2012 (7 ex.), 16.vi.2012 (9 ex.), 26.vi.2012 (2 ex.), 26.vii.2012 (5 ex.).

***153. Euphyia stellata* (Warren, 1893) (Plate 13.9)**

1893. *Glaucopteryx stellata* Warren, *Proc. Zool. Soc*., 25: 367.

1895. *Euphyia stellata*, Hampson, *Fauna of Brit. India*, 3: 369.

1959. *Euphyia stellata*, Aubert, *Wien. Ent. Ges.*, 44: 202.

1995. *Parentephria stellata* Warren, *In* Haruta*: Moths of Nepal,* 4: 7.

Distribution: India (Sikkim), World (Tibet, Nepal), New record to Uttarakhand; *Size:* 40mm; *Host Plant: Betula*, *Salix*, *Ulmus* sp.; *Abundance:* Common; *Altitude & Habitat:* 2800m (TK28), 3200m (CH32), 3400m (CH34), 3600m (CH36), Kharsu Oak Forest, Birch-Fir forest, Birch-Rhododendron Scrub forest, Deciduous Alpine scrub; *Specimen studied:* 13.v.2011 (4 ex.), 13.vii.2012 (2 ex.), 20.vii.2012 (6 ex.), 21.x.2012 (2 ex.).

***154. Xanthorhoe hampsoni* Prout, 1925 (Plate 13.10)**

1925. *Xanthorhoe hampsoni* Prout, *Nov. Zool.*, 32: 39.

1939. *Xanthorhoe hampsoni*, Seitz, *Macro Lep*., 12: 254.

1995. *Xanthorhoe hampsoni* Prout, *In* Haruta*: Moths of Nepal,* 4: 6.

Dsitrbution: India (Himachal Pradesh), World (Nepal), New record to Uttarakhand; *Size:* 32mm; *Host Plant:* The genus is of polyphagous habit; *Abundance:* Rare; *Altitude & Habitat:* 3200m (KK32), West Himalayan Upper Oak forest; *Specimen studied:* 29.v.2012 (2 ex.).

***155. Venusia crassisigna* Inoue, 1987 (Plate 13.11)**

1987. *Venusia crassisigna* Inoue, *Bull. Fac. Domestic Sci. Otsuma Women's Univ.*, 23: 225-226.

1994. *Venusia classisigna* Inoue, *In* Haruta*: Moths of Nepal*, 3: 16.

Distribution: India (Uttarakhand-First time record from India), World (Nepal); *Size:* 26mm; *Host Plant: Alnus*, *Betula*, *Sorbus*, *Salix*, *Malus*, *Quercus* sp.; *Abundance:* Rare; *Altitude & Habitat:* 3200m (CH32), 3400m (CH34), 3600m (CH36), Subalpine forest; *Specimen studied:* 15.vii.2012 (9 ex.), 16.vii.2012 (8 ex.), 17.vii.2012 (5 ex.).

***156. Venusia roseicosta* Yazaki, 1994 (Plate 13.12)**

1994. *Venusia roseicosta, In* Haruta*: Moths of Nepal*, 3: 16.

Distribution: India (Uttarakhand-First time record from India), World (Nepal); *Size:* 27mm; *Host Plant: Betula*, *Sorbus*, *Salix*, *Malus*, *Quercus* sp.; *Abundance:* Rare; *Altitude & Habitat:* 3200m (CH32), 3600m (CH36), Subalpine forest; *Specimen studied:* 15.vii.2012 (5 ex.), 17.vii.2012 (3 ex.).

***157. Heterothera dentifasciata* (Hampson, 1895) (Plate 14.1)**

1895. *Larentia dentifasciata* Hampson, *Fauna of Brit India*, 3: 379.

1941. *Thera dentifasciata*, Prout, *In* Seitz *Gross-Schmett. Erde*., 12: 324.

1997. *Heterothera dentifasciata*, Choi, *Systematic Entomology*, 22: 311.

Distribution: India (Himachal Pradesh), World (Pakistan, Nepal), New record to Uttarakhand; *Size:* 34mm; *Host Plant:* Deodar (*Cedrus deodara*); *Abundance:* Uncommon; *Altitude & Habitat:* 1600m (NT16), Subtropical Pine Broadleaved Mix Forest; *Specimen studied:* 30.x.2011 (6 ex.).

Some of the prominent genera of Larentiinae which were not identified upto species level were:

***158. Dysstroma* sp. (14.2)**

Genus *Distribution:* Throughout the World, most diverse in Tropics; *Size:* 38mm; *Host Plant: Alnus, Sorbus, Salix, Rubus* sp.; *Abundance:* Abundant; *Altitude & Habitat:* 1600m (BH16, NT16), 2200m (TK22), 2600m (HS26, KK26), 3200m (HD32,KK32), 3400m (HD34) Subtropical Broadleaved Mix forest, Moist Temperate Deciduous forest, Mixed Coniferous forest, Upper Oak forest, Birch-Rhododendron Scrub forest; *Specimen studied:* 23.x.2008 (4 ex.), 30.x.2008 (4 ex.), 24.x.2011 (3 ex.), 27.x.2011 (2 ex.), 25.v.2012 (1 ex.), 29.v.2012 (1 ex.), 22.vi.2012 (3 ex.), 26.vi.2012.

***159. Chartographa* sp. (Plate 14.3)**

Genus *Distribution:* Himalayas, Nepal; *Size:* 43mm; *Host Plant:* Unknown; *Abundance:* Rare; *Altitude & Habitat:* 2400m (CH24), Mixed Coniferous forest; *Specimen studied:* 15.vii.2012 (1 ex.).

***160. Rheumaptera* sp. (Plate 14.4)**

Genus *Distribution:* Throughout the world; *Size:* 44mm; *Host Plant: Betula, Alnus, Berberis, Salix* sp.; *Abundance:* Abundant; *Altitude & Habitat:* 3600m (CH36), Deciduous Alpine Scrub; *Specimen studied:* 17.vii.2012 (11 ex.).

X D. Subfamily Sterrhinae

The subfamily Sterrhinae characterized by only adult feature that appears to be general to almost all tribes is a hindwing discal spot with pale markings in a darker surround, the pale colour distinct from that of the general ground colour. Covell (1983) mentioned the presence of black discal spots on both wings, and indeed they are of more general occurrence than in other subfamilies. World fauna is diverse with approximately 2800 species described. From the study area most numerous species were from genus *Scopula*, all of which could not be identified upto species level. Following species were identified:

***161. Scopula pulchellata* (Fabricius, 1794) (Plate 14.5)**

1794. *Phalaena pulchellata* Fabricius, *Syst.*, 3: 171.

1858. *Acidalia nictata* Guenee, *Spec. Gen. Lep.*, 9: 506.

1861. *Acidalia ligataria* Walker, *List. Lep. Ins.*, 22: 748.

2003. *Scopula pulchellata* Fabricius, Ghosh, *Fauna of Sikkim*, 4: 217-342.

Distribution: India (Himachal Pradesh, Sikkim, Maharashtra), World (Myanmar); *Size:* 25mm; *Host Plant:* Polyphagous in general, From East Africa *Plumbago auriculata* is recorded as host plant; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 03.v.2009 (2 ex.), 03.v.2010 (3 ex.), 21.v.2010 (2 ex.), 08.v.2011 (2 ex.).

***162. Timandra griseata* (Petersen 1902) (Plate 14.6)**

1902. *Calothysanis griseata* Petersen, *Lep. Estl.*: 116.

1895. *Timandra amataria,* Hampson, *Fauna of British India* 3: 458.

2008. *Timandra griseata,* Basilenko, *EuroAsian Entomological Journal,* 7(2):180-181.

Distribution: India (Throughout), World (Sri Lanka, China, Siberia, Europe, Japan, Myanmar); *Size:* 39mm; *Host Plant: Polygonum chinense* is recorded as host plant from India; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Pine Broadleaved mix Forest; *Specimen studied:* 29.v.2009 (1 ex.), 04.v.2010 (3 ex.).

***163. Rhodostrophia pelloniaria* (Guenée, 1858) (Plate 14.7)**

1858. *Phyletis pelloniaria* Guenée, *Spec. Gen.*, 10: 169.

1895. *Phyletis pelloniaria,* Hampson, *Fauna of Brit. India*, 3: 456.

1935. *Rhodostrophia pelloniaria,* Seitz, *Macro Lep. Supl.*, 4: 25.

Distribution: India (Himachal Pradesh, Meghalaya), World (Pakistan), New record to Uttarakhand; *Size:* 32mm; *Abundance:* Common; *Altitude & Habitat:* 1600m (NT16), 2600m (HS26,TK26), 2800m (TK28), Subtropical Pine Broadleaved mix Forest, Western Mix Coniferous forest, Upper Oak Forest; *Specimen studied:* 24.x.2008 (3 ex.), 08.v.2011 (1 ex.), 11.vi.2012 (6 ex.), 14.vi.2012 (8 ex.).

***164. Rhodometra sacraria* (Linnaeus, 1767) (Plate 14.8)**

1767. *Phalaena sacraria* Linnaeus, *Syst. Nat. (Edn 12)*, 1 (2): 863.

1784. *Pyralis sacralis* Thunberg, *Diss. Ins. Suec.*, 1: 27.

1794. *Rhodometra fulvaria* Fabricius, *Ent. Syst.*, 3: 2, 160.

1997. *Rhodometra sacraria* Linnaeus, Mandal & Ghosh, *Fauna of West Bengal*, 7:491-532.

Distribution: India (North West Himalayas, Meghalaya, North India, West Bengal), World (Europe, Africa); *Size:* 26mm; *Host Plant: Polygonum*, *Rumex*, *Rhus*, *Oxygonum*, *Malus* sp.; *Abundance:* Rare; *Altitude & Habitat:* 2900m (KK30), Western Himalayan Upper Oak forest; *Specimen studied:* 28.v.2012 (2 ex.).

***165. Problepsis vulgaris* Butler, 1889 (Plate 14.9)**

1889. *Problepsis vulgaris* Butler, *Ill. Het.*, 7: 43.

1909. *Problepsis attenuate* Warren, *Nov. Zool.*, 16: 126.

2005. *Problepsis vulgaris* Butler, Walia, *Fauna of West. Himalaya* 2: 181-190.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, South India), World (Sri Lanka, Myanmar, Hong Kong); *Size:* 35mm; *Host Plant: Jasminum* of family Oleaceae; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved mix forest; *Specimen studied:* 08.vi.2009 (1 ex.).

***166. Problepsis albidior* Warren, 1899 (Plate 14.10)**

1899. *Problepsis albidior* Warren, *Nov. Zool*., 6: 33.

2005. *Problepsis albidior albidior* Warren, Walia, *Fauna of West. Himalaya* 2: 181-190.

Distribution: India (Himachal Pradesh, North India); *Size:* 41mm; *Host Plant:* Species of family Oleaceae; *Abundance:* Rare; *Altitude & Habitat:* 1800m (CH18), Mix Riverine forest; *Specimen studied:* 24.vii.2012 (2 ex.), 25.vii.2012 (1 ex.).

***167. Chrysocraspeda olearia* Guenée 1857 (Plate 14.11)**

1857. *Chrysocraspeda olearia* Guenée, *Spec. Gen*., 9: 430.

1895. *Chrysocraspeda olearia*, Hampson, *Fauna of Brit. India*, 3: 444.

1960. *Chrysocraspeda olearia*, Mathur, *Ind. Forest Leaflet (Ent.)*: 161.

2010. *Chrysocraspeda olearia*, Kumar *et al., Biological Forum*, 2(1): 1-5.

Distribution: India (Sikkim, North India); *Size:* 22mm; *Host Plant:* Jamun *(Syzygium cumini)*; *Abundance:* Rare; *Altitude & Habitat:* 2400m (JK24), Mohru Oak forest; *Specimen studied:* 14.v.2010 (1 ex.).

X E. Subfamily Desmobathrinae

This very rare subfamily is characterized by delicately built moths with elongated, slender appendages that tend to frequent the understorey of tropical habitat. Only two

tribes Desmobathrini and Eumeleini are included in this subfamily. One species was recorded from Gangotri Landscape Area:

***168. Eumelea rosalia* Stoll, 1781 (Plate 14.12)**

1781. *Eumelea rosalia* Stoll, *In* Cramer: *Pap. Exot.*, 4: 152.

1794. *Phalaena gravidata* Fabricius, *Ent. Syst.*, 3 (2): 175.

1966. *Eumelea rosalia*, Holloway, *The Moths of Borneo*, 9: 179.

2008. *Eumelea rosalia* Stoll, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand, Sikkim), World (China, Sri Lanka, Myanmar, Australia); *Size:* 52mm; *Host Plant: Mallotus*, *Macaranga* and *Elettaria* sp.; *Abundance:* Rare; *Altitude & Habitat:* 1600m (BH16), Subtropical Broadleaved forest; *Specimen studied:* 04.xi.2008 (1 ex.).

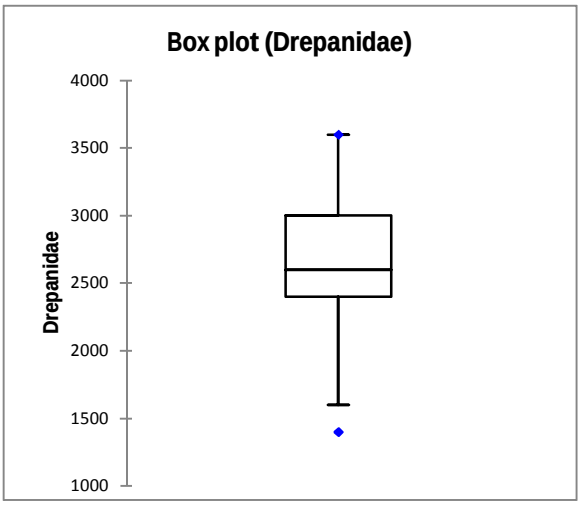
SUPERFAMILY DREPANOIDEA

XI. Family Drepanidae Boisduval, 1828

Commonly known as Hooktip moths, family Drepanidae comprises 812 species worldwide (Heppner 2008), but they are predominately Oriental (647 sp.); none are known for the Neotropics and only a few are in the Nearctic. Three subfamilies are known: Drepaninae, Oretinae, and Nidarinae (the latter only from Madagascar). Adults are small to medium size (18-66 mm wingspan), with head scaling normal. The haustellum small or absent in some species, maxillary palpi vestigial. The antennae are bipectinate to filiform; body somewhat robust. Wings are broadly triangular, usually with the forewings falcate; hindwings are mostly rounded. Maculations mostly are of shades of brown to yellow with various markings, sometimes more colorful, or hyaline to white with tan bands. Few species rest with their wings in a rather tent like position, others hold them flat to the surface. Some fly by day or are sometimes disturbed from among the foliage of the larval foodplants, or netted on the wing at dusk. However, they are most frequently encountered in light trap. Some adults are able to feed, with a rather short tongue and do not visit flowers. The larvae of many species are very distinctive, tapering to a point at the tail and usually resting with both head and tail raised. They usually feed on the leaves of trees and shrubs, pupating between leaves spun together with silk.

Mean species distribution of the family is around 2600m, while most of the species were recorded between 2400m and 2900m (Fig.3.9), however species range extends from 1600m to 3600m, with a rare occurance below 1500m. Following species were identified from GLA:

Fig 3.9: Altitudinal distribution of family Drepanidae (n=36) recorded in GLA



***169. Agnidra discispilaria* Moore, 1867 (Plate 15.1)**

1867. *Agnidra discispilaria* Moore, *Proc. zool. Soc. Lond.* : 619.

1892. *Albara discispilaria*, Swinhoe, 1892, *Cat. Het. Mus. Oxford* (1): 242.

1968. *Agnidra discispilaria*, Watson, *Bull. Br. Mus. nat. Hist. (Ent.) Suppl.* 12: 44.

1994. *Agnidra discispilaria* Moore, *In* Haruta*: Moths of Nepal*, 3: 3.

Distribution: India (Sikkim, West Bengal, North East India), World (Nepal, Thailand, Japan), New record to Uttarakhand; *Size:* 42mm; *Host Plant:* Different species of *Castanea* and *Quercus* are recorded as host plant from Japan; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Broadleaved Forest; *Specimen studied:* 15.vi.2011 (1 ex.).

***170. Auzata semipavonaria* Walker, 1862 (Plate 15.2)**

1862. *Auzata semipavonaria* Walker, *List Spec. Lepid. Insects Colln Br. Mus*., 26: 1620.

2008. *Auzata semipavonaria* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim), World (China); *Size:* 49mm; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 28.iv.2010 (1 ex.).

***171. Drepana pallida* Moore, 1879 (Plate 15.3)**

1879. *Drepana pallida* Moore, *Descr. Indian Lep. Atkinson*, (1): 84.

1922. *Drepana pallida*, Warren, *In* Seitz: *Gross-Schmett. Erde*, 10: 481.

2013. *Drepana pallida* Moore, Chandra & Sambath, *Jour. of Threat. Taxa*, 5(1): 3565-3570.

Distribution: India (Uttarakhand, Sikkim, West Bengal, Arunachal Pradesh), World (Myanmar); *Size:* 42mm; *Host Plant: Alnus*, *Betula*, *Quercus*, *Ulmus* sp.; *Abundance:* Common; *Altitude & Habitat:* 1400m (N14), 1600m (N16), 1800m (CH18), 2000m (CH20), Subtropical Pine Broadlaved mix Forest, Riverine Forest, Western Mixed Coniferous forest; *Specimen studied:* 02.v.2011 (1 ex.), 08.v.2011 (2 ex.), 22.vi.2012 (5 ex.), 25.vii.2012 (3 ex.).

***172. Tethea oberthueri* (Houlbert, 1921) (Plate 15.4)**

1921. *Saronaga Oberthüri* Houlbert, *In Oberthür, Étud. Lépid. Comp.* (2): 194.

1966. *Tethea oberthüri baluensis* Werny, *Untersuchen. Syst. (dissert.)* : (386-390).

1985. *Tethea oberthueri*, Kobes, *Heterocera Sumatrana*, 4: 10.

2008. *Tethea oberthueri* Houlbert, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand, North East Himalaya), World (Nepal, Taiwan, China, Borneo, Sumatra); *Size:* 60mm; *Host Plant: Quercus*, *Prunus*, *Sorbus* sp.; *Abundance:* Rare; *Altitude & Habitat:* 1800m (CH18), Mix Riverine forest; *Specimen studied:* 24.vii.2012 (2 ex.).

***173. Teldenia vestigiata* (Butler, 1880) (Plate 15.5)**

1880. *Corycia vestigiata* Butler, *Ann. Mag. Nat. Hist.*, 6(5): 222.

1998. *Teldenia vestigiata*, Holloway, *The Moths of Borneo*, 8: 19.

2008. *Teldenia vestigiata* Butler, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand, Sikkim, Nagaland, North East India), World (Sri Lanka, Myanmar, Java); *Size:* 26mm; *Host Plant: Shorea robusta*, *Terminalia* and *Eugenia* sp.; *Abundance:* Rare; *Altitude & Habitat:* 2200m (KK22), Moist Temperate Deciduous forest; *Specimen studied:* 10.v.2010 (1 ex.).

***174. Cyclidia substigmaria* (Hübner, 1825) (Plate 15.6)**

1831. *Euchera substigmaria* Hübner, *Zuträge Samml. exot. Schmett.*, 3: 29.

1862. *Abraxas capitata* Walker, *List. Spec. Lep. Ins. Colln. Brit. Mus*., 24: 1121.

1935. *Cyclidia substigmaria*, Nagamo, *Lingnan Sci. J.*, 14: 519-520.

2008. *Cyclidia substigmaria* Hübner, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Assam), World (Nepal, Myanmar, China); *Size:* 80mm; *Host Plant: Alangium chinense* is recorded as host plant from Old World; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Chir Pine forest; *Specimen studied:* 12.vi.2009 (2 ex.), 22.vi.2011 (2 ex.).

***175. Gaurena dierli* Werny, 1966 (Plate 15.7)**

1966. *Gaurena dierli* Werny, *Unters. Syst. Tribus Thyatirini, Macrothyatirini, Habrosynini and Tetheini* : 133.

1968. *Gaurena dierli*, Werny, *Khumbu Himal*, 3(1): 109.

1994. *Gaurena dierli* Werny, *In* Haruta*: Moths of Nepal*, 3: 91.

Distribution: India (Uttarakhand-First time record from India), World (Nepal., China); *Size:* 40mm; *Abundance:* Common; *Altitude & Habitat:* 2400m (CH24), 2800m (TK28), 3000m (CH30,HD30), 3200m (CH32, TK32), 3400m (HD34), Western Mix Coniferous forest, West Himalayan Upper Oak forest, Himalayan Temperate Parkland, Birch-Fir forest, Deciduous Alpine Scrub; *Specimen studied:* 14.vi.2012 (3 ex.), 16.vi.2012 (2 ex.), 22.vi.2012 (1 ex.), 26.vi.2012 (3 ex.), 28.vi.2012 (1 ex.), 10.vii.2012 (1 ex.), 13.vii.2012 (1 ex.), 15.vii.2012 (2 ex.), 17.vii.2012 (1 ex.).

***176. Habrosyne conscripta* Warren, 1912 (Plate 15.8)**

1912. *Habrosyne conscripta* Warren, In Setz: Gross-Schmett. (Pal.) 2: 323.

1994. *Habrosyne conscripta nepalensis* Warren, *In* Haruta*: Moths of Nepal*, 3: 92.

Distribution: India (Uttarakhand-First time record from India), World (China, Nepal); *Size:* 39mm; *Host Plant: Betula*, *Rubus* sp.; *Abundance:* Rare; *Altitude & Habitat:* 2600m (CH26, TK26), Western Mix Coniferous Forest; *Specimen studied:* 11.vi.2012 (2 ex.), 19.vii.2012 (2 ex.).

***177. Macrocilix mysticata* (Walker, 1863) (Plate 15.9)**

1863. *Argyris mysticata* Walker, *List Spec. Lepid. Insects Colln Br. Mus*. 26: 1617.

1968. *Macrocilix mysticata*, Watson, 1968, *Bull. Br. Mus. nat. Hist. (Ent.) Suppl*., 12: 131.

2013. *Macrocilix mysticata* Walker, Chandra & Sambath, *Jour. of Threat. Taxa*, 5(1): 3565-3570.

Distribution: India (Uttarakhand, Sikkim, Arunachal Pradesh), World (Myanmar, Taiwan, Japan, China); *Size:* 34mm; *Host Plant:* Different species of *Quercus, Castanopsis* are recorded as host plant from Japan and China; *Abundance:* Rare; *Altitude & Habitat:* 2900m (KK30), Kharsu Oak forest; *Specimen studied:* 27.v.2012 (4 ex.).

***178. Nordstromia duplicata* (Warren, 1922) (Plate 15.10)**

1922. *Albara duplicata* Warren, *In* Seitz: *Gross-Schmett. Erde*, 10: 469.

1931. *Albara duplicata*, Gaede, *In* Strand: *Lepid. Cat.* 49: 31.

1998. *Nordstromia duplicata*, Holloway, *The Moths of Borneo*, 8: 60.

Distribution: India (Nagaland, North East India), World (China), New record to Uttarakhand; *Size:* 36mm; *Host Plant*: *Quercus, Rubus, Fagus, Castanea* and *Betula* sp.; *Abundance:* Rare; *Altitude & Habitat:* 2450m (CH24), Western Mixed Coniferous forest; *Specimen studied:* 10.vii.2012 (3 ex.).

***179. Oreta pavaca* Moore, 1866 (Plate 15.11)**

1866. *Oreta pavaca* Moore, *Proc. zool. Soc. Lond.*, (3): 815.

1967. *Oreta pavaca*, Watson, *Bull. Br. Mus. nat. Hist. (Ent)*, 19(3): 181.

1994. *Oreta pavaca pavaca* Moore, *In* Haruta*: Moths of Nepal*, 3: 4.

Distribution: India (North India, Sikkim), World (Nepal, China); *Size:* 35mm; *Host Plant: Uncaria, Betula, Viburnum* sp.; *Abundance:* Uncommon; *Altitude & Habitat:* 2400m (CH24), 2600m (CH26), 3000m (CH30), Western Mix Coniferous forest, Himalayan Birch-Fir forest; *Specimen studied:* 10.vii.2012 (3 ex.), 13.vii.2012 (2 ex.), 19.vii.2012 (1 ex.).

***180. Thyatira batis* (Linnaeus, 1758) (Plate 15.12)**

1758. *Phalaena batis* Linnaeus, *Syst. Nat. (Edn 10)*, 1: 509.

1852. *Thyatira vicina*, Guenée, *Boisduval & Guenée: Hist. nat. Ins., Spec. gén. Lépid.*, 5(1):13.

1966. *Thyatira rubrescens*, Werny, *Untersuchen. Syst.* : 36-47.

1998. *Thyatira batis*, Holloway, *The Moths of Borneo*, 8: 74.

2008. *Thyatira batis* Linnaeus, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalaya, Uttarakhand, Sikkim), World (Nepal, China, Sumatra, Malaysia, Java, Borneo, Europe); *Size:* 45mm; *Host Plant:* Different species of *Rubus* are recorded as host plant all over its distribution range; *Abundance:* Rare; *Altitude & Habitat:* 2400m (CH24), Western Mix Coniferous forest; *Specimen studied:* 10.vii.2012 (2 ex.).

SUPERFAMILY BOMBYCOIDEA

This superfamily groups together many families of large moths associated primarily because of various specialized trends in each family which are neither found universally in the group, nor restricted to it. These include the reduction or loss of many structures which are present in other superfamilies. This has usually been associated with the development of very broad wings, in which the anal field of the hind wing is not folded when the insect is at rest, large bipectinate antennae, especially in males and the ability of the larva to spin elaborate cocoon. They have specialized in sedentary behaviour, are mostly unable to feed or drink, and are short-lived. They lay large eggs almost anywhere and all have broadly pectinate antennae in the male with the pectinations usually long until the tip of the antenna. The females emerge from the cocoon with almost all their eggs ready to be laid and are often much larger than the males. The males can detect the scent of the female with great efficiency. They have also specialized in strong extensive cocoons of silk; almost all the moths whose silk is used by humans come from this group. On these characters alone, therefore, there is no indication that the superfamily is monophyletic, a natural grouping. The families of Bombycoidea in South-East Asia are the Bombycidae, Eupterotidae, Lasiocampidae, Brahmeidae and Saturniidae.

XII. Family Bombycidae Latreille, 1802

“Furry’ or ‘woolly’ moths with head and body well covered in long hair-like scales. Wings are held partly out but flattened at rest. Antennae in male are very short, broadly pectinate to the tip, never bent. Antennal pectinations droop downwards. Antennae are held back under wings at rest. Wings are broad, hindwing is not nearly as large as forewings and usually with little pattern of colours. The folded part of the hindwing next to the body has an enhanced colour pattern. Females are usually with very large bodies in which almost all eggs are ready to be laid when the moth emerges

from the cocoon. The family is most diverse in the oriental region, but is recorded from all old world zoogeographic regions. I recorded 2 species from the study area:

***181. Triuncina religiosae* Helfer, 1837 (Plate 16.1)**

1837. *Triuncina religiosae* Helfer, *Journ. As. Soc. Beng.*, 6: 41.

1847. *Bombyx huttoni* Westwood, *Cabinet Oriental Ent.* : 26.

1979. *Triuncina religiosae*, Dierl, *Spixiana*, 3(2): 254.

Distribution: India (North West Himalaya, Uttarakhand, Sikkim, Assam, Arunachal Pradesh), World (Pakistan, Nepal, Bhutan, Taiwan, Vietnam); *Size:* 40mm; *Host Plant:* Wild Mulberry; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine mix forest; *Specimen studied:* 22.vi.2011 (1 ex.).

***182. Mustilia sphingiformis* Moore, 1879 (Plate 16.2)**

1879. *Mustilia sphingiformes* Moore, *Proc. Zool. Soc.*: 407.

2008. *Mustilia sphingiformis* Moore, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand), World (Bhutan, South East Asia, Vietnam, Myanmar); *Size:* 51mm; *Host Plant: Ficus retusa, Fraxinus, Symplocos, Camellia*; *Abundance:* Rare; *Altitude & Habitat:* 2800m (TK28), 3200m (TK32), Westen Himalayan Upper Oak forest, Temperate Parkland; *Specimen studied:* 14.vi.2012 (4 ex.), 15.vi.2012 (2 ex.), 16.vi.2012 (2 ex.).

XIII. Family Eupterotidae Swinhoe, 1892

'Furry' or 'woolly' moths with head and body well covered in long hair-like scales. Wings are held partly out but low roof-wise or flattened over body at rest. Antennae in male are broadly pectinate to the tip, never bent. Antennae are held back under wings at rest. Wings are broad, hindwings usually nearly as large as forewings and usually with a pattern of colours. The tip of the forewing is extended. Females are usually with very large bodies in which almost all eggs are ready to be laid when the moth emerges from the cocoon.

This family has its greatest diversity in the Ethiopian and oriental regions, with only a couple of Neotropical genera and a few in the Australian region. Worldwide some 400 described species in about 50 genera are known (Common 1990). I recorded 2 genera and 2 species from the study area.

***183. Apona caschmirensis* (Kollar, 1844) (Plate 16.3)**

1844. *Gastropacha caschmirensis* Kollar, *In* Hügel: *Kaschmir und das Reich der Siek*, 4: 472.

1856. *Apona pallida* Walker, *List Spec. Lepid. Insects Colln Br. Mus.* 7: 1763.

2008. *Apona caschmirensis* Kollar, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalayas, Kashmir, Uttarakhand, Sikkim); *Size:* 106mm; *Abundance:* Rare; *Altitude & Habitat:* 1800m (N18), 3400m (DV34), Moist Temperate Deciduous forest, Deciduous Alpine Scrub; *Specimen studied:* 04.x.2008 (4 ex.), 04.xi.2012 (3 ex.).

184. Eupterote (Hübner, 1820) **species complex:**

This is a complex group of species with varied external appearance in colour and markings. Same species can vary highly in different regions, even in short spatial scale. I recorded three distinct morphospecies: morph 1 **(Plate 16.4)** from 1800m (NT18, 3 ex.), morph 2 **(Plate 16.5)** from 2600m (TK26, 1 ex.) and morph 3 **(Plate 16.6)** from 3000m (CH30, 1 ex.); *Distribution:* India (Throughout); *Size:* 75mm-105mm; *Host Plant: Pinus, Erythrina, Cajanus, Gossypium, Hibiscus*; *Abundance:* Uncommon.

XIV. Family Lasiocampidae Harris, 1841

Lasiocampids may be recognized by the presence of a pincushion like organ on the underside of the palpi which is found in no other family. The moths in this family have no hearing organs, and the proboscis is reduced or absent. They also lack the hook-and-bristle mechanism between forewings and hindwings. The larvae are very hairy, often flattened, and often with spreading hairs on the sides of the larvae extending down to touch the branch they rest on, which helps to blur the outline of the larva. Some rest during the day on twigs and branches while others hide beneath bark and come out to feed at night.

The Lasiocampidae are reasonably diverse in the old world tropics, less so in New. They have moderate representation in the Holarctic and Australia. It includes about 1,500 species referred to about 150 genera (Regier *et al.* 2000). I recorded following species from the study area:

***185. Trabala vishnou* (Lefebvre, 1827) (Male: Plate 16.7, Female: Plate 16.8)**

1827. *Gastropacha vishnou* Lefèbvre, *Zool. j. Lond.* 3: 207.

1903. *Trabala vishnou*, Niceville, *Indian Mus. Notes*. 5: 107.

2013. *Trabala vishnou* Lefebvre, Chandra & Sambath, *Jour. of Threat. Taxa*, 5(1): 3565-3570.

Distribution: India (Himachal Pradesh, Uttarakhand, West Bengal, Sikkim, Assam, Meghalaya, Arunachal Pradesh, Maharashtra, Tamil Nadu, Andamans), World (Bangladesh, Bhutan, Sri Lanka, Myanmar, China, Indonesia, Java, Borneo); *Size:* 55m; *Host Plant: Punica*, *Acacia*, *Quercus*, *Castanea*; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 01.vi.2009 (1 ex.), 08.viii.2008 (2 ex.), 24.v.2011 (1 ex.), 15.vi.2011 (1 ex.).

***186. Gastropacha pardale* (Walker, 1855) (Plate 16.9)**

1855. *Megasoma pardale* Walker, *List. Spec. Lep. Ins. Brit. Mus.* 6: 1453.

1865. *Gastropacha abstracta* Walker, *Cat. Lep. Het. Brit. Mus.* 32: 551.

1892. *Estigena pardalis*, Hampson, *Fauna of Brit. India*, 1: 424.

1982. *Gastropacha pardale*, Barlow, *Intr. Moths S. E. Asia*, 51, p.305, pl 13.

Distribution: India (Himalaya, Uttarakhand, Andamans, Meghalaya), World (Java, Myanmar); *Size:* 42mm; *Host Plant: Carissa carandas*, *Camellia sinensis*, *Mangifera indica*, *Erythrina*; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 09.vi.2009 (1 ex.).

***187. Euthrix laeta* (Walker, 1855) (Plate 16.10)**

1855. *Amydona laeta* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 6: 1416.

1978. *Euthrix laeta*, *Lajonquiére, Ann. Soc. Ent. Fr.*, 14: 391.

2013. *Euthrix laeta* Walker, Chandra & Sambath, *Jour. of Threat. Taxa*, 5(1): 3565-3570.

Distribution: India (North West Himalayas, Uttarakhand, Sikkim, Arunachal Pradesh), World (Bangladesh, Myanmar, Sumatra); *Size:* 46mm; *Host Plant: Dalbergia latifolia*, *Dalbergia sissoo*; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Subtropical Chir Pine forest; *Specimen studied:* 29.xi.2011 (1 ex.).

***188. Malacosoma indica* (Walker, 1855) (Plate 16.11)**

1855. *Clisiocampa indica* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 6: 1489.

2011. *Malacosoma indica* Walker, Smetacek, *Jour. Threat. Taxa* 3(12): 2274.

Distribution: India (Himachal Pradesh, Uttarakhand, Eastern India); *Size:* 34mm; *Host Plant: Malus pumila, Quercus dilatata, Quercus incana, Salix denticulata*; *Abundance:* Common; *Altitude & Habitat:* 2000m (KK20), 2600m (CH26), 3000m (CH30),3400m (CH34), Moist Temperate Deciduous forest, Western Mix Coniferous forest, West Himalayan Birch-Fir Forest, Deciduous Alpine Scrub; *Specimen studied:* 09.vi.2011 (2 ex.), 19.vii.2012 (7 ex.), 13.vii.2012 (1 ex.), 15.vii.2012 (1 ex.), 16.vii.2012 (1 ex.).

***189. Paralebeda plagifera* (Walker, 1855) (Plate 16.12)**

1855. *Lebeda plagifera* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 6: 1459.

2008. *Paralebeda plagifera* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Meghalaya), World (Nepal, Java); *Size:* 105mm; *Host Plant: Alseodaphne semecarpifolia, Citrus, Maesa, Morus* sp.; *Abundance:* Uncommon; *Altitude & Habitat:* 1800m (CH18), 2400m (CH24), 2600m (CH26), Riverine Forest, Mixed Coniferous Forest; *Specimen studied:* 10.vii.2012 (1 ex.), 24.vii.2012 (5 ex.), 19.vii.2012 (2 ex.).

XV. Family Brahmaeidae Swinhoe, 1892

The Brahmaeidae are a small but spectacular family found in the African and Oriental tropics, and extending north into the warmer Palaearctic. They are characterized by presence of proboscis, large rounded and upturned palpi. Antennae are bipectinated in both sexes. Mid tibia is with a single pair of spurs, hind tibia with two pairs. Frenulum is absent. Only two species are recorded from India. From Gangotri Landscape Area single species was recorded:

***190. Brahmaea wallichii* (Gray, 1831) (Plate 17.1)**

1831. *Bombyx wallichii* Gray, *Zool. Misc.*: 39.

2008. *Brahmaea wallichii* Gray, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand, Sikkim, Meghalaya, Assam), World (Nepal, Myanmar, Bhutan, Taiwan, China, Japan); *Size:* 110mm; *Host Plant: Fraxinus micrantha, Ligustrum robustum* are recorded as host plant from India; *Abundance:*

Rare; *Altitude & Habitat:* 2400m (TK24), 3200m (TK32), Western Mixed Coniferous forest, Himalayan Temperate Parkland; *Specimen studied:* 10.vi.2012 (1 ex.), 16.vi.2012 (2 ex.).

XVI. Family Saturniidae Boisduval, 1837

Saturniids are very large (upto 250 mm) 'furry' or 'woolly' moths with head and body well covered in long hair-like scales. Wings are held partly out but flattened at rest. Antennae in male very short, broadly pectinate to the tip, but never bent. Antennal pectinations are stiffly projecting from each side of the antenna in one plane. Antennae are held partly up and out and back parallel to the front of the forewing. Both wings have either a triangular window or an eye-spot in the middle but in some the hindwing may just have a dot. Tip of the forewing are often broadly extended. Hindwings are smaller than forewings, but well patterned. The body is very small for the size of the moth.

The Saturniids are found worldwide. They have their greatest diversity in the tropics, particularly the Neotropics. Most of the species are highly decorative and are thus prized by collectors. The larvae are often highly polyphagous and easy to rear in captivity. I recorded 4 species from the study area:

***191. Antheraea assamensis* (Helfer, 1837) (Palte 17.2)**

1837. *Saturnia assamensis* Helfer, *J. Asiat. Soc. Bengal*, 6: 43.

1843. *Antheraea perotteti* Guérin-Méneville, *Mag. Zool*., (2) 5 (9): 1.

1987. *Antheraea assamensis*, Holloway, *The Moths of Borneo*, 3: 101.

2008. *Anthraea assamensis* Westwood, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhnd), World (Myanmar, Sundaland); *Size:* 160mm; *Host Plant: Litsea salicifolia, Malus sylvestris, Michelia, Persea, Quercus* sp.; *Abundance:* Rare; *Altitude & Habitat:* 1500m (BH16), Pine Broadleaved mix forest; *Specimen studied:* 30.x.2008 (1 ex.).

***192. Caligula thibeta* (Westwood 1853) (Plate 17.3)**

1853. *Saturnia thibeta* Westwood, *Proc. Zool. Soc. Lond*. 21: 166.

1986. *Caligula thibeta,* Nardelli, *Entomologischen Vereins Apollo, 7:11-23.*

Distribution: India (North West Himalaya, Uttarakhand), World (Tibet); *Size:* 130mm; *Host Plant: Glochidion zeylanicum, Ligustrum ovalifolium, Lyonia ovalifolia, Quercus variabilis*; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), 1500m (BH16), 3400m (DV34), Subtropical Pine Broadleaved Mix forest, Deciduous Alpine Scrub; *Specimen studied:* 03.x.2008 (2 ex.), 30.x.2008 (1 ex.), 30.x.2011 (3 ex.), 02.xi.2011 (1 ex.).

***193. Antheraea paphia* (Linnaeus, 1758) (Plate 17.4)**

1758. *Bombyx paphia* Linnaeus, *Syst. Nat.* 1: 496.

1997. *Antheraea paphia* Linnaeus, Gupta, *Fauna of West Bengal*, 7:409-428.

Distribution: India (Himachal Pradesh, Uttar Pradesh, West Bengal, Assam, Meghalaya, Bihar, Orissa, Madhya Pradesh, Maharashtra, Tamil Nadu, Karnataka, Punjab), World (Pakistan, Nepal, Bhutan, SriLanka, Myanmar, China); *Size:* 160mm; *Host Plant:* Polyphagous, some of the host plants recorded from India are *Anacardium occidentale, Anogeissus latifolia, Dalbergia, Erica tomentosa*, *Fagus, Ficus* etc.; *Abundance:* Rare; *Altitude & Habitat:* 1900m (NT18), Moist Temperate Deciduous forest; *Specimen studied:* 04.xi.2012 (1 ex.).

***194. Loepa katinka* (Westwood, 1848) (Plate 17.5)**

1848. *Saturnia katinka* Westwood, *Cabinet Orient. Ent.* : 25.

1953. *Loepa katinka*, Roepke, *Tidj. Ent*., 96: 228.

1997. *Loepa katinka* Westwood, Gupta, *Fauna of West Bengal*, 7:409-428.

2008. *Loepa katinka* Westwood, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himachal Pradesh, Uttarakhand, Uttar Pradesh, West Bengal, Sikkim, Assam, Meghalaya, Arunachal Pradesh, Tamil Nadu), World (Bangladesh, China, Sumatra, Indonesia, Java); *Size:* 98mm; *Host Plant: Ampelopsis, Cissus, Dillenia pentagyna, Impatiens, Leea guineensis, Polygonum, Salix babylonica, Vitis*; *Abundance:* Rare; *Altitude & Habitat:* 2400m (JK24), Mixed Coniferous forest; *Specimen studied:* 22.vi.2010 (1 ex.).

SUPERFAMILY SPHINGOIDEA

XVII. Family Sphingidae Latreille, 1802

Only one family, Sphingidae, is included in the superfamily Sphingoidea, but the family has sometimes been included in the superfamily Bombycoidea. Hawk moths are very well known and popular group for collectors as well as arguers for insect conservation. Although they were previously placed under Bombycoidea, they have evolved in a very different direction to the other bombycoid families. They have become superb fliers and voracious feeders at nectar, hovering before a flower to feed rather than alighting. They are important pollinators, often one of the few moths that can reach the nectaries of long tubular flowers. Most hawk moths fly at night but many fly at dusk when they can often be glimpsed speeding away against the sky. A few species in the genus *Cephonodes*, with clear wings, fly during the day.

The family is generally characterized by smooth-scaled head and body. The wings are held back near body but extended outwards and flat. The antennae are simple, fairly short, often very gradually thickening until near tip. The antennae are held flat, outwards from head at rest. Wings are relatively narrow, hindwing much shorter than forewing. They are highly streamlined moths with very long prominent proboscis.

Some of the species have a wide world distribution, but the family reaches its greatest development in wet tropical areas. The world fauna includes about 850 species referred to about 190 genera (Common 1990). Mean species distribution of the family in GLA is around 2200m, while most of the species were recorded between 1600m and 2600m (Fig.3.10), however species range extends from 1400m to 2800m.

Today the Sphingidae are usually divided into three subfamilies, Macroglossinae, Sphinginae and Smerinthinae. The Macroglossinae subfamily was represented by 9 species, the subfamily Sphiginae was represented by 2 species and the subfamily Smerinthinae was represented by 5 species from the study area.

Distribution: India (Throughout), World (Sri Lanka, Africa, Russia, Europe); *Size:* 120mm; *Host Plant: Jasminum sambac*, *Nerium oleander*, *Holarrhena antidysenterica*; *Abundance:* Uncommon; *Altitude & Habitat:* 1600m (NT16), 2500m (Village Gangar, Govind WLS), Subtropical Chir Pine Forest, Western Mix Coniferous forest; *Specimen studied:* 10.xi.2009 (1 ex.), 19.vii.2012 (1 ex.).

***197. Hippotion boerhaviae* (Fabricius, 1775) (Plate 17.8)**

1775. *Sphinx boerhaviae* Fabricius, *Syst. Ent.* : 542.

1790. *Sphinx octopunctata* Gmelin, *In* Linnaeus: *Syst. Nat. (edn 13)*, 1(5): 2386.

1903. *Hippotion boerhaviae*, Rothschild & Jordan, *In* Kitching & Cadiou, 2000: *Hawkmoths of the World: An annotated and illustrated revisionary checklist (Lepidoptera: Sphingidae)*: 756.

2010. *Hippotion boerhaviae* Fabricius, Majumdar & Kumar, *Fauna of Uttarakhand*, 2: 553-568.

Distribution: India (West Himalaya, Uttarakhand, Sikkim, West Bengal, Andhra Pradesh; Gujarat, Madhya Pradesh, Maharashtra; Orissa, Southern Peninsula), World (Pakistan, Bhutan, Malayasia, Java, Myanmar, Philippines, China, Sri Lanka, Australia, Japan); *Size:* 58mm; *Host Plant: Boerhavia diffusa*, *Boerhavia repens*, *Glossostigma spathulatum*, *Impatiens balsamina*, *Ipomoea cairica*, *Morinda umbellata*; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), 1800m (NT18), Pine Broadleaved Mix forest; *Specimen studied:* 09.v.2012 (1 ex.), 30.x.2012 (2 ex.).

***198. Hippotion rosetta* (Swinhoe, 1892) (Plte 17.9)**

1892. *Chaerocampa rosetta* Swinhoe, 1892, *Cat. Het. Mus. Oxford*, (1): 16.

1941. *Hippotion depictum* Dupont, *Verh. Ned. Akad. Wet. Amsterdam (Section 2)*, 40(1): 70.

1987. *Hippotion rosetta*, Holloway, *The Moths of Borneo*, 3: 173.

2013. *Hippotion rosetta* Swinhoe, Gurule & Nikam, *J. Threat. Taxa.* 5(12): 4693–4713.

Distribution: India (Uttarakhand, Sikkim, Maharashtra), World (Sri Lanka, Java, Australia); *Size:* 64mm; *Host Plant: Arachis*, *Impatiens balsamina*, *Vigna unguiculata* are recorded from Sri Lanka as host plant; *Abundance:* Uncommon; *Altitude & Habitat:* 2600m (KK26), 2800m (KK28), Mixed Coniferous forest, Western Himalayan Upper Oak forest; *Specimen studied:* 27.v.2012 (2 ex.), 12.vi.2012 (2 ex.).

***199. Macroglossum bombylans* (Boisduval, 1875) (Plate 17.10)**

1875. *Macroglossa bombylans* Boisduval, *Spec. Gen. Lep. Het*., 1: 334.

2000. *Macroglossum bombylans*, Kitching & Cardiou, *Hawkmoths of the World: An annotated and illustrated revisionary checklist (Lepidoptera: Sphingidae).*

2010. *Macroglossum bombylans* Boisduval, Majumdar & Kumar, *Fauna of Uttarakhand,* 2: 553-568.

Distribution: India (Uttarakhand, Western & Eastern Himalaya), World (Japan, China, Hong Kong); *Size:* 42mm; *Host Plant:* Different species of family Rubiaceae like *Hedyotis, Morinda, Paederia*; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 1500m (BH16), Subtropical Mix Broadleaved forest; *Specimen studied:* 30.x.2008 (1 ex.), 29.v.2009 (1 ex.).

***200. Rhopalopsyche nycteris* (Kollar, 1844) (Plate 17.11)**

1844. *Macroglossa nycteris* Kollar, *In Hugel's Kaschmir*, 4(2): 458.

1856. *Macroglossa volucris* Walker, *List. Lep. Ins. Brit. Mus*., 8: 94.

2010. *Rhopalopsyche nycteris nycteris* Kollar, Majumdar & Kumar, *Fauna of Uttarakhand,* 2: 553-568.

Distribution: India (Uttarakhand, Western & Eastern Himalayas, Meghalaya), World (Myanmar, China); *Size:* 38mm; *Abundance:* Rare; *Altitude & Habitat:* 2500m (HS26), Mohru Oak forest; *Specimen studied:* 23.x.2008 (1 ex.).

***201. Theretra alecto* (Linnaeus, 1758) (Plate 17.12)**

1758. *Sphinx alecto* Linnaeus, *Syst. Nat. (Edn 10)*, 1: 492.

1827. *Sphinx cretica* Boisduval, *Ann. Soc. linn. Paris*, 6: 118.

1892. *Theretra freyeri* Kirby, *Syn. Cat. Lepid. Het*., 1 : 650.

1903. *Theretra alecto*, Rothschild & Jordan, *In* Kitching & Cadiou, 2000: *Hawkmoths of the World: An annotated and illustrated revisionary checklist (Lepidoptera: Sphingidae)* : 776.

1997. *Theretra alecto* Linnaeus, Mandal & Maulik, *Fauna of West Bengal,* 7: 613-687.

2010. *Theretra alecto alecto* Linnaeus, Majumdar & Kumar, *Fauna of Uttarakhand,* 2: 553-568.

Distribution: India (Uttarakhand, West Bengal, Western & Eastern Himalaya, Throughout Peninsular India), World (Afghanistan, Pakistan, Bhutan, Sri Lanka, Myanmar, Java, Malaysia, Turkey, Japan, Hong Kong, Sulawesi, China, Borneo);

Size: 94mm; *Host Plant: Dillenia indica*, *Glochidion*, *Morinda*, *Pisum sativum*, *Rubia cordifolia*, *Saurauia napaulensis*, *Tectona grandis*, *Vitis vinifera*; *Abundance:* Rare; *Altitude & Habitat:* 2600m (TK26), Western Mixed Coniferous forest; *Specimen studied:*11.vi.2012 (1 ex.).

***202. Theretra nessus* (Drury, 1773) (Plate 18.1)**

1773. *Sphinx nessus* Drury, *Illust. Nat. Hist. Exot. Insect,* 2 : 46.

1793. *Sphinx equestris* Fabricius, *Ent. Syst*., 3(1): 365.

1882. *Theretra nessus*, Moore, *Lepid. Ceylon*, 2(1): 22.

2010. *Theretra nessus* Drury, Majumdar & Kumar, *Fauna of Uttarakhand,* 2: 553-568.

Distribution: India (Uttarakhand, West Bengal, Western & Eastern Himalaya, Peninsular India, Andamans), World (Sri Lanka, Myanmar, Borneo, Java, Japan, Australia, Hong Kong, Hawaii); *Size:* 125mm; *Host Plant: Amorphophallus*, *Barringtonia*, *Convolvulus*, *Dioscorea*, *Pongamia pinnata*; *Abundance:* Rare; *Altitude & Habitat:* 2200m (CH22), Mohru Oak forest; *Specimen studied:* 25.x.2010 (2 ex.).

***203. Theretra oldenlandiae* (Fabricius, 1775) (Plate 18.2)**

1775. *Sphinx oldenlandiae* Fabricius, *Syst. Ent.* : 542.

1882. *Xylophanes oldenlandiae*, Moore, *Lepid. Ceylon*, 2 (1): 17.

1903. *Theretra oldenlandiae*, Rothschild & Jordan, *In* Kitching & Cadiou, 2000: *Hawkmoths of the World: An annotated and illustrated revisionary checklist (Lepidoptera: Sphingidae)* : 781.

2010. *Theretra oldenlandiae oldenlandiae* Fabricius, Majumdar & Kumar, *Fauna of Uttarakhand,* 2: 553-568.

Distribution: India (Uttarakhand, West Bengal, Western & Eastern Himalaya, Peninsular India), World (Pakistan, Sri Lanka, Bhutan, Myanmar, Japan, New Guiene, Australia, Hong Kong, Philippines, Java); *Size:* 96mm; *Host Plant: Amorphophallus paeoniifolius, Arisaema tortuosum*, *Caladium*, *Cayratia trifolia*, *Colocasia*, *Impatiens*; Abundance: Rare; *Altitude & Habitat:* 2200m (CH22), Moist Temperate Deciduous forest; *Specimen studied:* 10.v.2010 (1 ex.).

***204. Nephele comma* Hopffer, 1857 (Plate 18.3)**

1857. *Nephele comma* Hopffer, *Mber. K. preuss. Akad. Wiss.* : 421

1892. *Nephele hespera* Saalmüller, *Fauna of Brit. India*, 1: 108.

2000. *Nephele comma*, Kitching & Cadiou, *Hawkmoths of the World; An annotated and illustrated revisionary checklist (Lepidoptera: Sphingidae)*

Distribution: India (Throughout), World (Sri Lanka, Australia, Africa, Madagascar); *Size:* 78mm; *Host Plant: Carissa caranda* of family Apocynaceae; *Abundance:* Rare; *Altitude & Habitat:* 2400m (TK24), Western Mixed Coniferous forest; *Specimen studied:* 10.vi.2012 (1 ex.).

XVII B. Subfamily Smerinthinae

***205. Ambulyx* sp. (Plate 18.4)**

Genus *Distribution:* India (Throughout), World (South East Asia, Africa); *Size:* 93mm; *Host Plant:* Species of Dipterocarpaceae, e.g *Shorea*; *Abundance:* Rare; *Altitude & Habitat:* 2600m (CH26), Western Mixed Coniferous forest; *Specimen studied:* 12.v.2011 (1 ex.).

***206. Amplypterus panopus* (Cramer, 1779) (Plate 18.5)**

1779. *Sphinx panopus* Cramer, *Uitl. Kapellen,* 3 (17-21): 50, 224.

1882. *Amblypterus panopus*, Moore, *Lepid. Ceylon,* 2(1): 13.

2000. *Amblypterus panopus*, Kitching & Cardiou, *Hawkmoths of the World: An annotated and illustrated revisionary checklist (Lepidoptera: Sphingidae).*

Distribution: India (Throughout including Andamans), World (Sri Lanka, Myanmar, Philippines, Sulawesi, Java, Hong Kong); *Size:* 130mm; *Host Plant: Calophyllum inophyllum*, *Mangifera indica*; *Abundance:* Rare; *Altitude & Habitat:* 1500m (BH16), Subtropical Broadleaved Forset; *Specimen studied:* 04.xi.2008 (2 ex.).

***207. Clanis stenosema* Rothschild & Jordan, 1907 (Plate 18.6)**

1907. *Clanis stenosema* Rothschild & Jordan, *Novit. Zool.*, 14 (1): 93.

1920. *Clanis brooksi* Rothschild, *Ann. Mag. Nat. Hist*., 5(30): 480.

2004. *Clanis stenosema,* Eitschberger, *Neue Ent. Nachr*., 58: 73.

Distribution: World (Sumatra, Java, Borneo, Phillipines); *Size:* 96mm; *Host Plant: Pongamia*, *Dalbergia*, *Stenocarpus*, *Xylia*, and *Butea*; *Abundance:* Rare; *Altitude & Habitat:* 2200m (CH22), Mohru Oak forest; *Specimen studied:* 14.v.2010 (1 ex.).

***208. Leucophlebia lineata* Westwood, 1848 (Plate 18.7)**

1848. *Leucophlebia lineata* Westwood, *Cabinet Orient. Ent.* : 46.

2003. *Leucophlebia lineata*, Eitschberger, *Neue Ent. Nachr*., 56: 8.

2013. *Leucophlebia lineata* Westwood, Gurule & Nikam, *J. Threat. Taxa.* 5(12): 4693–4713.

Distribution: India (West Bengal, Assam, Maharashtra, Western & Eastern Himalaya, Indian Peninsula), World (Bhutan, Nepal, Sri Lanka, China, Java, Malayasia, Nepal, Philippines); *Size:* 68mm; *Host Plant:* Species of Gramineae like *Saccharum officinarum*, Zea *mays*; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 1800m (CH18), Mix Riverine Forest; *Specimen studied:* 23.v.2010 (1 ex.), 25.vii.2012 (2 ex.).

***209. Marumba sperchius* (Ménétriés, 1857) (Plate 18.8)**

1857. *Smerinthus sperchius* Ménétriés, *Cat. lep. Petersb.*, 2: 137.

2000. *Marumba sperchius*, Kitching & Cadiou, *Hawkmoths of the World; An annotated and illustrated revisionary checklist (Lepidoptera: Sphingidae).*

2010. *Marumba sperchius albicans* Butler, Majumdar & Kumar, *Fauna of Uttarakhand,* 2: 553-568.

Distribution: India (North West Himalayas, Uttarakhand, Eastern Himalaya, Assam, Andamans), World (Sri Lanka, Japan, China, Java); *Size:* 86mm; *Host Plant: Bombax ceiba*, *Bridelia*, *Grewia paniculata*, *Helicteres isora*, *Hibiscus*, *Kydia calycina*, *Sterculia villosa*; *Abundance:* Rare; *Altitude & Habitat:* 2200m (CH22), Mohru Oak Forest; *Specimen studied:* 20.vii.2012 (3 ex.).

XVII C. Subfamily Sphinginae

***210. Psilogramma increta* (Walker, 1864) (Plate 18.9)**

1864. *Anceryx increta* Walker, *List Spec. Lepid. Insects Colln Br. Mus.* 31: 36.

1875. *Sphinx abietina* Boisduval, *Hist. nat. Ins., Spec. gén. Lépid. Hétérocères,* 1: 108.

2004. *Psilogramma increta*, Eitschberger, *Neue Ent. Nachr*., 57: 12.

2008. *Psilogramma increta* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himachal Pradesh, Uttarakhand, Maharashtra), World (China, Hong Kong); *Size:* 92mm; *Host Plant: Ligustrum*, *Sesamum*, *Tectona*; *Abundance:* Rare; *Altitude & Habitat:* 2400m (TK24), Western Mixed Coniferous forest; *Specimen studied:* 09.vi.2012 (2 ex.), 10.vi.2012 (1 ex.).

***211. Agrius convolvuli* (Linnaeus, 1758) (Plate 18.10)**

1758. *Sphinx convolvuli* Linnaeus, *Syst. Nat. (Edn 10)*, 1: 435.

1882. *Protoparce orientalis* Moore, *Lepid. Ceylon*, 2 (1): 5.

2000. *Agrius convolvuli*, Kitching & Cadiou, *Hawkmoths of the World: An annotated and illustrated revisionary checklist (Lepidoptera: Sphingidae).*

2008. *Agrius convolvuli* Linnaeus, Smetacek, *Bionotes:* 10(1):5-15.

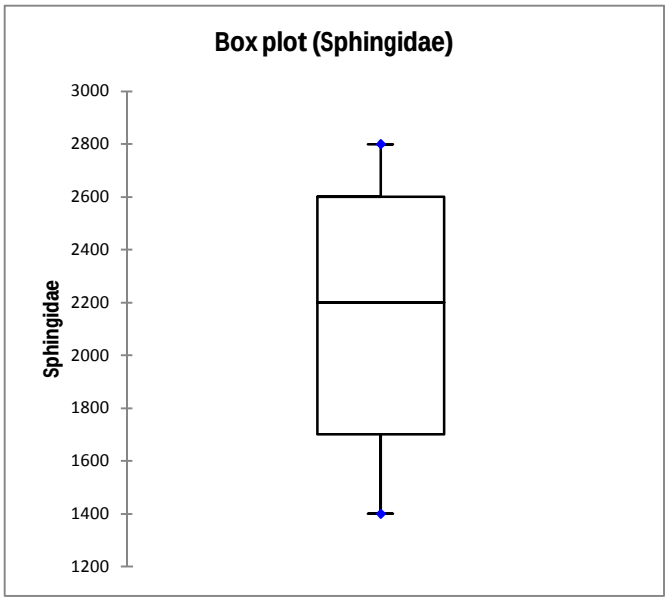
Distribution: India (Throughout including Uttarakhand, Maharashtra), World (Africa, South Asia, Australia); *Size:* 88mm; *Host Plant: Arachis hypogaea*, *Clitoria ternatea*, *Convolvulus*, *Glycine max*, *Helianthus*, *Helianthus tuberosus*, *Ipomoea batatas*; *Abundance:* Rare; *Altitude & Habitat:* 2200m (KK22), Mix Riverine Forest; *Specimen studied:* 02.v.2011 (3 ex.).

SUPERFAMILY NOCTUOIDEA

Noctuoidea is the superfamily of noctuid (Latin "night owl") or "owlet" moths, and has more than 70000 described species (Grimaldi & Engel 2013), the largest number of for any Lepidopteran superfamily. Its classification has not yet reached a satisfactory or stable state. Since the end of the 20th century, increasing availability of molecular phylogenetic data for this hugely successful radiation has led to several competing proposals for a taxonomic arrangement that correctly represents the relationships between the major lineages.

Briefly, the disputes center on the fact that in old treatments the distinctness of some groups, such as the Arctiidae or Lymantriidae, was overrated due to their characteristic appearance, while some less-studied lineages conventionally held to be Noctuidae are in fact quite distinct. This requires a rearrangement at least of the latter family (by simply including anything disputed within it). This is quite unwieldy, and various more refined treatments have been proposed in response to it. The presence of metathoracic tympanal organs is the chief apomorphic character that unites the families of Noctuoidea, although these organs are reduced or vestigial in some Doptidae and Ctenuchinae. There is usually a large counter-tympanal cavity at the base of the abdomen, with a projecting hood. The position of the hood in relation to the first abdominal spiracle is of special significance; it is prespiracular in Lymantriidae, Arctiidae but postspiracular in the Notodontidae and Noctuidae. Ocelli may be present or absent, but chaetostomata are never present.

Fig. 3.10: Altitudinal distribution of Family Sphingidae (n=38) recorded in GLA



XVII A. Subfamily Macroglossinae

***195. Acosmeryx anceus* (Stoll, 1781) (Plate 17.6)**

1781. *Sphinx anceus* Stoll, *In* Cramer: *Uitl. Kapellen*, 4(29-31): 124.

1875. *Acosmeryx daulis* Boisduval, *Spec. Gen. Lep. Het*., 1: 218.

1903. *Acosmeryx anceus*, Rothschild & Jordan, *In* Kitching & Cadiou, 2000: *Hawkmoths of the World: An annotated and illustrated revisionary checklist (Lepidoptera: Sphingidae)*: 528.

2008. *Acosmeryx anceus* Stoll, Smetacek, *Bionotes:* 10(1):5-15.

2010. *Acosmeryx anceus subdentata* Rothschild & Jordan, Majumdar & Kumar, *Fauna of Uttarakhand*, 2: 553-568.

Distribution: India (Uttarakhand, Himalayas, Sikkim, North East India, South India), World (Sri Lanka, Malaysia, Java, Borneo, Japan, New Guinea, Australia); *Size:* 84mm; *Host Plant: Dillenia pentagyna, Ipomoea batatas, Olea europaea*, *Vitis* sp.; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Pine Broadleaved Mix forest; *Specimen studied:* 21.v.2010 (1 ex.).

***196. Daphnis nerii* (Linnaeus, 1758) (Plate 17.7)**

1758. *Sphinx nerii* Linnaeus, *Syst. Nat. (Edn 10)*, 1: 490.

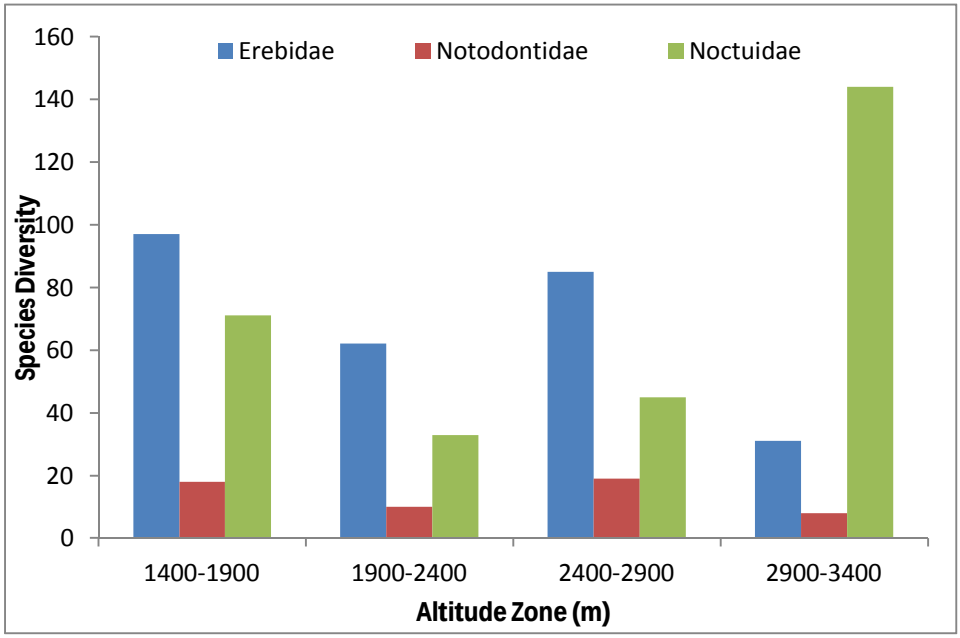
1882. *Daphnis nerii*, Moore, *Lepid. Ceylon*, 2(1): 14.

2013. *Daphnis nerii* Linnaeus, Gurule & Nikam, *J. Threat. Taxa.* 5(12): 4693–4713.

I recorded 6 families, according to older classification, under this superfamily from GLA, Arctiidae, Lymantriidae, Noctuidae, Notodontidae, Nolidae and Euteliidae. But as per with current classification scheme which recognizes subsequent changes in Noctuoidea according to Lafontaine & Schmidt (2010), five families are considered: Notodontidae, Erebidae (including Arctiidae and Lymantridae as subfamilies Arctiinae and Lymantriinae respectively), Euteliidae, Nolidae and Noctuidae.

The Arctiinae, the major saubfamily of Erebidae was most diverse in lower altitudinal zone. The Notodontidae was almost universally distributed in all the altitudinal zones. The Noctuidae, which is mainly composed of two major subfamilies, Hadeniinae and Noctuinae, was exceptionally diverse in highest altitudinal zone (Fig.3.11).

Fig. 3.11: Altitudinal distribution of three Noctuoid families, viz. Erebidae (n=242), Notodontidae (n=65) and Noctuidae (n=293) recorded in GLA



XVIII. Family Notodontidae Stephens, 1829

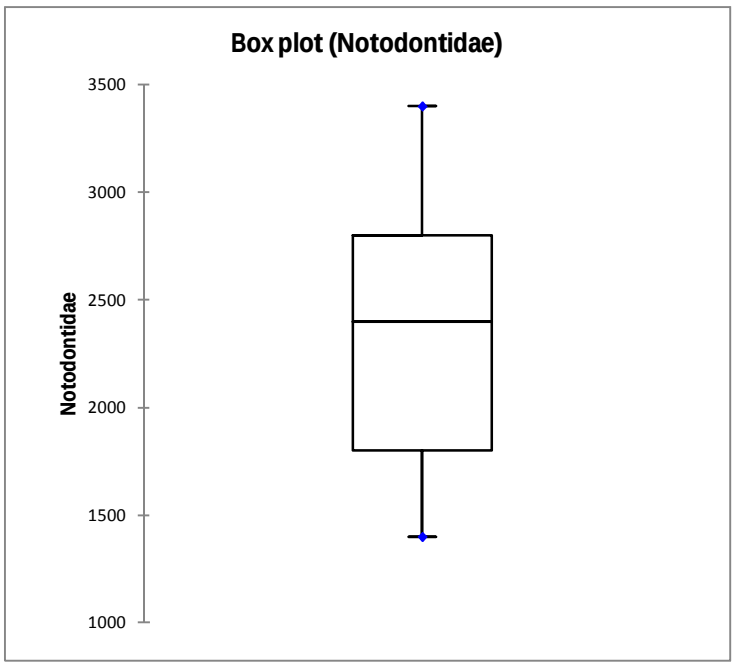
Family Notodontidae is very popular with amateur entomologists over past two centuries. The species are mostly moderate to large in size with cryptic wing patterns. The wing scaling is often coarse and the patterns are never very crisply defined; the body and legs are usually clothed densely with longer scales giving the whole insect a rather shaggy appearance. In collection, the specimens are prone to become greasy, indicating a high fat content in the adult moth. The larvae are often highly modified

into bizarre shapes, again primarily cryptic, but often with additional aggressive defenses such as protrusible lashes on modified anal clasp.

The adults are often with rather long, tapering forewings, which are normally held quite close to the body when at rest. The trailing edge of forewings of some species have prominent projections which are raised over the back when the moth is resting with its wings closed, hence the common name for the group is Prominent or Kitten moth. The adults are unable to feed and are seldom seen by day, but they especially comes to light at night. The wing markings are subtle and cryptic, with a preponderance of brown, grey and white, often in beautifully textured patterns, which help them blend with bark and dead leaves. This family contains about 2000 species referred to about 650 genera (Common 1990) and has a wide distribution in all regions of the world.

Mean species distribution of the family was around 2400m, while most of the species were abundant between 1800m and 2800m (Fig.3.12), however species range extends from 1400m to 3400m. Following species were identified from GLA:

Fig. 3.12: Altitudinal distribution of Family Notodontidae (n=65) recorded in GLA



***212. Allodonta sikkima* (Moore, 1879) (Plate 18.11)**

1879. *Pheosia sikkima* Moore, *Descr. Indian lep. Atkinson*, (1): 69.

1904. *Hyperaeschra collaris* Swinhoe, *Ann. Mag. Nat. Hist.*, 14(80): 132.

2008. *Allata sikkima*, Smetacek, *Bionotes* 10(1):5-55.

Distribution: India (Uttarakhand, Sikkim, Karnataka, Meghalaya, West Bengal), World (Borneo); *Size:* 39mm; *Host Plant: Castanea* from the family Fagaceae; *Abundance:* Rare, *Altitude & Habitat:* 2600m (TK26), 2800m (TK28), Western Mix coniferous forest, West Himalayan Upper Oak forest; *Specimen studied:* 12.vi.2012 (1 ex.), 14.vi.2012 (1 ex.).

***213. Cyphanta xanthochlora* Walker, 1865 (Plate 18.12)**

1865. *Cyphanta xanthochlora* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 33: 856.

1998. *Cyphanta xanthochlora* Walker, *In* Haruta: *Moths of Nepal,* 5: 72.

2001. *Cyphanta xanthochlora*, Schintkmeister & Lai, *Neue Entomologische Nachrichten*, 50: 32.

Distribution: India (Himalaya, Sikkim), World (China); *Size:* 56mm; *Host Plant:* Unknown; *Abundance:* Rare; *Altitude & Habitat:* 2800m (TK28), Kharsu Oak Forest; *Specimen studied:* 14.vi.2012 (1 ex.).

***214. Bireta longivitta* Walker, 1856 (Plate 19.1)**

1856. *Bireta longivitta* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 7: 1754.

1865. *Menapia xanthophila* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 32: 462.

2001. *Bireta longivitta*, Schintkmeister & Lai, *Neue Entomologische Nachrichten* : 50.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, Nagaland), World (Myanmar); *Size:* 54mm; *Host Plant:* From family Graminae, different species of bamboos like *Bambusa arundinacea* is recorded as host plant of the genus; *Abundance:* Uncommon; *Altitude & Habitat:* 1800m (CH18), 2600m (KK26), Mix Riverine forest, Western Mix Coniferous forest; *Specimen studied:* 26.v.2012 (3 ex.), 24.vii.2012 (2 ex.), 25.vii.2012 (5 ex.).

***215. Formofentonia orbifer* (Hampson, 1892) (Plate 19.2)**

1892. *Stauropus orbifer* Hampson, *Fauna of Br. India (Moths)*, 1: 152.

1925. *Formofentonia rotundata* Matsumura, *Zool. Mag. Tokyo*, 37: 396.

1983. *Formofentonia orbifer*, Holloway, *The Moths of Borneo*, 4: 63.

2008. *Formofentonia orbifer* Hampson, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand, North East Himalaya), World (Taiwan, Sundaland); *Size:* 36mm; *Host Plant: Fagus*, *Quercus*, *Terminalia*, *Castanea* are recorded as genus host plant; *Abundance:* Rare; *Altitude & Habitat:* 1800m (CH18), Mix Riverine forest; *Specimen studied:* 25.vii.2012 (1 ex.).

***216. Gazalina apsara* (Moore, 1859) (Plate 19.3)**

1859. *Dasychira apsara* Moore, In Horsfield & Moore, *Cat. Lep. Ins. Mus. Nat. East India House*, 2: 341.

1865. *Gazalina venosata* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 32: 398.

1875. *Oligoclona nervosa* Felder & Rogenhofer, *Reise Fregatte Novara, Bd.*, 2 (4): 95.

1922. *Gazalina apsara*, Swinhoe, *Ann. Mag. Nat. Hist*., 10(58): 472.

1998. *Gazalina apsara* Moore, *In* Haruta*: Moths of Nepal,* 5: 72.

Distribution: India (North West Himalayas, North India, Sikkim); *Size:* 46mm; *Host Plant: Quercus dilatata*, *Quercus lamellose*; *Abundance:* Abundant; *Altitude & Habitat:* 1400m (NT14), 1800m (CH18), 2200m (CH22), 2400m (CH24), 2600m (CH26), 2800m (T28), 3000m (CH30), 3200m (TK32); almost all kind of habitats recorded in the study area from Subtropical Chir Pine forest to Subalpine forest; *Specimen studied:*12.vi.2009 (3 ex.), 22.vi.2011 (2 ex.), 14.vi.2012 (1 ex.), 16.vi.2012 (4 ex.), 13.vii.2012 (1 ex.), 19.vii.2012 (1 ex.), 24.vii.2012 (3 ex.).

***217. Oligoclona chrysolopha* (Kollar, 1844) (Plate 19.4)**

1844. *Liparis chrysolopha* Kollar, *Hugel's Kaschmir*, 4: 470.

1967. *Ansonia chrysolopha*, Kitiakoff, *Gen. Ins.*, 212 B: 57.

1994. *Gazalina chrysolopha* Kollar, *In* Haruta*: Moths of Nepal,* 3: 163.

Distribution: India (North West Himalayas, Kashmir, Uttarakhand, Sikkim); *Size:*34mm; *Host Plant: Alnus nitida*, *Quercus incana*; *Abundance:* Abundant; *Altitude & Habitat:* 1400m (NT14), 1800m (CH18), 2200m (CH22), 2400m (CH24), 2600m (CH26), 3050m (CH30), Pine Forest, Riverine Forest, Mohru Oak forest, Mixed Coniferous forest, Birch-Fir forest; *Specimen studied:* 22.vi.2011 (3 ex.), 10.vii.2012 (7 ex.), 13.vii.2012 (2 ex.), 19.vii.2012 (1 ex.), 23.vii.2012 (2 ex.), 24.vii.2012 (1 ex.).

***218. Ginshachia gemmifera* (Moore, 1879) (Plate 19.5)**

1879. *Spatalia gemmifera* Moore, *Descr. Lep. Atkin.* : 62.

2001. *Ginshachia gemmifera*, Schintkmeister & Lai, *Neue Entomologische Nachrichten*, 50: 98.

2008. *Ginshachia gemmifera* Moore, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand, Sikkim), World (Java, Sumatra); *Size:* 64mm; *Host Plant: Quercus*, *Ulmus*, *Fagus* are recorded as genus host plant; *Abundance:* Rare; *Altitude & Habitat:* 2800m (TK28), Western Himalayan Upper Oak foresrt; *Specimen studied:* 14.vi.2012 (1 ex.).

***219. Homocentridia concentrica* (Oberthür, 1911) (Plate 19.6)**

1911. *Fentonia concentrica* Oberthür, *Étud. Lépid. Comp.*, 5(1): 336.

2001. *Homocentridia concentrica*, Schintkmeister & Lai, *Neue Entomologische Nachrichten* : 50.

Distribution: India (Uttarakhand-First time record from India), World (Europe); *Size:* 42mm; *Host Plant: Castanea*, *Fagus*, *Quercus* are recorded as genus host plant; *Abundance:* Rare; *Altitude & Habitat:* 1800m (CH18), Riverine forest; *Specimen studied:* 25.vii.2012 (2 ex.).

***220. Neodrymonia* sp. (Plate 19.7)**

Genus Distribution: South East Asia; *Size:* 41mm; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Chir Pine forest; *Specimen studied:* 11.vi.2012 (2 ex.).

***221. Phalera grotei* Moore, 1859 (Plate 19.8)**

1859. *Phalera grotei* Moore, *In* Horsfield & Moore: *Cat. Lep. Ins. Mus. Nat. East India House*, 2: 434.

1982. *Phalera grotei*, Holloway, *The Moths of Borneo*, 4: 36.

2013. *Phalera grotei* Moore, Gurule & Nikam, *J. Threat. Taxa.* 5(12): 4693–4713.

Distribution: India (Uttarakhand, Maharashtra), World (Sumatra, Borneo); *Size:* 78mm; *Host Plant: Quercus*, *Prunus*, *Betula*, *Corylus*, *Erythrina*; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved forest; *Specimen studied:* 02.viii.2010 (2 ex.), 22.vi.2011 (2 ex.).

***222. Phalera sangana* Moore, 1859 (19.9)**

1859. *Phalera sangana* Moore, *In* Horsfield & Moore: *Cat. Lep. Ins. Mus. Nat. East India House*, 2: 433.

1880. *Phalera stigmifera* Butler, *Ann. Mag. nat. Hist.*, 6(31): 66.

2001. *Phalera sangana*, Schintkmeister & Lai, *Neue Entomologische Nachrichten*, 50: 96.

Distribution: India (Sikkim, West Bengal), World (Bhutan, China), New record to Uttarakhand; *Size:* 82mm; *Host Plant: Erythrina suberosa*; *Abundance:* Rare; *Altitude & Habitat:* 1800m (CH18), Riverine forest; *Specimen studied:* 24.vii.2012 (5 ex.).

***223. Neopheosia fasciata* (Moore, 1888) (Plate 19.10)**

1888. *Pheosia fasciata* Moore, *Proc. zool. Soc. Lond.* : 401.

1920. *Neopheosia fasciata*, Matsumara, *Zool. Mag. Tokyo*, 32: 147.

1994. *Neopheosia fasciata* Moore, *In* Haruta*: Moths of Nepal*, 3: 168.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim), World (Sunda Island, Philippines); *Size:* 42mm; *Host Plant: Betula, Salix, Populus*; *Abundance:* 1400m (NT14), 1800m (NT18), Subtropical Chir Pine Forest, Riverine forest; *Specimen studied:* 28.iv.2010 (1 ex.), 25.vii.2012 (2 ex.).

***224. Ptilodon saturata* (Walker, 1865) (Plate 19.11)**

1865. *Lophopteryx saturata* Walker, *List. Lep. Het. Brit. Mus.*, 32: 415.

2001. *Ptilodon saturata*, Schintkmeister & Lai, *Neue Entomologische Nachrichten*, 50: 87.

Distribution: India (Sikkim), World (Java, Sumatra), New record to Uttarakhand; *Size:* 58mm; *Host Plant: Acer*, *Alnus*, *Betula*, *Malus*, *Fagus*, *Salix*, *Rosa*; *Abundance:* Abundant; *Altitude & Habitat:* 1800m (CH18), 2450m (CH24, TK24), 2600m (KK26, TK26), 2800m (TK28), 3050m (CH30), Riverine forest, Mix Coniferous forst; Kharsu Oak Forest, Birch-Fir Forest; *Specimen studied:* 26.v.2012 (2 ex.), 10.vi.2012 (6 ex.), 12.vi.2012 (3 ex.), 14.vi.2012 (4 ex.), 24.vi.2012 (3 ex.), 10.vii.2012 (1 ex.), 13.vii.2012 (9 ex.), 25.vii.2012 (1 ex.).

***225. Semidonta biloba* Oberthür, 1880 (Plate 19.12)**

1880. *Drymonia biloba* Oberthür, *Étud. d'Ent.*, 5: 63.

2001. *Semidonta biloba*, Schintkmeister & Lai, *Neue Entomologische Nachrichten* : 50.

Distribution: India (Uttarakhand-First time record from India)World (Japan); *Size:* 42mm; *Host Plant: Acer*, *Aesculus turbinate* are recorded as host plant from Japan; *Abundance:* Rare; *Altitude & Habitat:* 2450m (CH24), Western Mixed Coniferous forest; *Specimen studied:* 10.vii.2012 (9 ex.).

***226. Rachia plumosa* Moore, 1879 (Plate 20.1)**

1879. *Rachia plumosa* Moore, *Descr. Indian Lep. Atkinson*, (1): 70.

2001. *Rachia plumosa*, Schintkmeister & Lai, *Neue Entomologische Nachrichten* : 50.

Distribution: India (Sikkim,West Bengal, North East India), World (Nepal, Tibet, China), New record to Uttarakhand; *Size:* 74mm; *Abundance:* Abundant; *Altitude & Habitat:* 2400m (TK24), 2600m (TK26), 2800m (TK28), 3000m (CH30), 3200m (CH32), 3400m (CH34), Mixed Coniferous Forest, Kharsu Oak forest, Birch-Fir forest, Decduous Alpine Scub; *Specimen studied:* 09.vi.2012 (4 ex.), 11.vi.2012 (2 ex.), 14.vii.2012 (5 ex.), 16.vii.2012 (1 ex.), 13.vii.2012 (7 ex.), 15.vii.2012 (2 ex.), 16.vii.2012.

***227. Damata longipennis* Walker, 1855 (Plate 20.2)**

1855. *Damata longipennis* Walker, *List. Lep. Het. Brit. Mus.*, 5: 1044.

1950. *Damata japona* Bryk, Ark. Zool., 42A. 19: 30.

2008. *Damata longipennis* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand, Sikkim), World (Nepal, Thailand); *Size:* 62mm; *Abundance:* Rare; *Altitude & Habitat:* 2800m (TK28), Western Himlayan Upper Oak Forest; *Specimen studied:* 14.vi.2012 (5 ex).

***228. Tarsolepis remicauda* Butler, 1872 (Plate 20.3)**

1872. *Tarsolepis remicauda* Butler, *Ann. Mag. nat. Hist.*, 10(56): 125.

1976. *Tarsolepis remicauda*, Nakamura, *Tyô to Ga.*, 27(1): 35.

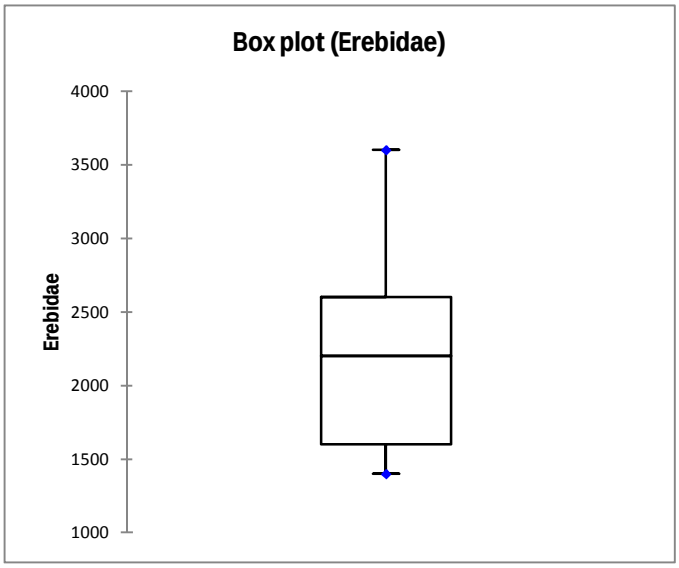
Distribution: India (Sikkim), World (Borneo, Java, Vietnam), New record to Uttarakhand; *Size:* 76mm; *Host Plant: Nephelium lappaceum* from family Sapindaceae is recroded as host plant from Thailand; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Subtropical Chir Pine forest; *Specimen studied:* 11.xi.2011 (1 ex.).

XIX. Family Erebidae Leach, 1815

This is the third largest family recorded in Gangotri Landscape Area comprising subfamilies Lymantriinae, Arctiinae, Catocaliinae and Calpinae.

Mean species distribution of the family is around 2200m, while most of the species and individuals were abundant between 1600m and 2600m (Fig.3.13), however species range extends from 1400m to 3600m.

Fig. 3.13: Altitudinal distribution of family Erebidae (n=242) recorded in GLA



XIX A. Subfamily Lymantriinae

This subfamily contains about 2,700 species distributed throughout the world (Zahiri *et al.* 2011), but reaches its greatest development in the old world tropics. These are furry, medium-sized or fairly large-bodied moths. They are collectively called tussoks on account of the characteristic tufts of hairs on the back of the larvae, which are incorporated into their silken cocoon, formed above ground. In the adults, the proboscis is usually absent, the thorax and abdomen are clothed in long piliform scales, and the females have dense bunch of specialized scales used to cover the egg masses.

From India 175 species has been recorded so far. I recorded following species from the study area:

229. Arctornis comma (Hutton, 1865) (Plate 20.4)

1865. *Ocinara comma* Hutton, *Trans. Ent. Soc. Lond.*, 2(3): 330.

1922. *Leucoma comma* Swinhoe, *Ann. Mag. Nat. Hist*., 10(58): 463.

1934. *Leucoma comma*, Collenette, *Novit. Zool*., 39: 138.

Distribution: India (Uttarakhand, Nilgiri Hills), World (Myanmar); *Size:* 40mm; *Host Plant: Camellia sinensis* is recorded as host plant from Taiwan; *Abundance:* Rare; *Altitude & Habitat:* 1800m (CH18), Riverine forest; *Specimen studied:* 25.vii.2012 (5 ex.).

***230. Somena scintillans* Walker, 1856 (Plate 20.5)**

1856. *Somena scintillans* Walker, *List Spec. Lepid. Insects Colln Br. Mus*., 7: 1734.

1923. *Nygmia scintillans*, Swinhoe, 1923, *Ann. Mag. Nat. Hist*., 11(61): 49.

1999. *Somena scintillans*, Holloway, *The Moths of Borneo*, 5: 51.

Distribution: India (North India, Andamans), World (Sri Lanka, Myanmar); *Size:* 26mm; *Host Plant:* Polyphagous, *Acacia nilotica*, *Aesculus indica*, *Bidens sulphurea*, *Buchanania latifolia*, *Cajanus cajan*; *Abundance:* Abundant; *Altitude & Habitat:* 1400m (NT14), 2450m (CH24), 2600m (CH26), Subtropical Chir Pine Forest, Western Mixed Coniferous forest; *Specimen studied:* 29.v.2009 (2 ex.), 31.v.2009 (1 ex.), 03.v.2010 (2 ex.), 15.v.2010 (2 ex.), 10.vii.2012 (5 ex.), 19.vii.2012 (4 ex.).

***231. Artaxa vitellina* (Kollar, 1848) (Plate 20.6)**

1848. *Liparis vitellina* Kollar, *Hugel's Kaschmir*, 4: 471.

1865. *Artaxa princeps* Walker, *List. Lep. Ins. Brit. Mus*., 32: 331.

1922. *Nygmia vitellina*, Swinhoe, *Ann. Mag. Nat. Est.* 10(58):483.

Distribution: India (North West Himalaya, Uttarakhand, North India); *Size:* 38mm; *Host Plant: Anogeissus acuminate*, *Jasminum*, *Lantana camara*, *Mallotus philippensis*, *Ricinus communis*, *Shorea robusta*, *Terminalia myriocarpa*, *Ziziphus mauritiana*; *Abundance:* Abundant; *Altitude & Habitat:* 1400m (NT14), 1800m (CH18), 2200m (CH22), 2400m (CH24), 2600m (KK26, TK26), 2800m (TK28), Subtropical Pine Broadleaved mix Forest, Riverine forest, Mohru Oak Forest, Mixed Coniferous forest, Upper Oak forest; *Specimen studied:* 30.v.2009 (1 ex.), 03.vi.2009 (3 ex.), 30.vi.2009 (2 ex.), 26.v.2012 (7 ex.), 15.vi.2012 (1 ex.), 10.vii.2012 (2 ex.), 23.vii.2012 (9 ex.), 25.vii.2012 (2 ex.).

***232. Laelia exclamationis* (Kollar, 1848) (Plate 20.7)**

1848. *Euprepia exclamationis* Kollar, *In* Hügel, *Kaschmir und das Reich der Siek*, 4: 469.

1855. *Repena cervina* Walker, *List Spec. Lepid. Insects Colln Br. Mus*., 4: 800.

1883. *Laelia rotunda* Moore, *Lepid. Ceylon*, 2(2): 110.

1923. *Laelia exclamationis*, Swinhoe, *Ann. Mag. Nat. Hist*., 11(61): 94.

2008. *Laelia exclamationis* Kollar, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalaya, Uttarakhand, Sikkim), World (Sri Lanka); *Size:* 36mm; *Host Plant:* Species of families Graminae and Cannaceae like *Canna, Cynodon dactylon, Panicum maximum*; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), 2400m (CH24), Subtropical Pine Broadleaved Mix Forest, Moist Temperate Deciduous forest, Mixed Coniferous forest; *Specimen studied:* 03.v.2010 (1 ex.), 23.v.2010 (2 ex.), 09.vi.2011 (4 ex.), 10.vii.2012 (3 ex.).

***233. Dasychira cerebosa* (Swinhoe, 1903) (Plate 20.8)**

1903. *Lymantra cerebrosa* Swinhoe, *Trans. Ent. Soc. Lond.* (3): 483.

1923. *Orgyia cerebosa*, Swinhoe, *Ann. Mag. Nat. Hist.* 11(63): 304'

1933. *Dasychira cerebosa*, Collenette, *Novit. Zool.* 39: 32.

Distribution: India (Himachal Pradesh, Sikkim), New record to Uttarakhand; *Size:* 56mm; *Host Plant:* Polyphagous, recorded plants belong to *Lantana, Quercus, Ulmus, Prunus, Smilax, Juglans* etc.; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 2600m (KK26), Subtropical Broadleaved forest, Mixed Coniferous forest; *Specimen studied:* 20.v.2009 (2 ex.), 30.v.2009 (1 ex.), 21.v.2010 (3 ex.), 09.v.2011 (1 ex.), 25.v.2012 (2 ex.).

***234. Lymantria concolor* Walker, 1855 (Plate 20.9)**

1855. *Lymantria concolor* Walker, *List Spec. Lepid. Insects Colln Br. Mus*., 4: 876.

1888. *Lymantria carnecolor* Moore, *Proc. zool. Soc. Lond.* : 399.

1923. *Liparis concolor*, Swinhoe, Ann. Mag. Nat. Hist. 11(64): 428.

2008. *Lymantria concolor superans* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India(North West Himalayas, Himachal Pradesh, Uttarakhand, Sikkim, Nagaland), World (Bangladesh, China, Myanmar); *Size:* 46mm; *Host Plant:* Polyphagous, *Malus pumila, Quercus incana, Quercus serrata* are recorded from

India; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 2200m (KK22), Subtropical Pine Broadleaved Mix forest, Moist Temperate Deciduous forest; *Specimen studied:* 29.v.2009 (2 ex.), 30.v.2009 (7 ex.), 18.v.2011 (1 ex.).

***235. Lymantria mathura* Moore, 1865 (Plate 20.10)**

1865. *Lymantria mathura* Moore, *Proc. zool. Soc. Lond.*, (3): 805.

1879. *Lymantria umbrina* Moore, *Descr. Indian lep. Atkinson*, (1): 55.

1934. *Lymantria mathura*, Collenette, Novit. Zool. 39: 149.

2008. *Lymantria mathura* Moore, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalayas, Uttarakhand, Sikkim, West Bengal), World (China, Nepal, Japan); *Size:* 56mm; *Host Plant:* Polyphagous including *Breonia cadamba*, *Lagerstroemia parviflora*, *Mangifera indica*, *Planchonia careya*, *Quercus incana*, *Quercus serrata*, *Shorea robusta*, *Terminalia arjuna*, *Terminalia bellirica* ; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Chir Pine forest; *Specimen studied:* 12.vi.2009 (1 ex.).

***236. Himala argentea* (Walker, 1855) (Plate 20.11)**

1855. *Redoa argentea* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 4: 827.

1859. *Dasychira ilita* Moore, *In* Horsfield & Moore: *Cat. Lep. Ins. Mus. Nat. East India House*, 2 : 341.

1922. *Himala argentea*, Swinhoe, *Ann. Mag. Nat. Hist.* (9) 10 (58): 471.

2008. *Himala argentea* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalaya, Uttarakhand, Sikkim, Assam, West Bengal); *Size:* 42mm; *Host Plant: Albizia* of family Leguminoseae; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 1800m (NT18, CH18), 2000m (TK22), Subtropical Pine Broadleaved Mix Forest, Riverine forest, Moist Temperate Deciduous forest; *Specimen studied:* 21.v.2010 (1 ex.), 18.v.2011 (1 ex.), 09.vi.2011 (1 ex.), 24.vii.2012 (3 ex.).

***237. Leucoma clara* (Walker 1865) (Plate 20.12)**

1865. *Redoa clara*, Walker *Cat. Lep*., 32: 343

1892. *Caviria clara*, Hampson, *Fauna of Brit. India*, 1: 490.

2005. *Leucoma clara*, Kendrik, *Fauna Conserv. Dept. Project Report*, 39.

Distribution: India (Sikkim), World (Taiwan, Hong Kong), New record to Uttarakhand; *Size:* 36mm; *Host Plant: Alseodaphnae*, *Salix*, *Macaranga*, *Litsea*, *Mallotus* are recorded as genus host; *Abundance:* Rare; *Altitude & Habitat:* 2400m (JK24), Western Mixed Coniferous forest; *Specimen studied:* 22.vi.2010 (1 ex.).

XIX B. Subfamily Arctiinae

This is a huge subfamily with a world fauna of some 11,000 species referred to about 900 genera (Braga *et al.* 2014). It is represented in all regions, but is most numerous in the tropics. The Arctiinae are defined principally by the presence of a tymbal organ on the metepisternum and aprespiracular counter-tympanal hood. Another potential Arctiid apomorphy is the presence of a pair of glands, possibly pheromonal, dorsally and anteriorly between the ovipositor lobes. These are frequently branched, usually in a regular dichotomous manner. Members of this family are frequently brightly coloured and many are presumed to be poisonous or distasteful to predators. Arctiids also have hearing organs on the thorax and sound-producing organs on the sides of the thorax. Following species were recorded from GLA:

***238. Amsacta lactinea* (Cramer, 1777) (Plate 21.1)**

1777. *Phalaena lactinea* Cramer, *Uitl. Kapellen*, 2 (9-16): 58, 149.

1793. *Bombyx sanguinolenta* Fabricius, *Ent. Syst*., 3(1): 473.

1883. *Aloa marginata* Moore, *Proc. zool. Soc. Lond.* : 15.

1901. *Amsacta lactinea*, Hampson, *Cat. Lepid. Phalaenae Br. Mus*., 3: 328.

2014. *Amsacta lactinea,* Meena *et al.*, *Bioscan* 9(4): 1375-1381.

Distribution: India (Uttarakhand), World (Japan, China, Taiwan, Java, Sumatra, Sri Lanka, Myanmar); *Size:* 54mm; *Host Plant:* Polyphagous, some of the host species recorded are *Abutilon, Clerodendrum infortunatum*, *Cochlospermum religiosum*, *Crotalaria juncea*, *Eleusine coracana*, *Ipomoea batatas*, *Macrotyloma uniflorum*, *Pennisetum americanum*; *Abundance:* Uncommon; *Altitude & Habitat:* 3200m (TK32), Himalayan Temperate Parkland; *Specimen studied:* 17.vi.2012 (8 ex.).

***239. Areas galactina* (Hoever, 1840) (Plate 21.2)**

1840. *Chelonia galactina* Hoever, *Tijdschr. nat. Gesch.* 7 : 280.

1901. *Pericallia galactina*, Hampson, *Cat. Lepid. Phalaenae Br. Mus.* 3 : 356.

1988. *Areas galactina*, Holloway, *The Moths of Borneo*, 6: 50.

2003. *Areas galactina* Hoever, Kirti & Sodhi, *Zoos' Print Journal*, 18 (7):1143-1146.

2008. *Areas galactina* Hoever, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalayas, Uttarakhand, Sikkim, Meghalaya, Nagaland), World (China, Nepal, Bhutan, Bangladesh, Borneo, Java, Phillipines, Indonesia); *Size:* 69mm; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 22.vi.2011 (4 ex.), 26.vi.2011 (2 ex.).

***240. Areas imperialis* (Kollar, 1844) (Plate 21.3)**

1844. *Euprepia imperialis* Kollar, *In* Hügel: *Kaschmir und das Reich der Siek.*, 4: 466.

1901. *Pericallia imperialis*, Hampson, *Cat. Lepid. Phalaenae Br. Mus.*, 3: 356.

2003. *Areas imperialis* Kollar, Kirti & Sodhi, *Zoos' Print Journal*, 18 (7):1143-1146.

2008. *Areas imperialis* Kollar, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalayas, Uttarakhand, Sikkim), World (Tibet, Nepal); *Size:* 75mm; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 24.vi.2011 (1 ex.).

***241. Argina astrea* (Drury, 1773) (Plate 21.4)**

1773. *Phalaena astrea* Drury, *Illust. Nat. Hist. Exot. Insects*, 2: 11.

1764. *Phalaena cribraria* Clerck, *Icon. Ins. Rariorum*, 54.

1775. *Bombyx pylotis* Fabricius, *Syst. Ent.* : 585.

1988. *Argina astrea*, Holloway, *The Moths of Borneo*, 6: 54.

2003. *Argina astrea* Drury, Kirti & Sodhi, *Zoos' Print Journal*, 18 (7):1143-1146.

2008. *Argina astrea* Drury, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Throughout including Uttarakhand, Sikkim), World (China, Taiwan, Madagascar, Ghana, New Guinea, Japan, Indonesia, Sri Lanka, Bangladesh, Nepal); *Size:* 36mm; *Host Plant: Crotalaria*, *Melilotus*, *Theobroma*; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Subtropical Pine Broadleaved Mix Forest; *Specimen studied:* 09.vi.2009 (4 ex.), 26.vi.2011 (2 ex.).

***242. Asura calamaria* (Moore, 1888) (Plate 21.5)**

1888. *Setina calamaria* Moore, *Proc. zool. Soc. Lond.* : 392.

1890. *Setina punctata* Elwes, *Proc. Zool. Soc. Lond.* : 389.

1900. *Asura calamaria*, Hampson, *Cat. Lep. Phalaenae Br. Mus.*, 2: 462.

2008. *Asura calamaria* Moore, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand, Sikkim, Punjab, Nagaland, North East Himalaya, Nilgiri Hills), World (Java, Sundaland); *Size:* 24mm; *Host Plant: Acacia, Bougainvillea, Oryza*; *Abundance:* Common; *Altitude & Habitat:* 1800m (CH18), 2400m (CH24), Riverine forest, Western Mixed Coniferous forest; *Specimen studied:* 10.vii.2012 (11 ex.), 24.vii.2012 (3 ex.), 25.vii.2012 (4 ex.).

***243. Chrysorabdia bivitta* (Walker, 1856) (Plate 21.6)**

1856. *Lithosia bivitta* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 7: 1682.

1866. *Lithosia disjuncta* Moore, *Proc. Zool. Soc. Lond*., (3): 797.

1900. *Chrysorabdia bivitta*, Hampson, *Cat. Lep. Phalaenae Br. Mus.*, 2: 183.

2010. *Chrysorabdia bivitta* Walker, Majumdar, *Fauna of Uttarakhand,* 2: 501-529.

Distribution: India (North West Himalayas, Uttarakhand, Himachal Pradesh, Sikkim, Assam, Manipur, Meghalaya), World (Myanmar); *Size:* 52mm; *Host Plant:* Lichenes; *Abundance:* Rare, *Altitude & Habitat:* 1400m (NT14), 1800 (CH18), Subtropical Broadleaved Forest, Riverine forest; *Specimen studied:* 29.v.2009 (1 ex.), 24.vii.2012 (5 ex.).

***244. Chrysorabdia viridata* (Walker, 1894) (Plate 21.7)**

1894. *Lithosia viridata* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 31: 225.

1872. *Gnophria strigata* Möschler, *Stettin Ent. Ztg.*, 33(7-9): 353.

1900. *Chrysorabdia viridata*, Hampson, *Cat. Lep. Phalaenae Br. Mus.*, 2: 183.

2010. *Chrysorabdia viridata* Walker, Majumdar, *Fauna of Uttarakhand,* 2: 501-529.

Distribution: India (Himachal Pradesh, Uttarakhand, West Bengal, Sikkim, Assam, Meghalaya, Arunachal Pradesh), World (Bangladesh, Bhutan, China); *Size:* 35mm; *Host Plant:* Lichenes; *Abundance:* Uncommon; *Altitude & Habitat:* 2600m (TK26), 2800m (TK28), 3200m (TK32), Western Mix Coniferous Forest, Upper Himalayan

Oak forest, Himalayan Temperate parkland; *Specimen studied:* 12.vi.2012 (5 ex.), 14.vi.2012 (3 ex.), 16.vi.2012 (1 ex.).

***245. Creatonotos gangis* (Linnaeus, 1763) (Plate 21.8)**

1763. *Phalaena gangis* Linnaeus, *Amoenitates Acad*., 6: 410.

1767. *Phalaena interrupta* Linnaeus, *Syst. Nat. (Edn 12)*, 1(2): 840.

1901. *Creatonotus gangis*, Hampson, *Cat. Lepid. Phalaenae Br. Mus*., 3: 333.

1995. *Creatonotos gangis*, Goodger & Watson, *The Afrotropical Tiger-Moths* : 99-100.

2013. *Creatonotos gangis* Linnaeus, Gurule & Nikam, *J. Threat. Taxa*. 5(12): 4693–4713.

Distribution: India (Throughout including Uttarakhand, West Bengal, Maharashtra), World (China, Taiwan, Nepal, Bhutan, Pakistan, Sri Lanka, Java, Sumatra, Philippines, Queensland); *Size:* 56mm; *Host Plant: Bambusa*, *Brassica*, *Coffea*, *Eleusine coracana*, *Ipomoea batatas*, *Medicago sativa*, *Mimulus gracilis*, *Oryza sativa*; *Abundance:* Uncommon; *Altitude & Habitat:* 1800m (CH18), Riverine Forest; *Specimen studied:* 24.vii.2012 (7 ex.).

***246. Creatonotos transiens* (Walker, 1855) (Plate 21.9)**

1855. *Spilosoma transiens* Walker, *List Spec. Lepid. Insects Colln Br. Mus*., 3: 675.

1901. *Creatonotus transiens*, Hampson, *Cat. Lepid. Phalaenae Br. Mus*., 3: 334.

1988. *Creatonotos transiens*, Holloway, *The Moths of Borneo*, 6: 52.

2003. *Creatonotos transiens* Walker, Kirti & Sodhi, *Zoos' Print Journal*, 18 (7):1143-1146.

2013. *Creatonotos transiens* Walker, Gurule & Nikam, *J. Threat. Taxa*. 5(12): 4693–4713.

Distribution: India (Throughout), World (China, Tibet, Hong Kong, Afghanistan, Bangladesh, Myanmar, Borneo, Sulawesi, Lombok, Philippines); *Size*: 54mm; *Host Plant: Cedrela toona*, *Ehretia laevis*, *Ficus religiosa*, *Lantana camara*, *Toona ciliata*, *Zea mays*; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 8.xi.2010 (3 ex.), 08.v.2011 (2 ex.), 22.vi.2011 (7 ex.), 26.vi.2011 (2 ex.).

***247. Agylla beema* (Moore 1865) (Plate 21.10)**

1865. *Lithosia beema* Moore, *Proc. zool. Soc. Lond*., (3): 798.

1900. *Agylla beema*, Hampson, *Cat. Lep. Phalaenae Br. Mus*., 2: 197.

2003. *Agylla beema* Moore, Majumdar, *Fauna of Sikkim*, 4: 175-216.

Distribution: India (Sikkim), New record to Uttarakhand; *Size:* 55mm; *Host Plant:* Unknown; *Abundance:* Abundant; *Altitude & Habitat:* 1800m (CH18), 2000m (KK20), 2400m (CH24, TK24), 2600m (KK26, TK26), 2800m (TK28), Riverine Forest, Moist Temperate Deciduous forest, Mix Coniferous forest, Upper Oak forest; *Specimen studied:* 09.vi.2011 (4 ex.), 26.vi.2012 (3 ex.), 09.vi.2012 (2 ex.), 12.vi.2012 (8 ex.), 15.vi.2012 (2 ex.), 10.vii.2012 (4 ex.), 24.vii.2012 (5 ex.).

***248. Agylla prasena* (Moore, 1859) (Plate 21.11)**

1859. *Tripura prasena* Moore, *In* Horsfield & Moore: *Cat. Lep. Ins. Mus. Nat. East India House*, 2: 299.

1900. *Agylla prasena*, Hampson, *Cat. Lep. Phalaenae Br. Mus*., 2: 210.

2003. *Agylla prasena* Moore, Majumdar, *Fauna of Sikkim*, 4: 175-216.

Distribution: India (North West Himalaya, Himachal Pradesh, Sikkim, Assam, Nagaland); *Size:* 56mm; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 03.vi.2009 (3 ex.), 09.vi.2009 (1 ex.), 22.vi.2009 (2 ex.).

***249. Eilema caniola* (Hübner, 1827) (Plate 21.12)**

1827. *Bombyx caniola* Hübner, *Europ. Schmett*., 2: 220.

1834. *Lithosia lacteola* Boisduval, *Icon. hist. Lépid. Europ*., 2: 100.

1900. *Ilema caniola*, Hampson, *Cat. Lep. Phalaenae Br. Mus*., 2: 169.

1993. *Eilema caniola*, Dubatolov, *Tshistjakov, Viidalepp, A list of the Lithosiinae of the territory of the former USSR (Lepidoptera, Arctiidae); Atalanta (Wurzburg)* : 165-175.

Distribution: India (Uttarakhand-First time record from India), World (Nepal, Africa, Asia); *Size:* 39mm; *Host Plant:* Lichenes; *Abundance:* Rare; *Altitude & Habitat:* 2400m (KK24), Mixed Coniferous Forest; *Specimen studied:* 22.vi.2011 (2 ex.).

***250. Eilema antica* (Walker, 1854) (Plate 22.1)**

1854. *Lithosia antica* Walker, *List Lep*., 2: 505.

1859. *Lithosia natava* Moore, *Cat. Lep. E. Ind. Co.*: 304.

1877. *Lithosia sarawaka* Butler, *Trans. Ent. Soc. London* : 350.

2011. *Eilema antica,* Gurule *et al*., *Proceedings International Conference on Biodiversity and its Conservation:* 9.

Distribution: India (Uttarakhand, Sikkim, Meghalaya, Maharashtra, Nicobars), World (Sri Lanka, Borneo, Java); *Size:* 26mm; *Host Plant:* Lichenes; *Abundance:* Common; *Altitude & Habitat:*1800m (NT18), 2400m (CH24), 3000m (CH30) Subtropical Broadleaved forest, Riverine forest, Western Mixed Coniferous forest, Western Himalayan Birch-Fir Forest; *Specimen studied:*12.vi.2009 (6 ex.), 10.vii.2012 (4 ex.), 13.vii.2012 (11 ex.).

***251. Estigmene quadriramosa* (Kollar, 1844) (Plate 22.2)**

1844. *Euprepia quadriramosa* Kollar, *In* Hügel: *Kaschmir und das Reich der Siek*, 4: 468.

1901. *Estigmene quadriramosa,* Hampson, *Cat. Lepid. Phalaenae Br. Mus*., 3: 342.

1910. *Estigmene quadriramosa,* Rothschild, *Novit. Zool*. 17(2):165.

Distribution: India (North West Himalayas, Kashmir, Uttarakhand, Meghalaya, Nagaland), World (Tibet, Nepal); *Size:* 40mm; *Host Plant:* Polyphagous, *Prunus*, *Rumex*, *Malus*; *Abundance:* Common; *Altitude & Habitat:* 1600m (NT16), 1800m (CH18), 2400m (JK24), Subtropical Broadleaved Forest, Riverine Forest, Western Mixed Coniferous Forest; *Specimen studied:* 18.v.2011 (4 ex.), 22.vi.2011 (2 ex.), 25.vii.2012 (6 ex.).

***252. Utetheisa lotrix* (Cramer, 1779) (Plate 22.3)**

1779. *Geometra lotrix* Cramer, *Uitl. Kapellen*, 2(9-16): 109.

1914. *Utetheisa rubra* Rothschild, *In* Seitz: *Gross-Schmett. Erde*., 10: 260.

1939. *Utetheisa lotrix*, Jordan, *Novit. Zool*., 41(3): 287.

2013. *Utetheisa lotrix* Cramer, Gurule & Nikam, *J. Threat. Taxa.* 5(12): 4693–4713.

Distribution: India (Throughout), World (Sri Lanka, Phillipines, Australia, Europe, Africa); *Size:* 42mm; *Host Plant: Crotalaria*, *Dahlia*, *Heliotropium*, *Oryza sativa*; *Abundance:* Uncommon; *Altitude & Habitat:* 1600m (NT16), 2400m (TK24), Subtropical Broadleaved Forest, Mixed Coniferous Forest; *Specimen studied:* 22.vi.2010 (1 ex.), 02.vi.2011 (1 ex.).

***253. Macrobrochis pallens* (Hampson, 1894) (Plate 22.4)**

1894. *Macrobrochis pallens* Hampson, *Fauna of Br. India,* 2: 66.

1900. *Agylla pallens*, Hampson, *Cat. Lep. Phalaenae Br. Mus.*, 2: 210.

2008. *Macrobrochis pallens* Hampson, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalayas, Himachal Pradesh, Uttarakhand); *Size:* 54mm; *Host Plant:* Unknown; *Abundance:* Common; *Altitude & Hanbitat:* 1400m (NT14), 1800m (CH18), 2400m (CH24), 2600m (TK26), Subtropical Broadleaved Forest, Riverine Forest, Mixed Coniferous forest; *Specimen studied:*29.v.2009 (5 ex.), 12.vi.2012 (4 ex.), 10.vii.2012 (2 ex.), 24.vii.2012 (2 ex.).

***254. Miltochrista cuneonotata* (Walker, 1855) (Plate 22.5)**

1855. *Ammatho cuneonotata* Walker, *List Lep. Brit. Mus.*, 3: 759.

1888. *Miltochrista collivolans* Butler, *Ann. Mag. Nat. Hist*., 8: 380.

2003. *Miltochrista cuneonotata* Walker, Majumdar, *Fauna of Sikkim*, 4: 175-216.

Distribution: India (Sikkim, Assam, Nagaland, Arunachal Pradesh), World (Sri Lanka, Sumatra, Borneo), New record to Uttarakhand; *Size:* 38mm; *Host Plant: Syzygium*, *Citrus*; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Broadleaved Forest; *Specimen studied:* 30.v.2009 (1 ex.), 30.x.2011 (1 ex.).

***255. Panaxia principalis* (Kollar, 1844) (Plate 22.6)**

1844. *Euprepia principalis* Kollar, *In* Hugel's: *Kaschmir*. 4(2): 465.

1975. *Panaxia principalis*, Dierl, *Ent. Germanica*, 2(2): 181-188.

2010. *Callimorpha principalis*, Majumdar, *Fauna of Uttarakhand*, 2: 501-529.

Distribution: India (North West Himalayas, Kashmir, Uttarakhand, Sikkim), World (Myanmar); *Size:* 78mm; *Host Plant:* Polyphagous, *Plantago* of family Plantaginaceae is recorded as host plant from India; *Abundance:* Uncommon; *Altitude & Habitat:* 1800m (CH18), 2200m (CH22), 3050m (CH30), Riverine Forest, Mohru Oak forest and West Himalayn Birch-Fir forest; *Specimen studied:* 13.vii.2012 (1 ex.), 23.vii.2012 (1 ex.), 24.vii.2012 (2 ex.).

***256. Panaxia similis* (F. Moore, 1879) (Plate 22.7)**

1879. *Hypercompa similis* F. Moore, *Proc. Zool. Soc. London* : 397.

2013. *Panaxia similis*, Uniyal *et al., An Assessment of Entomofauna for management & Conservation of Biodiversity in Gangotri Landscape, Wildlife Institute of India, Final Project Report:* 226.

Distribution: India (Himachal Pradesh, Sikkim), New record to Uttarakhand; *Size:* 50mm; *Abundance:* Abundant; *Altitude & Habitat:* 1400m (NT14),1800m (CH18),2400m (CH24,KK24,TK24), 2600m (TK26), 2800m (TK28),Subtropical Pine Broadleaved Mixed Forest, Riverine Forst, Western Mixed Coniferous Forest, Western Himalayan Upper Oak Forest; *Specimen studied:* 30.v.2009 (5 ex.), 22.vi.2011 (1 ex.), 11.vi.2012 (7 ex.), 12.vi.2012 (5 ex.), 14.vi.2012 (1 ex.), 10.vii.2012 (2 ex.), 25.vii.2012 (2 ex.).

***257. Sidyma albifinis* Walker 1856 (Plate 22.8)**

1856. *Sidyma albifinis* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 7: 1686.

1900. *Agylla albifinis*, Hampson, *Cat. Lep. Phalaenae Br. Mus.*, 2: 193.

2008. *Sidyma albifinis* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalaya); *Size:* 42mm; *Host Plant:* Unknown; *Abundance:* Common; *Altitude & Habitat:*2200m (CH22), 2400m (CH24), 3050m (CH30), 3200m (TK32), 3400m (CH34), Mohru Oak Forest, Western Mixed Coniferous Forest, Birch-Fir Forest, Himalayan Temperate parkland, Deciduous Alpine Scrub; *Specimen studied:* 16.vi.2012 (2 ex.), 10.vii.2012 (2 ex.), 13.vii.2012 (6 ex.), 16.vii.2012 (4 ex.), 20.vii.2012 (2 ex.).

***258. Spilosoma melli* (Daniel, 1943) (Plate 22.9)**

1943. *Spilarctia melli* Daniel, *Mitt. Munchn. Ent. Ges.*, 33: 713.

Distribution: India (Himalayas), World (China, Nepal); *Size:* 40mm; *Abundance:* Abundant; *Altitude & Habitat:* 2600m (CH26), 3000m (CH30), 3600m (CH36), Western Mixed Coniferous Forest, Himalayan Temperate parkland, Western Himalayan Birch-Fir Forest, Deciduous Alpine Scrub; *Specimen studied:* 13.vii.2012 (1 ex.), 17.vii.2012 (2 ex.), 19.vii.2012 (2 ex.), 22.vi.2012 (1 ex.).

***259. Spilosoma casigneta* (Kollar, 1884) (Plate 22.10)**

1884. *Euprepia casigneta* Kollar, *In* Hugel's Kaschmir, 4: 49.

1888. *Spilarctia sagittifera* Moore, *Proc. Zool. Soc. London* : 394.

2010. *Spilarctia casigneta* Kollar, Majumdar, *Fauna of Uttarakhand*, 2: 501-529.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim, West Bengal, Maharashtra, Assam, Manipur, Nagaland, Meghalaya, Arunachal Pradesh, Tamil Nadu), World (China,Tibet, Bhutan); *Size:* 45mm; *Host Plant: Arachis hypogaea*, *Glycine max*, *Helianthus annuus*, *Lablab purpureus*, *Mikania cordata*, *Ricinus communis*, *Sesamum indicum*; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), 2200m (CH22), 2600m (CH26), Subtropical Pine Broadleaved Mix forest, Mohru Oak Forest, Western Mixed Coniferous Forest; *Specimen studied:* 29.v.2009 (4 ex.), 04.v.2010 (2 ex.), 08.v.2011 (1 ex.), 19.vii.2012 (1 ex.), 23.vii.2012 (2 ex.).

***260. Spilosoma erythrozonata* (Kollar, 1844) (Plate 22.11)**

1844. *Euprepia erythrozonata* Kollar, *In* Hugel: *Kashmir*, 4: 468.

1869. *Spilosoma cognate* Walker, *Char. Und. Lep.*: 11.

2008. *Spilarctia erythrozona* Kollar, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalayas, Kashmir, Uttarakhand); *Size:* 42mm; *Abundance:* Abundant; *Altitude & Habitat:* 1400m to 3400m, at almost all altitudinal zones, Subtropical Pine Broadleaved mix forest to Deciduous Alpine Scrub; Maximum individuals were recorded at Taluka 3200m, Himalayan Temperte parkland which is a disturbed habitat category; *Specimen studied:* 29.v.2009 (2 ex.), 03.vi.2009 (1 ex.), 02.v.2011 (3 ex.), 13.v.2011 (4 ex.), 25.v.2012 (2 ex.), 10.vi.2012 (2 ex.), 12.vi.2012 (1 ex.), 16.vi.2012 (4 ex.), 23.vii.2012 (1 ex.) etc.

***261. Spilosoma obliqua* Walker, 1855 (Plate 22.12)**

1855. *Spilosoma obliqua* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 3: 679 .

2010. *Spilarctia obliqua* Walker, Majumdar, *Fauna of Uttarakhand*, 2: 501-529.

Distribution: India (Throughout including Uttarakhand), World (Afghanistan, Pakistan, Bhutan, Myanmar, Bangladesh, China); *Size:* 40mm; *Host Plant:* Polyphagous, some of the host plants recorded from India are *Arachis hypogaea*, *Beta vulgaris*, *Brassica nigra*, *Cannabis sativa*, *Cedrela toona*, *Helianthus annuus*, *Morinda citrifolia*, *Morus alba*, *Parthenium* etc. Major pest to groundnut, mulberry, cashew, pulses etc; *Abundance:* Abundant; *Altitude & Habitat:* 1400m, 1800m (CH18), 2200m (CH22), 2400m (CH24), 3200m (TK32), Subtropical Broadleaved forest, Riverine forest, Mohru oak forest, Western Mixed Coniferous forest, Himalayan Temperate Parkland; *Specimen studied:* 12.vi.2009 (5 ex.), 16.vi.2012 (3

ex.), 10.vii.2012 (1 ex.), 20.vii.2012 (2 ex.), 23.vii.2012 (6 ex.), 25.vii.2012 (2 ex.) etc.

***262. Spilosoma strigatula* Walker, 1855 (Plate 23.1)**

1855. *Spilosoma strigatula* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 3: 613.

1901. *Diacrisia strigatula*, Hampson, *Cat. Lepid. Phalaenae Br. Mus.*, 3: 306.

1988. *Spilosoma strigatula*, Holloway, *The Moths of Borneo*, 6: 45.

1995. *Spilarctia strigatula* Walker, *In* Haruta*: Moths of Nepal,* 4:43.

Distribution: India, World (Thailand, Sundaland, Nepal, Myanmar, Java, Borneo); *Size:* 44mm; *Host Plant:* Polyphagous; *Abundance:* Common; *Altitude & Habitat:* 1600m (NT16), 2800m (TK28), Subtropical Pine Broadleaved Mix forest, West Himalayan Upper Oak forest; *Specimen studied:* 03.vi.2009 (2 ex.), 26.vi.2011 (3 ex.), 14.vi.2012 (11 ex.).

***263. Spilosoma unifascia* (Walker, 1855) (Plate 23.2)**

1855. *Andala unifascia* Walker, *List. Het. Brit. Mus.*, 3: 774.

1864. *Alphaea varia* Walker, *List. Lep. Het. Brit. Mus.*, 31: 297.

1892. *Thyrgorina unifascia*, Hampson, *Fauna of Brit. India*, 2: 13.

2011. *Spilosoma unifascia,* Sanyal *et al*., *Envis Bulletin, Wildlife Institute of India,* 14:123

Distribution: India (North West Himalaya); *Size:* 41mm; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 12.vi.2009 (1 ex.).

***264. Spilosoma punctaria* (Stoll, 1782) (Plate 23.3)**

1782. *Bombyx punctaria* Stoll, *Pap. Exot*., 4: 2, 398.

1881. *Spilosoma doerrisi* Oberthur, *Et. Ent*., 5: 31.

2000. *Spilosoma punctaria,* Ueda *et al.*, *Bull. Kitakyushu Mus. Nat. Hist*., 19: 43-75.

Distribution: India (Sikkim, Nagaland), World (Myanmar, Korea, Nepal, China, Japan), New record to Uttarakhand; *Size:* 34mm; *Host Plant: Chrysanthemum* is recorded as host plant from Thailand; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), 2400m (CH24, JK24, TK24), Subtropical Pine forest, Mixed Coniferous forest, Mohru Oak forest; *Specimen studied:* 31.v.2009 (6 ex.),

12.vi.2009 (8 ex.), 13.v.2011 (2 ex.), 22.vi.2011 (1 ex.), 09.vi.2012 (3 ex.), 10.vii.2012 (2 ex.).

***265. Spilosoma melanostigma* Erschoff, 1872 (Plate 23.4)**

1872. *Spilosoma melanostigma* Erschoff, *Horae Soc. Ent. Ross.*, 8(4): 316.

2008. *Spilarctia melanostigma* Erschoff, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand, Sikkim, Assam), World (Central Asia, Uzbekistan, Afghanistan); *Size:* 46mm; *Abundance:* Common; *Altitude & Habitat:* 2400m (CH24), 2600m (CH26), 2800m (TK28), 3000m (CH30), Western Mixed Coniferous forest, Upper Oak Forest, Western Himalayan Birch-Fir forest; *Specimen studied:* 14.vi.2012 (4 ex.), 10.vii.2012 (3 ex.), 13.vii.2012 (3 ex.), 19.vii.2012 (4 ex.).

***266. Spilosoma leopardina* (Kollar, 1844) (Plate 23.5)**

1844. *Euprepia leopardina* Kollar, *In* Hugel: *Kaschmir*, 4(2): 467.

1869. *Ardices liturata* Walker, *Char. Und. Lep.* : 12.

1914. *Diacrisia suffuse* Rothschild, *Gross-Schmett. D. Erde.*, 10: 23.

2008. *Spilarctia leopardina* Kollar, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalayas, Kashmir, Uttarakhand, Meghalaya), World (Nepal); *Size:* 45mm; *Abundance:* Abundant; *Altitude & Habitat:* 1800m to 3200m, (CH18, CH22, CH24, TK26, TK28, CH30, HD30, TK32), Riverine Forest, Mixed Coniferous forest, Upper Oak Forest, Birch-Fir Forest, Temperate parkland; *Specimen studied:* 12.vi.2012 (7 ex.), 14.vi.2012 (3 ex.), 16.vi.2012 (2 ex.), 22.vi.2012 (4 ex.), 20.vii.2012 (9 ex.) etc.

***267. Chionaema coccinea* Moore 1878 (Plate 23.6)**

1878. *Bizone coccinea* Moore, *Proc. Zool. Soc. Lond.*, 28. pl. 3, f. 14, TL: Sikkim

1900. *Chionaema coccinea*, Hampson, *Cat. Lep. Phalaenae Br. Mus.*, 2: 322

1995. *Cyana coccinea*, Holloway, *Moths of Borneo*, 7: 338.

1995. *Chionaema coccinea* Moore, Hutacharena & Nepachon, *Chck. of Forest insects of Thailand.*

Distribution: India (Uttarakhand, Sikkim, Andamans), World (Myanmar, Thailand); *Size:* 31mm; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 1600m

(NT16), 1800m (NT18), Subtropical Pine Broadleaved forest; *Specimen studied:* 07.v.2010 (1 ex.), 22.vi.2011 (1 ex.), 27.vi.2011 (2 ex.).

***268. Chionaema peregrina* (Walker, 1854) (Plate 23.7)**

1854. *Cyana peregrine* Walker, *Cat. Lep.*, 31: 56.

1877. *Bizone pallens* Butler, *Trans. Ent. Soc.*: 103.

2013. *Cyana peregrina*, Aslam, *Arthropods*, 2(4): 237-241.

Distribution: India (Throughout), World (Pakistan, China, Sri Lanka, Myanmar, Sumatra); *Size:* 28mm; *Abundance:* Common; *Altitude & Habitat:* 1600m (NT16), 2000m (KK20), Pine Broadleaved Mix forest, Moist Temperate Deciduous forest; *Specimen studied:* 02.v.2011(1 ex.), 08.v.2011 (2 ex.), 23.v.2012 (1 ex.).

***269. Chionaema signa* Walker, 1854 (Plate 23.8)**

1854. *Cyana signa* Walker, *Cat. Lep.*, 31: 58.

2013. *Cyana signa* Walker, Chandra & Sambath, *Jour. of Threat. Taxa*, 5(1): 3565-3570.

Distribution: India (Himalayas, Himachal Pradesh, Sikkim, Meghalaya, Arunachal Pradesh), World (Myanmar); *Size:* 35mm; *Abundance:* Common; *Altitude & Habitat:* 2400m (TK24), 2600m (KK26), 2800m (TK28), 3000m (CH30), Western Mixed Coniferous forest, Upper Oak Forest, Brch-Fir forest; *Specimen studied:* 09.vi.2012 (3 ex.), 14.vi.2012 (1 ex.), 10.vii,2012 (2 ex.), 19.vii.2012 (1 ex.).

***270. Ceryx imaon* (Cramer, 1780) (Plate 23.9)**

1780. *Syntomoides imaon* Cramer, *Pap. Exot. Iii.*: 94.

1996. *Ceryx imaon*, Easton & Pun, *Tropical Lepidoptera*, 7(2): 113-118.

Distribution: India (Uttarakhand, Sikkim, Meghalaya), World (Sri Lanka, Myanmar, Sumatra); *Size:* 34mm; *Host Plant: Citrus*, *Lantana*, *Anacardium*; *Abundance:* Rare; *Altitude & Habitat*: 1400m (NT14), Subtropical Broadleaved forest; *Specimen studied:* 08.xi.2010 (2 ex.).

XIX C. Subfamily Catocalinae

This large group, commonly known as underwings, is especially well developed in tropical and subtropical areas. It includes most of the largest species of Noctuoidae as well as some very small species. Some have brightly coloured and banded hindwing,

forewings somber and brightly in colour. They are often with prominently spined legs and semi-looper larvae with some reduction in prolegs. The larvae feed on the foliage of shrubs, trees and vines, and pupate in rather scant like cocoon. I recorded following species from GLA:

***271. Anomis mesogona* (Walker, 1857) (Plate 23.10)**

1857. *Gonitis mesogona* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 13: 1002.

1894. *Cosmophila mesogona*, Hampson, *Fauna of Brit. India*, 2: 408.

2012. *Anomis mesogona* Walker, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Throughout), World (Sri Lanka, Myanmar, Java, Africa); *Size:* 44mm; *Host Plant: Citrus*, *Lantana camara*, *Rosa*, *Rubus*, *Vitis*; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), 1800m (CH18), Subtropical Pine Broadleaved Mix forest, Riverine Forest; *Specimen studied:* 09.v.2011 (1 ex.), 25.vii.2012 (2 ex.).

***272. Arcte coerula* (Guenée, 1852) (Plate 23.11)**

1852. *Cocytodes coerula* Guenée, *Noct.*, 3: 41.

2008. *Arcte coerula* Guenée, Smetacek, *Bionotes:* 10(1):5-15.

2012. *Arcte coerula* Guenée, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Uttarakhand), World (South-East Asia, Fiji, Nepal, Japan, New Guinea, Taiwan, Norfolk Island); *Size:* 84mm; *Host Plant: Boehmeria*, *Debregeasia salicifolia*, *Girardinia diversifolia*; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved mix forest; *Specimen studied:* 04.v.2010 (1 ex.), 22.vi.2011 (1 ex.).

***273. Bastilla acuta* (Moore, 1883) (Plate 23.12)**

1883. *Ophiusa acuta* Moore, *Proc. Zool. Soc.*: 27.

2008. *Bastilla acuta* Moore, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: Himalaya (Uttarakhand, Meghalaya), World (Taiwan, Peninsular Malaysia, Sumatra, Borneo); *Size:* 62mm; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Broadleaved forest; *Specimen studied:* 22.vi.2011 (1 ex.).

***274. Bastilla crameri* (Moore, 1885) (Plate 24.1)**

1885. *Ophiusa crameri* Moore, *Lep. Ceyl*., iii: 177

1885. *Dysgonia discalis* Moore, *Lep. Ceyl*., 3: 177.

2008. *Bastilla crameri* Moore, Smetacek, *Bionotes:* 10(1):5-15.

2013. *Dysgonia crameri* Moore, Sivasankaran *et al.*, *Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Throughout including Uttarakhand, Maharashtra, Andamans), World (Sri Lanka, Myanmar, Malaysia, Sumatra, Borneo, Africa); *Size:* 65mm; *Host Plant: Sandoricum* and *Phyllanthus* species; *Abundance:* Rare; *Altitude & Habitat:* 1800m (NT18), Riverine Forest; *Specimen studied:* 24.vii.2012 (1 ex.), 25.vii.2012 (1 ex.).

***275. Catocala armandi* Ponj, 1888 (Plate 24.2)**

1888. *Catocala armandi* Ponj, *Bull. Soc. Ent. Fr*., 8(6): 208.

2003. *Catocala armandi*, Goater & Fibiger, *Noctuidae Europaeae*, 10: 83.

Distribution: India (Uttarakhand-First time record from India), World (South East Asia, Nepal, Tibet, Taiwan); *Size:* 80mm; *Host Plant: Quercus*, *Juglans*, *Prunus*; *Abundance:* 2200m (CH22, TK22), 2800m (TK28), Moist Temperate Deciduous Forest, Mohru Oak forest, West Himalayan Upper Oak Forest; *Specimen studied:* 27.x.2011 (1 ex.), 14.vi.2012 (2 ex.), 20.vii.2012 (1 ex.).

***276. Dysgonia algira* Linnaeus, 1767 (Plate 24.3)**

1767. *Phalaena algira* Linnaeus, Syst. Nat.i:836

1894. *Ophiusa algira* Guenée, Hampson, *fauna of British India* 2: 500.

2003. *Dysgonia algira*, Goater *et al*., *Noctuidae Europaeae*, 10:65.

Distribution: India (Throughout), World (Europe, Africa, Japan, China, Sri Lanka, Myanmar); *Size:* 44mm; *Host Plant: Coriaria nepalensis* (Coriariaceae); *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 01.vi.2009 (1 ex.), 06.v.2010 (1 ex.), 15.v.2010 (1 ex.).

***277. Hypopyra vespertilio* (Fabricius, 1787) (Plate 24.4)**

1787. *Noctua vespertilio* Fabricius, *Mantissa Insectoru*, 2: 136.

1947. *Hypopyra vespertilio*, Gardner, *Trans. R. Ent. Soc. London*, 98: 80.

2008. *Hypopyra vespertilio* Fabricius, Smetacek, *Bionotes:* 10(1):5-15.

2013. *Hypopyra vespertilio* Fabricius, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Throughout including Andamans), World (Sri Lanka, China, Japan, Myanmar); *Size:* 76mm; *Host Plant: Albizia lebbeck, Camellia sinensis*; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Subtropical Chir Pine Forest; *Specimen studied:* 26.vi.2011 (1 ex.).

***278. Ophiusa tirhaca* (Cramer, 1780) (Plate 24.5)**

1780. *Noctua tirhaca* Cramer, *Pap. Exot.*, 2: 116.

1942. *Ophiusa tirhaca*, Transend, *J. E. Afr. Nat. Hist. Soc*., 16: 212.

2003. *Ophiusa tirhaca*, Goater & Fibiger, *Noctuidae Europaeae*, 10: 54.

2008. *Ophiusa tirhaca* Cramer, Smetacek, *Bionotes:* 10(1):5-15.

2013. *Ophiusa tirrhaca* Cramer, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Throughout), World (Asia, Europe, Africa, Australia); *Size:* 64mm; *Host Plant: Pistacia lentiscus*, *Rhus coriaria*, *Shorea robusta*, *Terminalia bellirica*, *Terminalia tomentosa*; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved mix forest; *Specimen studied:* 04.v.2010 (1 ex.).

***279. Remigia discios* (Kollar, 1848) (Plate 24.6)**

1848. *Ophiusa discios* Kollar, *In* Hugel: *Kaschmir,* 4: 477.

1894. *Remigia discios* Hampson, *Fauna of Brit. India* : 525.

2008. *Mocis discios* Kollar, Smetacek, *Bionotes:* 10(1):5-15.

2013. *Remigia discios* Kollar, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (North West Himalaya, Uttarakhand), World (Nepal); *Size:* 52mm; *Host Plant: Hevea brasiliensi*, *Vigna mungo, Vigna unguiculata, Butea monosperma*I, *Cajanus cajan*, *Desmodium dalbergioides*, *Gossypium sp.*; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Chir Pine forest; *Specimen studied:* 03.v.2010 (3 ex.), 15.v.2010 (1 ex.), 09.v.2011 (1 ex.).

***280. Spirama retorta* (Clerck, 1764) (Plate 24.7)**

1764. *Phalaena retorta* Clerck, *Icones Ins. Rariorum,* 2: 54.

1764. *Noctua retorta*, Linnaeus, *Mus. Lud. Ulr.* : 376.

1947. *Spirama retorta*, Gardner, *Trans. R. Ent. Soc. London,* 98: 83.

2008. *Spirama retorta* Cramer, Smetacek, *Bionotes:* 10(1):5-15.

2013. *Spirama retorta* Cramer, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Throughout), World (Sri Lanka, Nepal, China, Thailand, Myanmar, Java); *Size:* 60mm; *Host Plant: Acacia pennata*, *Albizia lebbeck*, *Cassia surattensis*; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Broadleaved Forest; *Specimen studied:* 04.v.2010 (3 ex.), 19.v.2010 (2 ex.), 23.v.2010 (2 ex.).

***281. Lagoptera juno* (Dalman, 1823) (Plate 24.8)**

1823. *Noctua juno* Dalman, *Anal. Entom.*: 52.

1840. *Ophideres elegans* Hoeven, *Tijd. Nat. Gesch.*, 7: 280.

1915. *Dermoleipa juno*, Rothschild, *Novit. Zool.*, 22(2): 211.

2002. *Lagoptera juno* Dalman, Rose, *Zoos' Print Journal,* 17(2): 707-721.

2013. *Thyas juno* Dalman, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Himalyas, Uttarakhand, Nilgiri Hills), World (China, Japan, Korea, Thailand, Borneo, Java, Sulawesi); *Size:* 93mm; *Host Plant: Castanea*, *Quercus*, *Juglans* and *Pterocarya*; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mix Forest; *Specimen studied:* 02.vi.2011 (1 ex.).

***282. Trigonodes hyppasia* (Cramer, 1779) (Plate 24.9)**

1779. *Noctua hyppasia* Cramer, *Pap. Exot.*, 3: 99.

1942. *Trigonodes hyppasia*, Sevastopulo, *J. Bombay Nat. Soc.*, 43: 45.

1953. *Trigonodes hyppasia*, Beric, *Mus. Stor. Nat. Gen.*, 66: 295.

2008. *Trigonodes hyppasia* Cramer, Smetacek, *Bionotes:* 10(1):5-15.

2013. *Trigonodes hyppasia* Cramer, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Throughout including Uttarakhand), World (Africa, Madagaskar, Sri Lanka, Myanmar, China, Java, Australia); *Size:* 46mm; *Host Plant: Indigofera*, *Medicago sativa*, *Rhynchosia minima*; *Abundance:* Rare; *Altitude & Habitat:* 1500m (BH16), Subtropical Broadleaved Forest; *Specimen studied:* 30.x.2008 (1 ex.).

XIX D. Subfamily Calpinae

Status of this closely related subfamily of Catocalinae is somewhat disputed; it is sometimes merged into the Catocalinae. Most of the calpine genera are not further classified; the phylogenetic structure of this group is essentially unresolved, and, in many cases it is even doubtful whether the genera are indeed correctly placed in this subfamily. Following species were recorded from GLA:

***283. Bamra lepida* (Moore, 1867) (Plate 24.10)**

1867. *Agriopis lepida* Moore, *Proc. Zool. Soc. London* : 56.

1874. *Pandesma sublimis* Felder, *Reise. Novara Lep. Het*., 1: 23.

2004. *Bamra lepida* Moore, Ades & Kendrick, *A checklist of HongKong fauna*.

Distribution: India (North West Himalaya, Sikkim), World (Nepal, Taiwan, Hong Kong); *Size:* 42mm; *Host Plant: Albizia*, *Arachis*; *Abundance:* Rare; *Altitide & Habitat:* 1600m (NT16), Subtropical Pine Broadleaved Mix Foresr; *Specimen studied:* 22.vi.2011 (1 ex.).

***284. Calesia haemorrhoa* Guenée, 1852 (Plate 24.11)**

1852. *Calesia haemorrhoa* Guenée, *Noct.*, 3: 258.

1874. *Calesia patna* Felder, *Reise. Novara Lep. Het.*, 1: 23.

1947. *Calesia haemorrhoa*, Gardner, *Trans. R. Ent. Soc. London*, 98: 69.

2008. *Calesia haemorrhoa* Guenée, Smetacek, *Bionotes:* 10(1):5-15.

2013. *Calesia haemorrhoa* Guenée, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Uttarakhand), World (Sri Lanka, Myanmar); *Size:* 46mm; *Host Plant: Barleria cristata*, *Eranthemum nervosum*, *Justicia vasica*; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Chir Pine Forest; *Specimen studied:* 29.v.2009 (1 ex.), 24.vi.2011 (1 ex.).

***285. Cymatophoropsis sinuata* (Moore, 1879) (Plate 24.12)**

1879. *Gluphisia sinuata* Moore, *Proc. Zool. Soc. Londo*n : 405.

1882. *Risoba confluens*, Moore, *Lep. Atk.* : 92.

2008. *Cymatophoropsis sinuata* Moore, Smetacek, *Bionotes:* 10(1):5-15.

2013. *Cymatophoropsis sinuata* Moore, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim); *Size:* 38mm; *Abundance:* Uncommon; *Altitude & Habitat:* 3200m (TK32, CH32), 3400m (CH34, HD34), Himalayan Temperate Parkland, Western Himalayan Birch-Fir forest, Birch-Rhododendron Scrub Forest, Deciduous Alpine Scrub; *Specimen studied:* 16.vi.2012 (1 ex.), 26.vi.2012 (2 ex.), 15.vii.2012 (2 ex,), 16.vii.2012 (1 ex.).

***286. Ericeia pertendens* (Walker, 1858) (Plate 25.1)**

1858. *Remigia pertendens* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 14: 1512.

1922. *Ericeia gonioptila* Prout, *Bull. Hill. Mus.*, 1: 233.

1996. *Ericeia pertendens*, Nielsen & Rangsi, *Checklist of the Lepidoptera of Australia; CSIRO.*

2008. *Ericeia pertendens* Walker, Smetacek, *Bionotes:* 10(1):5-15.

2013. *Ericeia pertendens* Walker, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Throughout including Uttarakhand, Andamans), World (Sri Lanka, Myanmar, China, Australia); *Size:* 42mm; *Host Plant: Cassia*, *Albizia*, *Dalbergia*, *Xylia*, *Mimosa*; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Chir Pine forest, Pine Broadleaved Mix forest; *Specimen studied:* 03.v.2010 (4 ex.), 21.v.2010 (5 ex.), 24.v.2011 (4 ex.), 22.vi.2011 (2 ex.).

***287. Lacera procellosa* Butler, 1879 (Plate 25.2)**

1879. *Lacera procellosa* Butler, *Ann. Mag. Nat Hist.*, 4(5): 368.

1780. *Lacera alope* Cramer, *Pap. Exot.*, 3: 286.

2013. *Lacera procellosa* Butler, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Throughout including Andamans), Wolrd (Sri Lanka, Japan, China, Myanmar, South Africa, Madagascar); *Size:* 52mm; *Host Plant:*

Caesalpinia crista, *Caesalpinia decapetala*, *Caesalpinia mimosoides*, *Moullava spicata*; *Abudance:* Rare; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Pine Broadleaved Mix Forest; *Specimen studied:* 04.v.2010 (1 ex.), 24.v.2011 (2 ex.), 26.vi.2011 (2 ex.).

***288. Oraesia emarginata* (Fabricius, 1794) (Plate 25.3)**

1794. *Noctua emarginata* Fabricius, *Ent. Syst.*, 3(2): 82.

1852. *Oraesia metallescens* Guenee, *In* Boisduval & Guenee: *Hist. Nat. Ins.(Lepid.),* 6: 364.

1918. *Oraesia camaguina* Swinhoe, *Ann. Mag. Nat. Hist*., 2: 90.

2008. *Oraesia emarginata*, Zaspel & Branham, *Insecta Mundi*, 6: 47.

2008. *Oraesia emarginata* Fabricius, Smetacek, *Bionotes:* 10(1):5-15.

2013. *Oraesia emarginata* Fabricius, Sivasankaran *et al.*, *Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Throughout including Uttarakhand), World (Sri Lanka, Nepal, China, Myanmar, Philippines); *Size:* 42mm; *Host Plant: Cissampelos pareira*, *Cocculus*, *Ipomoea*, *Malus pumila*, *Prunus*, *Sida*, *Vitis*; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Pine Broadleaved Mix Forest; *Specimen studied:* 29.v.2009 (3 ex.), 04.v.2010 (2 ex.), 06.v.2010 (2 ex.), 23.v.2010 (3 ex.), 22.vi.2011 (1 ex.), 26.vi.2011 (1ex.).

***289. Othreis fullonia* (Clerck, 1764) (Plate 25.4)**

1764. *Phalaena fullonia* Clerck, *Icones* : 18.

1775. *Noctua pomona* Cramer, *Pap. Exot*., 1: 122.

1857. *Ophideres obliterans* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 13: 1229.

2002. *Othreis fullonia* Clerck, Rose, *Zoos' Print Journal,* 17(2): 707-721.

Distribution: India (Assam), World (Asia, Africa, New Guinea, Australia), New record to Uttarakhand; *Size:* 76mm; *Host Plant: Achyranthes*, *Menispermum*, *Tiliacora*; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Chir Pine forest; *Specimen studied:* 12.vi.2009 (1 ex.).

XX. Family Euteliidae Grote, 1882

They are moderate-sized noctuoids, often with complexly patterned wings. At rest the wings are held out away from the body and sometimes rolled. The forewings are fairly slender, with at least a slight bulge on the outer margin, with squared to rounded apex, wing pattern usually complex. Hindwings are squared to rounded, sometimes are boldly patterned. Hind tibial spurs are long, hind tarsal spines are present. Abdomens are smooth, often boldly coloured. Only one species was recorded from GLA:

***290. Eutelia adulatrix* (Hübner, 1813) (Plate 25.5)**

1813. *Noctua adulatrix* Hübner, *Samml. eur. Schmett.*, 4: 111.

2010. *Eutelia adulatrix*, Fibiger, Ronkay, Yela & Zilli, *Noctuidae Europeaea*, 12: 136.

Distribution: India (Throughout), World (Sri Lanka, Java, Europe, Afghanistan, Kazkhstan, Asia, Australia); *Size:* 34mm; *Host Plant: Cotinus coggygria*, *Pinus*, *Pistacia*, *Rhus*; *Abundnce:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Chir Pine forest; *Specimen studied:* 03.v.2010 (1 ex.), 05.v.2010 (1 ex.).

XXI. Family Nolidae Hampson, 1894

Nolidae is a small family of moth with about 1,400 described species worldwide (Pohl *et al.* 2010) which was previously considered as a subfamily under Noctuidae. They are mostly small with dull colouration, the main distinguishing feature being the tufts of raised scales on the forewings, which gives the family their common name as tuft moths. The larvae also tend to have subdued colours and tufts of short hairs. Three species were recorded from the study area:

***291. Gabala argentata* Butler, 1878 (Plate 25.6)**

1878. *Gabala argentata* Butler, *Ill. Het. Brit. Mus.*, 2: 56.

1913. *Gabala suffuse* Warren, *Seitz Gr.-Schm. Pal.*, 3: 294.

1989. *Gabala argentata*, Poole, *Lepdopterorum Catalogus (n. s.)*: 118.

2009. *Gabala argentata* Butler, Byun *et al.*, *Jour. of Korean Nature*, 2(2): 155-161.

Distribution: India (Arunachal Pradesh), World (Hong Kong, Taiwan, Japan, Korea), New record to Uttarakhand; *Size:* 28mm; *Host Plant: Rhus hypoleuca* is recorded as host plant from Hong Kong; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Subtropical Chir Pine Forest; *Specimen studied:* 29.v.2009 (1 ex.).

***292. Risoba prominens* Moore, 1881 (Plate 25.7)**

1881. *Risoba prominens* Moore, *Proc. Zool. Soc. London* : 329.

2003. *Risoba prominens*, Holloway, *The Moths of Borneo*, 18: 218, 219.

2008. *Risoba prominens* Moore, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Uttarakhand), World (Sri Lanka, Myanmar, China, Java, Japan, Vietnam, Sundaland); *Size:* 32mm; *Host Plant: Pterocarya stenoptera* of family Juglandaceae; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Chir Pine forest; *Specimen studied:* 03.v.2010 (1 ex.), 31.x.2011 (1 ex.).

***293. Xanthodes transversa* (Guenée, 1852) (Plate 25.8)**

1852. *Xanthodes transversa* Guenée, *Noct*. 2: 211.

1891. *Trileuca dentalis* Smith, *Trans. Am. Ent. Soc.*, 18: 123.

1918. *Acontia talauta* Swinhoe, *Ann. Nat. Hist*. 2: 74.

1989. *Xanthodes transversa*, Poole, *Lepidopterorum Catalogus, Noctuidae* : 118.

2008. *Xanthodes transversa* Guenée, Smetacek, *Bionotes:* 10(1):5-15.

2013. *Xanthodes transversa* Guenée, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Throughout including Uttarakhand), World (Sri Lanka, China, Myanmar, Java); *Size:* 42mm; *Host Plant: Abelmoschus crinitus*, *Abelmoschus esculentus*, *Alcea rosea*, *Gossypium*, *Hibiscus*, *Sida*, *Solanum melongena*, *Urena lobata*; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), Subtropical Chir Pine Forest; *Specimen studied:* 30.v.2011 (2 ex.), 24.vi.2011 (3 ex.).

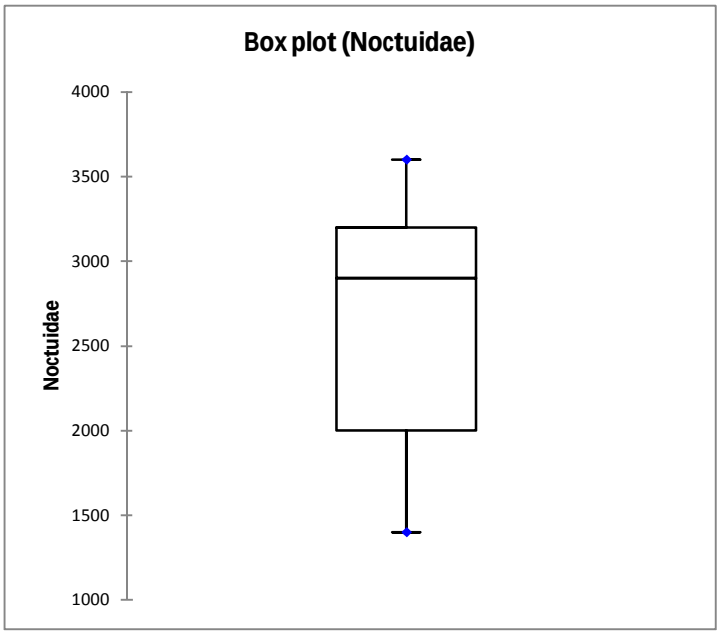
XXII. Family Noctuidae Latreille, 1809

Containing over more than 35,000 known species placed in 29 sub-families and 4,200 genera (Sivasankaran 2012), the Noctuidae is the largest family of moths. They occur in all the regions, but both the genera and species are more abundant in the tropical areas of the world. Most noctuids are specialized for powerful, maneuverable flight and fly mainly at night. The majority of the long-distance migrant moths are noctuids. They require regular refueling for flight and feed at flowers, oozing tree-sap, aphid honeydew or sugary baits. Most of the species rest with the trailing edges of the forewings brought together or slightly overlapping, over the folded hindwings, and hold their wings tent like over the body. Most noctuid larvae feed on the leaves, stems

or roots of grasses or broadleaved herbaceous plants, but some feed on the foliage of trees and shrubs.

The current concept of the Noctuidae includes only the Triifinae subfamilies, characterized by loss of vein M2 such that the posterior angle of the cell has only three veins arising from it, M3, CuA1 and CuA2. The trifines are of great interest as they have been highly successful at moving into, and diversifying within, open habitats, feeding on herbaceous plants. Many are highly dispersive, sometimes migratory, being quick to colonise ephemeral, weedy habitats, the early stages in vegetational succession. This versatility has brought them into conflict with man. Some of the most devastating pests in tropical agriculture are trifine noctuids. Their predominance at high latitudes is reflected in the tropics at high altitudes.

Fig. 3.14: Altitudinal distribution of family Noctuidae (n=293) recorded in GLA.



Mean species distribution of the family is around 2900m, while most of the species and individuals were abundant between 2000m and 3200m (Fig.3.14), however species range extends from 1400m to 3600m.

The trifid subfamilies recorded from the study area are:

XXII A. Subfamily Plusiinae

This is easily recognized subfamily containing species with adults having fairly stout body, long, dense scales on the body and dorsal thoracic crests and dorsal tufts on the

abdomen. The labial palpi are well developed, with the apical segment long, and the eyes have lashes. The forewing is smooth-scaled and always has an areole. I recorded following species from GLA:

***294. Autographa nigrisigna* (Walker, 1857) (Plate 25.9)**

1857. *Plusia nigrisigna* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 12: 928.

1977. *Autographa nigrisigna*, Dufay, *Entomologica Basil*, 2: 140.

2008. *Autographa nigrisigna* Walker, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (Himachal Pradesh, Uttarakhand, Punjab, Sikkim); *Size:* 43mm; *Host Plant: Brassica rapa*, *Cajanus cajan*, *Cannabis sativa*, *Cicer arietinum*, *Lactuca sativa*, *Medicago sativa*, *Mentha*, *Nicotiana tabacum*, *Pisum sativum*, *Trifolium alexandrinum*, *Vigna mungo*; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Pine Broadleaved Mix Forest; *Specimen studied:* 04.v.2010 (2 ex.), 18.v.2011(2 ex.).

***295. Autographa purpureofusa* (Hampson, 1894) (Plate 25.10)**

1894. *Plusia purpureofusa* Hampson, *Fauna of Br. India*, 2: 570.

2008. *Autographa purpureofusa*, Ronkay, Ronkay & Behounek, *Witt Catalogue*, 1: 94.

Distribution: India (Sikkim), World (Myanmar), New record to Uttarakhand; *Size:* 32mm; *Host Plant: Betula*, *Lonicera*, *Urtica*; *Abundance:* Rare; *Altitude & Habitat:* 3000m (HD30), Himalayan Temperate Parkland; *Specimen studied:* 26.vi.2012 (1 ex.).

***296. Chrysodeixis acuta* (Walker, 1857) (Plate 25.11)**

1858. *Plusia acuta* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 12: 922.

1963. *Neoplusia furihatai* Okano, *Ins. Matsumurana*, 25: 90.

2008. *Chrysodeixis acuta* Walker, Smetacek, *Bionotes:* 10(1):5-15.

2010. *Chrysodeixis acuta*; Ronkay, Ronkay & Behounek, *Witt Catalogue*, 4: 90.

2013. *Chrysodeixis acuta* Walker, Sivasankaran *et al.*, *Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Throughout), World (Japan, China, Africa, Canary Islands, South Asia, Indonesia); *Size:* 38mm; *Host Plant: Zea mays*, *Solanum*, *Canna*, *Gossypium*,

Helianthus annuus, *Musa*, *Nicotiana*; *Abundance:* Rare; *Altitude & Habitat:* 2600m (TK26), Western Mixed Coniferous Forest; *Specimen studied:* 12.vi.2012 (1 ex.).

***297. Erythroplusia pyropia* (Butler, 1879) (Plate 25.12)**

1879. *Plusia pyropia* Butler, *Ann. Mag. Nat. Hist*., 4(23): 367.

1978. *Peroplusia pseudopyropia* Chou & Lu, *Acta ent. Sinica*, 21(1): 75.

2008. *Eryhtroplusia pyropia*, Ronkay, Ronkay & Behounek, *Witt Catalogue*, 1: 21.

2008. *Erythroplusia pyropia* Butler, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India(Himachal Pradesh, Uttarakhand, Sikkim, Nagaland, Meghalaya), World (Japan); *Size:* 30mm; *Host Plant: Oryza sativa*, *Artemisia*, *Sparganium*; *Abundance:* Rare; *Altitude & Habitat:* 2600m (TK26), 2800m (TK28), Western Mix Coniferous forest, Western Himalayan Upper Oak forest; *Specimen studied:* 12.vi.2012 (1 ex.), 14.vi.2012 (1 ex.).

***298. Plusiopalpa* sp. (Plate 26.1)**

Genus Distribution: World (Nepal, Africa); *Size:* 34mm; *Host Plant: Mikania*, *Trema*; *Abundance:* Uncommon; *Altitude & Habitat:* 1500m (BH16), 3000m (CH30), Subtropical Broadleaved forest, Wstern Himalayan Birch-Fir forest; *Specimen studied:* 30.x.2008 (5 ex.), 13.vii.2012 (2 ex.).

***299. Thysanoplusia orichalcea* (Fabricius, 1775) (Plate 26.2)**

1775. *Noctua orichalcea* Fabricius, *Syst. Ent*. : 607.

1813. *Noctua aurifera* Hübner, *Samml. eur. Schmett*., (4): 463.

1914. *Thysanoplusia orichalcea*, Holloway, *Fauna of Brit. India*, 14: 295.

2008. *Thysanoplusia orichalcea* Fabricius, Smetacek, *Bionotes:* 10(1):5-15.

2013. *Thysanoplusia orichalcea* Fabricius, Sivasankaran *et al.*, *Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Throughout), World (Sri Lanka, China, Japan, Africa, South Asia, Indonesia, New Guinea); *Size:* 44mm; *Host Plant:* Family Umbelliferae. Pest to crops such as Sunflower, Potato and Soybean; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Chir Pine Forest; *Specimen studied:* 29.x.2009 (2 ex.).

XXII B. Subfamily Acontiinae

This is a small subfamily and do not hold an overly large number of genera at present. Single species was recorded from GLA:

***300. Pseudeustrotia dimera* (Hampson, 1910) (Plate 26.3)**

1910. *Eustrotia dimera* Hampson, *Cat. Lep. Phal.*, 10: 600.

1989. *Pseudeustrotia dimera*, Poole, *Lepidopterorum catalogus (n.s.)– Noctuidae* : 118.

Distribution: India (Sikkim), World (Nepal), New record to Uttarakhand; *Size:* 35mm; *Host Plant: Rumex*, *Polygonum*, *Quercus* is recorded as genus host plant; *Abundance:* Rare; *Altitude & Habitat:* 2400m (TK24), 2600m (CH26), Western Mix Coniferous forest; *Specimen studied:* 11.vi.2012 (1 ex.), 10.vii.2012 (2 ex.).

XXII C. Subfamily Acronictinae

This subfamily is characterized by possession of secondary setae on the larval trunk. They are commonly known as Daggers with dagger like markings on grey foerewing in many species. The larvae are also elaborately marked. I recorded 4 species from GLA, mostly in high abundance from subalpine Birch-Rhododendron habitats.

***301. Auchmis indica* (Walker, 1865) (Plate 26.4)**

1865. *Xylophasia indica* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 32: 647.

2007. *Auchmis indica*, Fibiger & Hacker, *Noctuidae Europaeae.*, 9: 194.

Distribution: India; *Size:* 42mm; *Host Plant: Abies pindrow*, *Aesculus indica* are recorded as host plant from India; *Abundance:* Common; *Altitude & Habitat:* 1600m (NT16), 1800m (CH18), 2000m (KK20), Subtropical Broadleaved Forest, Mix Riverine forest; *Specimen studied:* 04.v.2010 (3 ex.), 21.v.2010 (2 ex.), 02.v.2011 (1 ex.), 25.vii.2012 (4 ex.).

***302. Diphtherocome fasciata* (Moore, 1888) (Plate 26.5)**

1888. *Dipthera fasciata* Moore, *Proc. Zool. Soc. London* : 408.

1994. *Diphtherocome fasciata* Moore, *In* Haruta*: Moths of Nepal*, 3: 96.

Distribution: India (North West Himalaya, Himachal Pradesh, Sikkim), World (Nepal); *Size:* 32mm; *Host Plant: Mimosa*, *Waltheria* etc.; *Abundance:* Common; *Altitude & Habitat:* 2600m (TK26), 2800m (TK28),3200m(TK32,HD32),Mixed

Coniferous Forest, Kharsu Oak Forest, Himalayan Temperate parkland, Birch-Rhododendron Scrub Forest; *Specimen studied:*12.vi.2012 (1 ex.), 14.vi.2012 (2 ex.), 15.vi.2012 (2 ex.), 16.vi.2012 (4 ex.), 17.vi.2012 (6 ex.), 22.vi.2012 (3 ex.).

***303. Diphtherocome pallida* (Moore, 1867) (Plate 26.6)**

1867. *Dipthera pallida* Moore, *Proc. Zool. Soc. London* : 46.

1994. *Diphtherocome pallida* Moore, *In* Haruta*: Moths of Nepal,* 3: 96.

Distribution: India (Western Himalaya, West Bengal), World (Nepal); *Size:* 37mm; *Host Plant: Mimosa*, *Waltheria*; *Abundance:* Abundant; *Altitude & Habitat:* 2400m (TK24), 2600m (TK26), 2800m (TK28), 3000m (CH30, HD30), 3200m (CH32, HD32, TK32), 3400m (CH34), 3600m (CH36), Western Mixed Coniferous forest, Western Himalayan Upper Oak Forest, Himalayan Temperate parkland, Birch-Fir forest, Birch-Rhododendron Scrub Forest, Deciduous Alpine scrub; *Specimen studied:* 10.vi.2012 (4 ex.), 12.vi.2012 (6 ex.), 14.vi.2012 (2 ex.), 15.vi.2012 (4 ex.), 16.vi.2012 (6 ex.), 13.vii.2012 (2 ex.), 15.vii.2012 (1 ex.), 16.vii.2012 (2 ex.), 17.vii.2012 (1 ex.) etc.

***304. Nacna malachite* (Oberthür, 1880) (Plate 26.7)**

1881. *Telesilla malachite* Oberthur, *Et. Ent.*, 5: 80.

1894. *Diphthera malachitis*, Hampson, *Fauna of Brit. India*, 2: 294.

Distribution: India (Himachal Pradesh, Sikkim), World (Nepal), New record to Uttarakhand; *Size:* 40mm; *Host Plant: Mimosa*, *Waltheria*; *Abundance:* Uncommon; *Altitude & Habitat:* 2600m (CH26), 2800m (TK28), Western Mixed Coniferous forest, Himalayan Upper Oak Forest; *Specimen studied:* 12.v.2010 (2 ex.), 14.vi.2012 (4 ex.).

XXII D. Subfamily Cuculliinae

This small subfamily, which is best developed in the northern temperate regions of the world, may not be homogenous. The adults are very similar to Amphipyrinae and Acronictiinae, but the eyes have lashes in the front. The tibiae are rarely spined and the larvae are without secondary setae. I recorded 2 species from GLA, from subalpine forest areas:

***305. Cucullia pullata* (Moore, 1881) (Plate 26.8)**

1881. *Callaenia pullata* Moore, *Proc. Zool. Soc. London* : 358.

2013. *Cucullia pullata* Moore, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (North West Himalaya, Himachal Pradesh, Sikkim), World (Nepal); *Size:* 70mm; *Host Plant: Artemisia*, *Aster*, *Betula*, *Prunus*, *Alnus*, *Verbascum* are recorded as genus host plant; *Abundance:* Rare; *Altitude & Habitat:* 3300m (TK32), Himalayan Temperate Parkland; *Specimen studied:* 16.vi.2012 (1 ex.).

***306. Valeriodes heterocampa* (Moore, 1882) (Plate 26.9)**

1882. *Pachaetra heterocampa* Moore, *Lep. Atk.*: 115.

1989. *Valeriodes heterocampa*, Poole, *Lepidopterorum Catalogus (n.s.)* : 118.

1995. *Valeriodes heterocampa* Moore, *In* Haruta*: Moths of Nepal*, 4: 63.

Distribution: India (West Bengal, Sikkim), World (Nepal, China), New record to Uttarakhand; *Size:* 36mm; *Host Plant: Betula*, *Alnus*, *Viburnum*, *Tsuga*, *Salix* are recoded as genus host plant; *Abundance:* Common; *Altitude & Habitat:* 3200m (CH32), 3400m (CH34), 3600m (CH36), West Himalayan Birch-Fir Forest, Deciduous Alpine scub; *Specimen studied:* 15.vii.2012 (4 ex.), 16.vii.2012 (5 ex.), 17.vii.2012 (3 ex.).

XXII E. Subfamily Amphipyrinae

Commonly known as arches, brindles, minors, rustics or ears, this subfamily is large and diverse originally grouped together on shared pattern of wing venation, lack of eye-lashes and lack of spines on legs. They are stout noctuids with rectangular shiny forewings, brownish to greyish with closely set orbicular and reniform spots, the most common species with coppery hindwing. They have spiny, stem-borer larvae. I recorded 5 morphospecies from GLA among which only two could be identified upto species level:

***307. Amphipyra monolitha* Guenée, 1852 (Plate 26.10)**

1852. *Amphipyra monolitha* Guenée, *Noct.* 2: 414.

2007. *Amphipyra monolitha*, Fibiger & Hacker, *Noctuidae Europaeae*. 9: 23.

Distribution: India (Himachal Pradesh, Uttarakhand, Sikkim), World (North China, Japan); *Size:* 56mm; *Host Plant: Castanea crenata*, *Quercus acutissima*, *Quercus serrata*, *Quercus variabilis* are recorded as host plants from Japan; *Abundance:* Rare; *Altitude & Habitat:* 2450m (CH24), 3400m (CH34), 3600m (CH36), Western Mixed Coniferous forest, Birch-Fir forest, Deciduous Alpine Scrub; *Specimen studied:* 10.vii.2012 (5 ex.), 16.vii.2012 (1 ex.), 17.vii.2012 (2 ex.).

***308. Amphipyra cupreipennis* Moore, 1882 (Plate 26.11)**

1882. *Amphipyra cupreipennis* Moore, *Lep. Atk.* : 155.

1888. *Amphipyra cupripennis*, Cotes & Swinhoe, *Cat. Moths of India*, 3: 2256.

1894. *Amphipyra cupripennis*, Hampson, *Fauna of Brit. India*, 2: 192.

2013. *Amphipyra cupreipennis* Moore, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Sikkim, West Bengal), New record to Uttarakhand; *Size:* 46mm; *Host Plant: Quercus*, *Vitis*; *Abundance:* Rare; *Altitude & Habitat:* 2100m (TK22), Moist Temperate Deciduous forest; *Specimen studied:* 25.x.2011 (1 ex.).

XXII F. Subfamily Agaristinae

The Agaristinae have often been treated as a full family, though with relationships to the Noctuidae. The group is defined by the presence of a more or less well developed paired vesicle at the base of the abdomen associated with counter-tympanal organ. Adults are generally active by day and brightly coloured. I recorded two diurnal and one nocturnal species:

***309. Mimeusemia peshwa* (Moore, 1859) (Plate 26.12)**

1858. *Eusemia peshwa* Moore, *In* Horsfield & Moore: *Cat. Lep. Ins. Mus. Nat.*, 2: 289.

1901. *Mimeusemia peshwa* Hampson, *Cat. Lepid. Phalaenae Br. Mus.*, 3: 613.

2013. *Mimeusemia peshwa* Moore, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (North West Himalaya, Himachal Pradesh, Sikkim); *Size:* 52mm; *Host Plant: Dillenia pentagyna* of family Dilleniaceae is recorded as genus host plant; *Abundance:* Rare; *Altitude & Habitat:* 1800m (CH18), Mix Riverine forest; *Specimen studied:* 24.vii.2012 (1 ex.).

***310. Episteme lectrix* (Linnaeus, 1764) (Plate 27.1)**

1764. *Phalaena lectrix* Linnaeus, *Mus. Lud. Ulr.* : 389.

1936. *Eusemia lectrix*, Mell, *In* Poole: *Lepidopterorum Catalogus* : 366.

2004. *Episteme lectrix* Linnaeus, Ades & Kendrick, *A checklist of HongKong fauna.*

Distribution: India (Himalayas), World (China); *Size:* 65mm; *Host Plant: Dioscorea, Smilax* recorded from China; *Abundance:* Rare; *Altitude & Habitat:* 1600m (NT16), Subtropical Broadleaved Forest; *Specimen studied:* 18.v.2010 (1 ex.).

***311. Aegocera bimacula* Walker, 1854 (Plate 27.2)**

1854. *Aegocera bimacula* Walker, *List Spec. Lepid. Insects Colln Br. Mus.* 1: 57.

1894. *Aegocera bimacula*, Hampson, *Fauna of Brit. India*, 2: 158.

2014. *Aegocera bimacula* Walker, Singh & Sekhon, *J. Chem. Bio. Phy. Sci.*: 5(1): 532-537

Distribution: India (Madhya Pradesh, Sikkim), World (Sri Lanka), New record to Uttarakhand; *Size:* 45mm; *Host Plant: Dillenia pentagyna, Leea guineensis, Vitis*; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Broadleaved Forest; *Specimen studied:* 08.xi.2010 (1 ex.).

XXII G. Subfamily Heliothinae

The Heliothinae are a relatively small subfamily found predominantly in semiarid subtropical habitats. They decrease in diversity in the humid tropics and into temperate latitudes. The group includes a number of serious crop pests and thus has been studied exclusively. The most defining character of the subfamily is its larvae with spiny skin and a peculiar arrangement of setae on the prothorax. I recorded 3 species from GLA:

***312. Helicoverpa armigera* (Hübner, 1827) (Plate 27.3)**

1827. *Noctua armigera* Hübner, *Samml. eur. Schmett.* 4: 79.

1964. *Chloridea armigera*, Boursin, *Bull. Mens. Soc. Linn. Lyon.* 33: 240.

1965. *Helicoverpa armigera*, Hardwick, *Mem. Ent. Soc. Can.* 40: 9, 91.

1989. *Helicoverpa armigera*, Holloway, *The Moths of Borneo.* 12: 75.

2013. *Helicoverpa armigera* Hübner, Sivasankaran *et al.*, *Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Throughout), World (Africa, Asia); *Size:* 36mm; *Host Plant:* Polyphagous, recorded as major pest to cotton, castor, pigeonpea, sunflower, chickpea, black gram, maize, bhendi, potato, tomato, tobacco, rose, etc.; *Abundance:* Abundant; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), 1800m (CH18), 2600m (TK26), Subtropical Chir Pine forest, Pine Broadleaved Mix forest, Riverine forest, Mixed Coniferous forest; *Specimen studied:* 18.v.2010 (1 ex.) , 13.xi.2010 (2 ex.), 26.vi.2011 (4 ex.), 24.vii.2012 (2 ex.), 26.v.2012 (3 ex.).

***313. Aspila peltigera* (Schiffermüller, 1776) (Plate 27.4)**

1776. *Noctua peltigera* Schiffermüller, *Wien. Verz.*: 89.

1964. *Chloridea peltigera* Boursin, *Bull. Mens. Soc. Linn. Lyon.* 33: 240.

2013. *Heliothis peltigera*, Gurule & Nikam, *Jour. of Threat. Taxa*, 5(12):4712.

Distribution: India (North West India), World (Europe, South Africa, New Zealand); *Size:* 40mm; *Host Plant: Allium*, *Atropa*, *Calendula*, *Gossypium*, *Ricinus*, *Sorghum*; *Abundance:* Uncommon, *Altitude & Habitat:* 2100m (TK22), Moist Temperate Deciduous forest; *Specimen studied:* 08.x.2011 (1 ex.), 25.x.2011 (1 ex.).

***314. Pyrrhia umbra* (Hüfnagel, 1766) (Plate 27.5)**

1766. *Phalaena umbra* Hüfnagel, *Berl. Mag.* 3: 294.

1964. *Pyrrhia umbra*, Boursin, *Bull. Mens. Soc. Linn. Lyon.* 33: 240.

2013. *Pyrrhia umbra* Hüfnagel, Sivasankaran *et al.*, *Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (North West Himalaya, Uttarakhand, Nagaland), World (Europe, Japan); *Size:* 35mm; *Host Plant: Polygonum*, *Rhus*, *Rosa*, *Rhododendron arboreum*; *Abundance:* Rare; *Altitude & Habitat:* 2200m (KK20), Moist Temperate Deciduous forest; *Specimen studied:* 10.vi.2011 (4 ex.).

XXII H. Subfamily Hadeninae

The hadeninae can be best defined as trifines with hairy eyes. Thay have stocky thorax with broad, usually well-patterned forewings held in shallow tent like fashion, with ends forming a V-shape. I recorded following species:

***315. Anapoma albicosta* (Moore, 1881) (Plate 27.6)**

1881. *Leucania albicosta* Moore, *Proc. Zool. Soc. Lond.*: 338.

2002. *Anapoma albicosta*, Hacker, Ronkay & Hreblay, *Noctuidae Europaeae.* 4: 166.

Distribution: India (North West Himalaya, Sikkim, West Bengal, Meghalaya), World (Sri Lanka); Size: 45mm; *Host Plant:* Polyphagous; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 29.v.2009 (1 ex.).

***316. Apamea aquila* Donzel, 1837 (Plate 27.7)**

1837. *Apamea aquila* Donzel, *Ann. Soc. Ent. Fr.* 6: 476.

1910. *Hadena albomaculata* Graman, *Intern. Ent. Zeitschr.* 4: 171.

1964. *Apamea aquila*, Boursin, *Bull. Mens. Soc. Linn. Lyon.* 33: 234.

1995. *Apamea aquila oriens* Warren, *In* Haruta*: Moths of Nepal,* 4:64.

Distribution: India (North India), World (Central Asia, Nepal, Japan, Siberia); *Size:* 44mm; *Host Plant:* Citrus, species of family Graminae; *Abundance:* Common; *Altitude & Habitat:* 2400m (CH24, TK24), 2600m (TK26), 2800m (TK28), 3200m (CH32); Western Mix Coniferous forest, Upper Oak forest, West Himalayan Birch-Fir forest; *Specimen studied:* 10.vi.2012 (1 ex.), 12.vi.2012 (2 ex.), 14.vi.2012 (1 ex.), 10.vii.2012 (3 ex.), 15.vii.2012 (2 ex.).

***317. Callopistria albolineola* (Graeser, 1888) (Plate 27.8)**

1888. *Eriopus albolineola* Graeser, *Berl. Ent. Zeit.*: 337.

1908. *Eriopus albolineola*, Hampson, *Cat. Lepid. Phalaenae Br. Mus.* 7: 547.

2007. *Callopistria albolineola*, Fibiger & Hacker, *Noctuidae Europaeae.* 9: 50.

Distribution: India (Western Himalaya), World (Nepal, Europe); *Size:* 36mm; *Host Plant: Adiantum*, *Ceterach*; *Abundance:* Common; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 30.v.2009 (7 ex.), 12.vi.2009 (3 ex.), 01.vi.2009 (3 ex.), 22.vi.2011 (4 ex.).

***318. Callopistria placodoides* (Guenée, 1852) (Plate 27.9)**

1852. *Eriopus placodoides* Guenée, In Boisduval & Guenée: *Hist. Nat. Ins., Spec. gén. Lépid.* 6(2): 296.

1874. *Eriopus doleschalli* Felder & Rogenhofer, *Reise Fregatte Novara,* Bd. 2(4): 110.

1989. *Callopistria placodoides*, Holloway, *The Moths of Borneo.* 12: 167.

2013. *Callopistria placodoides* Guenée, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Nilgiri Hills), World (Java, Australia, Borneo), New record to Uttarakhand; *Size:* 36mm; *Host Plant: Pteridium* of family Dennstaedtiaceae; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), 1800m (CH18), Subtropical Pine Broadleaved Mix forest, Mix Riverine forest; *Specimen studied:* 03.v.2010 (2 ex.), 04.v.2010 (1 ex.), 06.v.2010 (1 ex.), 15.vii.2012 (2 ex.).

***319. Callopistria repleta* Walker, 1857 (Plate 27.10)**

1857. *Callopistria repleta* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 12: 865.

1928. *Eriopus repleta* postpallida Prout, *Bull. Hill Mus.*, 2: 72.

1989. *Callopistria replete*, Holloway, *The Moths of Borneo*, 12: 163.

2013. *Callopistria repleta* Walker, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (North West Himalaya), World (China, Japan, Malaysia, Sumatra, Borneo); *Size:* 40mm; *Host Plant: Pteridium aquilinum* of family Dennstaedtiaceae; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mix Forest; *Specimen studied:* 06.v.2010 (3 ex.).

***320. Callopistria rivularis* Walker, 1858 (Plate 27.11)**

1858. *Callopistria rivularis* Walker, *List Spec. Lepid. Insects Colln Br. Mus.* 12: 867.

1908. *Eriopus xanthopera*, Hampson, *Cat. Lep. Phal*., 7: 545.

1976. *Callopistria rivularis*, Holloway, *The Moths of Borneo*, 12: 167.

2008. *Callopistria rivularis* Walker, Smetacek, *Bionotes:* 10(1):5-15.

2013. *Callopistria rivularis* Walker, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (North West Himalayas, Nilgiri Hills), World (Sri Lanka); *Size:* 28mm; *Host Plant: Adiantum caudatum, Adiantum philippense* of family Adiantaceae; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Pine Broadleaved Mix forest; *Specimen studied:* 12.vi.2009 (1 ex.), 03.v.2010 (2 ex.).

***321. Euplexia plumbeola* Hampson, 1894 (Plate 27.12)**

1894. *Euplexia plumbeola* Hampson, *Moths of Brit. India*,. 2: 217.

1989. *Euplexia plumbeola*, Poole, *Lepidopterorum catalogus (n.s.) – Noctuidae. 118.*

2013. *Euplexia plumbeola* Hampson, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Sikkim), New record to Uttarakhand; *Size:* 43mm; *Host Plant: Alnus, Betula, Viburnum, Salix, Tsuga*; *Abundance:* Rare, *Altitude & Habitat:* 2800m (TK28), 3200m (KK32), Western Himalayan Upper Oak forest; *Specimen studied:* 29.v.2012 (2 ex.), 14.vi.2012 (1 ex.).

***322. Euplexia semifascia* (Walker, 1865) (Plate 28.1)**

1865. *Hadena semifascia* Walker, *List Spec. Lepid. Insects Colln Br. Mus.* 33: 737.

1891. *Euplexia semifascia*, Hampson, *Ill. Het. Brit. Mus.*8: 14, 143.

2013. *Euplexia semifascia* Walker, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (North West India, Maharashtra, South India); *Size:* 34mm; *Host Plant: Alnus, Betula, Viburnum, Salix, Tsuga*; *Abundance:* Abundant; *Altitude & Habitat:* 2600m (TK26), 2800m (TK28), Western Mixed Coniferous forest, Upper Oak forest; *Specimen studied:* 11.vi.2012 (4 ex.), 12.vi.2012 (5 ex.), 14.vi.2012 (3 ex.), 15.vi.2012 (3 ex.).

***323. Euplexia tibetensis* Warren, 1912 (Plate 28.2)**

1912. *Euplexia tibetensis* Warren, *Nov. Zool*. 19: 27.

1989. *Euplexia tibetensis*, Poole, *Lepidopterorum catalogus (n.s.) – Noctuidae*: 118.

1998. *Trachea tibetensis* Warren, *In* Haruta: *Moths of Nepal*, 5: 266.

Distribution: India (Uttarakhand-First time record from India), World (Nepal); *Size:* 36mm; *Host Plant: Alnus, Betula, Viburnum, Salix, Tsuga*; *Abundance:* Uncommon; *Altitude & Habitat:* 3000m (HD30), 3200m (HD32, KK32), Western Himalayan Upper Oak forest, Birch-Rhododendron Scrub Forest; *Specimen studied:* 29.v.2012 (2 ex.), 22.vi.2012 (3 ex.), 26.vi.2012 (3 ex.).

***324. Ebertidia haderonides* Boursin, 1968 (Plate 28.3)**

1968. *Ebertidia haderonides* Boursin, *Entomops*, 12: 126.

1995. *Ebertidia haderonides* Boursin, *In* Haruta*: Moths of Nepal*, 4: 58.

Distribution: India (Uttarakhand-First time record from India), World (Nepal); *Size:* 46mm; *Abundance:* Common; *Altitude & Habitat:* 3400m (CH34), Deciduous Alpine Scrub; *Specimen studied:* 13.v.2011 (2 ex.).

***325. Haderonia culta* (Moore, 1881) (Plate 28.4)**

1881. *Mamestra culta* Moore, *Proc. Zool. Soc. London* : 347.

1900. *Hadena subviolacea* Leech, *Trans. Ent. Soc.* : 55.

1989. *Haderonia culta,* Poole, *Lepidopterorum catalogus (n.s.) – Noctuidae* : 118.

1995. *Haderonia culta* Moore, *In* Haruta*: Moths of Nepal,* 4: 58.

Distribution: India (Himachal Pradesh), World (Nepal), New record to Uttarakhand; *Size:* 48mm; *Host Plant: Fragaria*, *Primula*, *Silene*, *Lychnis* are some of the genus host plant; *Abundance:* Abundant; *Altitude & Habitat:* 2400m (TK24), 2800m (TK28), 3000m (CH30, HD30), 3300m (CH32), 3400m (CH34), 3600m (CH36), Western Mix Coniferous forest, Upper Oak forest, Western Himalayan Birch-Fir forest, Deciduous Alpine Scrub; *Specimen studied:* 09.vi.2012 (5 ex.), 10.vi.2012 (3 ex.), 14.vi.2012 (4 ex.), 22.vi.2012 (7 ex.), 13.vii.2012 (1 ex.), 15.vii.2012 (2 ex.), 17.vii.2012 (1 ex.).

***326. Heliophobus texturata* (Alphéraky, 1892) (Plate 28.5)**

1892. *Mamestra texturata* Alphéraky, *Horae Soc. ent. ross.*, 26(3-4): 446.

1964. *Heliophobus texturata*, Boursin, *Bull. Mens. Soc. Linn. Lyon.,* 33: 217.

1978. *Heliophobus texturata*, Sules, *Notul. Ent*., 58: 27-31.

1995. *Sideridis (Heliophobus) texturata* Alphéraky, *In* Haruta*: Moths of Nepal,* 4: 58.

Distribution: India (Uttarakhand-First time record from India), World (Nepal); *Size:* 36mm; *Host Plant: Astragalus*, *Vicia*; *Abundance:* Abundant; *Altitude & Habitat:* 3000m (HD30), 3200m (HD32), 3400m (HD34), Birch-Rhododendron Scrub forest; Deciduous Alpine Scrub; *Specimen studied:* 22.vi.2012 (6 ex.), 26.vi.2012 (4 ex.), 28.vi.2012 (2 ex.).

***327. Leucania compta* Moore, 1881 (Plate 28.6)**

1862. *Leucania compta* Moore, *Proc. Zool. Soc. London,* 336.

1890. *Leucania nefasta* Swinhoe, *Trans. ent. Soc. Lond.* : 219.

1891. *Leucania stramen* Hampson, *Ill. Het. Brit. Mus.,* 8: 68.

1989. *Leucania compta, Lepidopterorum catalogus (n.s.) – Noctuidae* : 118.

2013. *Leucania compta,* Islam *et al., Int. Jour. of Fauna & Biol. Studies,* 1(1):56-62.

Distribution: India (Nagaland, South India), World (Borneo, Myanmar, Philippines, New Guinea), New record to Uttarakhand; *Size:* 28mm; *Host Plant: Oryza sativa*; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Broadleaved Forest; *Specimen studied:* 31.v.2009 (3 ex.).

***328. Lophotyna albosignata* (Moore, 1881) (Plate 28.7)**

1881. *Trigonophora albosignata* Moore, *Proc. Zool. Soc. London* : 255.

1956. *Lophotyna albosignata*, Boursin, *Z. Wien. Ent. Ges.*, 41: 298-301.

1981. *Lophotyna albosignata*, Owada, *The Lepidopterological Society of Japan*, 31(3, 4): 149-152.

Distribution: India (North West Himalaya, Himachal Pradesh); *Size:* 46mm; *Host Plant: Quercus*, *Acer*, *Fagus*, *Salix*; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Broadleaved forest; *Specimen studied:* 02.xi.2011 (3 ex.).

***329. Phlogophora subpurpurea* Leech, 1900 (Plate 28.8)**

1900. *Phlogophora subpurpurea* Leech, *Trans. Ent. Soc.*: 71.

1995. *Phlogophora subpurpurea* Leech, *In* Haruta*: Moths of Nepal*, 4: 65.

2007. *Phlogophora subpurpurea*, Fibiger & Hacker, *Noctuidae Europaeae*, 9: 186.

Distribution: India (Uttarakhand-First time record from India), World (Nepal, China); *Size:* 46mm; *Abundance:* Rare; *Altitude & Habitat:* 3300m (CH32), West Himalayan Birch-Fir forest; *Specimen studied:* 15.vii.2012 (2 ex.).

***330. Polia scotochlora* Kollar, 1848 (Plate 28.9)**

1848. *Polia scotochlora* Kollar, *In* Huegel: *Kaschmir*, 4: 482.

1852. *Polia stevensii* Guenee, *Noct*., 2: 38.

1995. *Polia scotochlora* Kollar, *In* Haruta*: Moths of Nepal*, 4: 56.

Distribution: India (Kashmir, Uttarakhand, Punjab), World (Nepal); *Size:* 52mm; *Host Plant: Alnus*, *Betula*, *Prunus*, *Polygonum*, *Quercus*, *Salix*; *Size:* 46mm; *Altitude & Habitat:* 3000m (HD30), 3200m (KK32), 3600m (CH36). Himalayan Temperate parkland, West Himalayan Upper Oak forest, Deciduous Alpine scrub; *Specimen studied:* 29.v.2012 (3 ex.), 26.vii.2012 (3 ex.), 17.vi.2012 (1 ex.).

***331. Prospalta leucospila* Walker, 1857 (Plate 28.10)**

1857. *Prospalta leucospila* Walker, *List Spec. Lepid. Insects Colln Br. Mus*., 13: 1114.

1989. *Prospalta leucospila,* Poole, *Lepidopterorum Catalogus, Noctuidae*: 118.

Distribution: India (Sikkim), New record to Uttarakhand; *Size:* 29mm; *Host Plant: Centaurea, Coreopsis*; *Abundance:* Rare; *Altitude & Habitat:* 1800m (CH18), 2400m (CH24), Riverine Forest, Western Mixed Coniferous forest; *Specimen studied:* 10.vii.2012 (1 ex.), 25.vii.2012 (4 ex.).

***332. Spodoptera littoralis* (Boisduval, 1833) (Plate 28.11)**

1833. *Hadena littoralis* Boisduval, *Nouv. Ann. Mus. Hist. Nat. Paris*, 2(2): 239.

1845. *Hadena retina* Freyer, *Neuere Beitr. Schmett*., 5: 161.

2007. *Spodoptera littoralis*, Fibiger & Hacker, *Noctuidae Europaeae*, 9: 56.

2013. *Spodoptera littoralis* Boisduval, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Throughout), World (Mauritius, Africa, Madagascar); *Size:* 38mm; *Host Plant:* Polyphagous, some of the host plants recorded from India are *Antirrhinum*, *Brassica*, *Coffea*, *Cucurbita Ipomoea cairica*, *Lactuca sativa, Zea mays, Zinnia* etc. Major pest to cotton, tobacco, groundnut, sorghum, maize, soybean etc; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), Subtropical Pine Broadleaved Mix Forest; *Specimen studied:* 02.v.2010 (4 ex.), 09.v.2010 (2 ex.); 22.vi.2011 (6 ex.), 26.vi.2011 ex (5 ex.).

XXII I. Subfamily Noctuinae

They are commonly known as Darts and Clays. This group has traditionally been recognized by possession of spined hind tibiae. Another potential defining feature for the group is its resting posture: the wings of each side are held in the same plane rather than at angle to each other forming a roof. I recorded 6 genera and 10 species from GLA:

***333. Chersotis* sp. (Plate 28.12)**

Genus Distribution: World (Nepal, China); *Size:* 36mm; *Host Plant: Lychnis*, *Melilotus*, *Asperula*, *Galium* are some host plants recorded for the genus; *Abundance:*

Rare; *Altitude & Habitat:* 3400m (DV34), Deciduous Alpine scrub; *Specimen studied:* 03.x.2008 (1 ex.), 04.x.2008 (2 ex.).

***334. Diarsia albipennis* (Butler, 1889) (Plate 29.1)**

1889. *Agrotis albipennis* Butler, *Het. B.M.*, 7: 58.

1994. *Diarsia albipennis* Butler, *In* Haruta**:** *Moths of Nepal*, 3: 99.

Distribution: India (Himachal Pradesh), World (Nepal, China); *Size:* 40mm; *Host Plant: Rumex, Salix, Betula, Alnus, Primula, Rubus, Fragaria* are some genus host plant recorded; *Abundance:* Rare; *Altitude & Habitat:* 2500m (HS26), Mohru Oak forest; *Specimen studied:* 23.x.2008 (1 ex.).

***335. Diarsia nigrosigna* (Moore, 1881) (Plate 29.2)**

1881. *Graphiphora nigrosigna*, Moore, *Proc. Zool. Soc*.: 352

1894. *Agrotis descripta*, Brem, *In* Hampson: *Fauna of Brit. India*, 2: 184.

1994. *Diarsia nigrosigna* Moore, *In* Haruta**:** *Moths of Nepal*, 3: 100.

2008. *Diarsia nigrosigna* Moore, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalayas, Uttarakhand, Sikkim, Nilgiri Hills), World (Nepal); *Size:* 38mm; *Host Plant: Rumex, Salix, Betula, Alnus, Primula, Rubus, Fragaria* etc; *Abundance:* Rare; Altitude & Habitat: 3400m (HD34), Deciduous Alpine Scrub; *Specimen studied:* 29.vi.2012 (1 ex).

***336. Hermonassa consignata* Walker, 1865 (Plate 29.3)**

1865. *Hermonassa consignata* Walker, *List Spec. Lepid. Insects Colln Br. Mus.*, 32: 632.

1912. *Hermonassa olive* Warren, *Seitz Cr. Schm. Indoaustr*., 11: 62.

1989. *Hermonassa consignata*, Poole, *Lepidopterorum catalogus (n.s.)- Noctuidae* : 118.

2013. *Hermonassa consignata* Moore, Sivasankaran *et al., Rec. Zool. Surv. India,* 111(3):79-101.

Distribution: India (Kashmir, Himachal Pradesh, Sikkim,West Bengal), New record to Uttarakhand; *Size:* 31mm; *Abundance:* Abundant; *Altitude & Habitat:* 3200m (CH32, HD32), 3400m (CH34), 3600m (CH36), Birch-Rhododendron Scrub Forest, Deciduous Alpine Scrub; *Specimen studied:* 22.vi.2012 (5 ex.), 15.vii.2012 (4 ex.), 16.vii.2012 (3 ex.), 17.vii.2012 (2 ex.).

***337. Hermonassa incisa* Moore, 1882 (Plate 29.4)**

1882. *Hermonassa incisa* Moore, *Lep. Akt.* : 120.

2013. *Hermonassa incisa* Moore, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Himachal Pradesh, Sikkim, West Bengal), New record to Uttarakhand; *Size:* 33mm; *Abundance:* Abundant; *Altitude & Habitat:* 3000m (CH30), 3200m (CH32, TK32), 3400m (CH34), 3600m (CH36), Himalayan Temperate Parkland, Western Himalayan Birch-Fir forest, Birch-Rhododendron Forest, Deciduous Alpine Scrub; *Specimen studied:* 16.vi.2012 (5 ex.), 13.vii.2012 (2 ex.), 15.vii.2012 (1 ex.) , 16.vii.2012 (4 ex.), 17.vii.2012 (1 ex.).

***338. Hermonassa sinuata* Moore, 1881 (Plate 29.5)**

1881. *Hermonassa sinuata* Moore, *Proc. Zool. Soc. London* : 353.

2013. *Hermonassa sinuata* Moore, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Sikkim, West Bengal), New record to Uttarakhand; *Size:* 35mm; *Abundance:* Abundant; *Altitude & Habitat:* 3200m (CH32, TK32), 3400m (CH34, HD34), Himalayan Temperate Parkland, Western Himalayan Birch-Fir forest, Birch-Rhododendron Forest, Deciduous Alpine Scrub; *Specimen studied:* 16.vi.2012 (4 ex.), 22.vi.2012 (2 ex.), 26.vi.2012 (5 ex.), 15.vii.2012 (3 ex.), 17.vii.2012 (2 ex.).

***339. Ochropleura triangularis* Moore, 1867 (Plate 29.6)**

1867. *Ochropleura triangularis* Moore, *Proc. Zool. Soc. London* : 55.

1997. *Albocosta triangularis*, Fibiger, *Noctuidae Europaeae*, 3: 126.

2008. *Ochropleura triangularis* Moore, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalayas, Uttarakhand, Sikkim, West Bengal), World (Nepal); *Size:* 34mm; *Host Plant: Brassica nigra, Cedrus deodara, Fragaria, Nicotiana, Pisum sativum, Triticum, Salix* are some of the genus host plant recorded from India; *Abundance:* Abundant; *Altitude & Habitat:* 2600m (CH26), 3000m (HD30), 3200m (CH32, TK32), 3400m (CH34), Western Mixed Coniferous forest, Himalayan Temperate Parkland, Western Himalayan Birch-Fir forest, Deciduous Alpine Scrub; *Specimen studied:* 16.vi.2012 (2 ex.), 22.vi.2012 (5 ex.), 15.vii.2012 (2 ex.), 16.vii.2012 (1 ex.), 19.vii.2012 (7 ex.).

***340. Ochropleura flammatra* (Denis & Schiffermüller, 1775) (Plate 29.7)**

1775. *Noctua flammatra* Denis & Schiffermüller, *Ankündung eines systematischen Werkes von den Schmetterlingen der Wienergegend*: 80.

1849. *Agrotis deleta* Kollar, *In* Kollar & Redtenbacher: *Ins. Süd-Persien*: 12.

1965. *Ochropleura flammatra*, Boursin, *Bull. Mens. Soc. Linn. Lyon*, 33: 212.

2008. *Ochropleura flammatra* Fabricius, Smetacek, *Bionotes:* 10(1):5-15.

Distribution: India (North West Himalayas, Uttarakhand, Punjab, Sikkim), World (Europe); *Size:* 52mm; *Host Plant: Asphodelus fistulosus, Cedrus deodara, Fragaria, Nicotiana tabacum, Pisum sativum, Taraxacum, Vigna mungo*; *Abundance:* Uncommon; *Altitude & Habitat:* 1400m (NT14), 2100m (TK22), Subtropical Pine Broadleaved Mix Forest, Moist Temperate Deciduous forest; *Specimen studied:* 01.vi.2009 (1 ex.), 27.x.2011 (3 ex.).

***341. Trichoridia hampsoni* (Leech, 1900) (Plate 29.8)**

1900. *Eurois hampsoni* Leech, *Trans. R. Ent. Soc. Lond*.

1995. *Trichoridia hampsoni* Leech, *In* Haruta**:** *Moths of Nepal*, 4: 62.

Distribution: India (North West Himalaya), World (Nepal); *Size:* 41mm; *Host Plant: Acer, Alnus, Betula, Fragaria, Salix* etc. are recorded as genus host plant; *Abundance:* Rare; *Altitude & Habitat:* 3200m (KK32), 3400m (CH34), Western Himalyan Upper Oak forest, Deciduous Alpine Scrub; *Specimen studied:* 29.v.2012 (3 ex.), 16.vii.2012 (3 ex.).

***342. Xestia bdelygma* (Boursin, 1963) (Plate 29.9)**

1963. *Amathes bdelygma* Boursin, *Forsch. Ber. Nordhein-Westf*., 1170: 59.

1989. *Xestia bdelygma*, Poole, *Lepidopterorum catalogus (n.s.)- Noctuidae* : 118.

1995. *Xestia bdelygma* Boursin, *In* Haruta**:** *Moths of Nepal*, 4: 54.

Distribution: India (Uttarakhand-First time record from India), World (China, Nepal); *Size:* 29mm; *Host Plant: Pinus, Rubus, Betula, Picea, Alnus, Primula, Rumex, Abies, Larix, Acer* are recorded as genus host plant; *Abundance:* Abundant; *Altitude & Habitat:* 3300m (CH32), 3400m (CH34), Western Himalayan Birch-Fir forest, Deciduous Alpine Scub; *Specimen studied:* 15.vii.2012 (8 ex.), 16.vii.2012 (11 ex.).

***343. Xestia angara* Hacker & Peks, 1990 (Plate 29.10)**

1990. *Xestia angara* Hacker & Peks, *Esperiana*, 1: 297.

1995. *Xestia angara* Hacker & Peks, *In* Haruta**:** *Moths of Nepal*, 4: 55.

Distribution: India (North India, Himalaya, Uttarakhand), World (Nepal); *Size:* 32mm; *Host Plant: Pinus, Rubus, Betula, Picea, Alnus, Primula, Rumex, Abies, Larix, Acer* are recorded as genus host plant; *Abundance:* Rare; *Altitude & Habitat:* 2600m (TK26), Western Mixed Coniferous Forest; *Specimen studied:* 11.vi.2012 (2 ex.).

***344. Xestia junctura* Moore, 1881 (Plate 29.11)**

1881. *Agrotis junctura* Moore, *Proc. Zool. Soc.*: 351.

1989. *Xestia junctura*, Poole, *Lepidopterorum catalogus (n.s.)– Noctuidae* : 118.

1995. *Xestia junctura* Moore, *In* Haruta**:** *Moths of Nepal*, 4: 70.

Distribution: India (North West Himalaya, Himachal Pradesh), World (Nepal); *Size:* 34mm; *Host Plant: Pinus, Rubus, Betula, Picea, Alnus, Primula, Rumex, Abies, Larix, Acer* are recorded as genus host plant; *Abundance:* Common; *Altitude & Habitat:* 3200m (HD32), 3400m (HD34), 3600m (CH36), Western Himalayan Birch Fir forest, Birch Rhododendron Scrub Forest, Deciduous Alpine Scrub; *Specimen studied:* 13.v.2010 (1 ex.) , 26.vi.2012 (1 ex.), 28.vi.2012 (3 ex.), 16.vii.2012 (1 ex.), 17.vii.2012 (2 ex.).

***345. Estimata clavata* (Hampson, 1907) (Plate 29.12)**

1907. *Episilia clavata* Hampson, *Ann. Mag. Nat. Hist.*, 19: 244.

1995. *Estimata clavata* Hampson, *In* Haruta**:** *Moths of Nepal*, 4: 56.

Distribution: India (Punjab), World (Nepal), New record to Uttarakhand; *Size:* 29mm; *Host Plant: Festuca* of family Graminae is recorded as genus host plant from Europe; *Abundance:* Common; *Altitude & Habitat:* 3400m (CH34), Deciduous Alpine Scrub; *Specimen studied:* 13.v.2010 (6 ex.).

***346. Euxoa hypochlora* Boursin, 1964 (Plate 30.1)**

1964. *Euxoa hypochlora* Boursin, *Veroff. Zool. St. Samml. Munch.*, 8: 10.

1995. *Euxoa hypochlora* Boursin, *In* Haruta**:** *Moths of Nepal*, 4: 56.

Distribution: India (Uttarakhand-First time record from India), World (Nepal, Afghanistan); *Size:* 34mm; *Host Plant: Prunus, Salix, Acer* are recorded as genus host

plant; *Abundance:* Common; *Altitude & Habitat:* 1600m (BH16), 3350m (DV34), Subtropical Pine Broadleaved mix Forest, West Himalayan Birch-Fir forest; *Specimen studied:* 30.ix.2008 (4 ex.), 04.x.2008 (2 ex.), 30.x.2008 (2ex.)

***347. Agrotis ipsilon* (Hüfnagel, 1766) (Plate 30.2)**

1766. *Phalaena ipsilon* Hufnagel, *Berlin. Magazin*., 3(4): 416.

1857. *Agrotis bipars* Walker, *List Spec. Lepid. Insects Colln Br. Mus*., 10: 334.

1898. *Agrotis aureolum* Schaus, *J. N.Y. Ent. Soc.*, 6: 107.

1989. *Agrotis ipsilon*, Holloway, *The Moths of Borneo*, 12: 65.

2013. *Agrotis ipsilon* Hüfnagel, Sivasankaran *et al., Rec. Zool. Surv. India*, 111(3):79-101.

Distribution: India (Throughout including Uttarakhand), World (Asia, Africa, South America, North America, Australia); *Size:* 46mm; *Host Plant:* Polyphagous, *Apium graveolens*, *Arachis hypogaea*, *Beta vulgaris*, *Brassica nigra*, *Brassica oleracea*, *Cedrus deodara* are some of the host plants recorded from India; *Abundance:* Abundant; *Altitude & Habitat:* 1400m (NT14), 1600m (NT16), 2100m (CH20), Subtropical Pine Broadleaved Mix forest, Moist Temperate Deciduous Forest; *Specimen studied:* 01.vi.2009 (4 ex.), 09.v.2010 (2 ex.), 08.v.2011 (3 ex.), 09.v.2011 (2 ex.), 02.v.2011 (4ex.) etc.

XXII J. Unassigned Subfamily

The following species of Noctuidae were not assigned to any subfamily:

***348. Axylia renalis* Moore, 1881 (Plate 30.3)**

1881. *Axylia renalis* Moore, *Proc. Zool. Soc. London* : 341.

1989. *Axylia renalis* Poole, *Lepidopterorum Catalogus, Noctuidae* : 118.

Distribution: India (North West Himalaya, Punjab, Kashmir); *Size:* 46mm; *Host Plant: Sorghum bicolor* from family Gramineae; *Abundance:* Rare; *Altitude & Habitat:* 1400m (NT14), Subtropical Chir Pine Forest; *Specimen studied:* 30.v.2009 (5 ex.), 31.v.2009 (2 ex.).

***349. Bryopolia centralasiae* (Staudinger, 1882) (Plate 30.4)**

1882. *Polia centralasiae* Staudinger, *Stettin ent. Ztg*., 43: 37.

1882. *Hecatera modesta* Moore, *Lep. Atk.* : 125.

1887. *Polia asiatica* Alphéraky, *Stett. Ent. Zeit.* : 169.

1954. *Bryopolia centralasiae*, Boursin, *Bull. Soc. Fonad. Ler. Ent*., 38: 86.

Distribution: India (Kashmir), World (Nepal), New record to Uttarakhand; *Size:* 48mm; *Host Plant: Alnus, Betula, Prunus, Quercus, Acer* are recorded as some of the host plants for the genus; *Abundance:* Rare; *Altitude & Habitat:* 3400m (CW34), Deciduous Alpine Scrub; *Specimen studied:* 13.x.2008 (1 ex.), 14.x.2008 (2 ex.).

***350. Dasypolia atrox* Hacker & Peks 1993 (Plate 30.5)**

1993. *Dasypolia atrox* Hacker & Peks, *In* Ronkay, Yela & Hreblay: *Noctuidae Europaeae, Hadeninae II*, 5:201.

1995. *Dasypolia atrox* Hacker & Peks, *In* Haruta**:** *Moths of Nepal*, 4: 63.

Distribution: India (North West India), World (Nepal); *Size:* 72mm; *Host Plant: Aegopodium, Angelica, Heracleum* of family Umbelliferae are recorded as some of the host plants for the genus; *Abundance:* Uncommon; *Altitude & Habitat:* 3400m (DV34), Deciduous Alpine Scrub; *Specimen studied:* 04.x.2008 (3 ex.), 23.x.2008 (1 ex.).

***351. Anaplectoides perviridis* (Warren, 1912) (Plate 30.6)**

1912. *Eurois perviridis* Warren, *Novit. Zool*., 19: 9.

1993. *Anaplectoides perviridis*, Fibiger, *Noctuidae Europaeae, Noctuinae II*, 2: 181.

1994. *Anaplectoides perviridis* Warren, *In* Haruta**:** *Moths of Nepal*, 3:101.

Distribution: India (Uttarakhand-First time record from India), World (Nepal); *Size:* 62mm; *Host Plant: Betula, Alnus, Rubus, Salix, Rumex* are some of the host plants recorded for the genus; *Abundance:* Common; *Altitude & Habitat:* 2400m (TK24), 2600m (CH26), 3050m (CH30), 3600m (CH36), Western Mixed Coniferous forest, Western Himalayan Birch-Fir forest, Deciduous Alpine Scrub; *Specimen studied:* 10.vi.2012 (1 ex.), 10.vii.2012 (1 ex.), 13.vii.2012 (3 ex.), 17.vii.2012 (1 ex.), 19.vii.2012 (1 ex.).

Conclusion

The present study, a systematic inventory of moths, is the first of its kind in Gangotri Landscape and is one of the few studies on moth communities in Western Himalayan Landscape in India. The study added 19 species to the list of moths recorded from India. Besides, it also recorded 87 species first time from state Uttarakhand, which were previously recorded from other extremes of Himalaya like north-eastern hills. The state being comparatively well explored previously for moth diversity, these new records signify the importance of more such works in the unexplored parts of this mountainous state. Concentrating on multiple families instead of a few selected ones ensured an overall picture of moth assemblage in a typical Western Himalayan gradient. The species compilation with their specific altitude and habitat information produces an initial baseline data which if accessible to wide range of users, will accelerate the rate of description, documentation and understanding of Himalayan moth diversity. Such kind of faunistic baseline data is a rich source of biodiversity information which produces first step in a sound conservation strategy for the target site as well as the taxa concerned. Taxonomic knowledge of this highly diverse faunal element, which is extremely important to maintain ecological integrity of any particular landscape but surely has inadequate information base, will enable scientifically informed bio-monitoring in future, that requires increased accuracy and species level identification to detect the subtle environmental changes associated with human impact as well as climate change.

Plate 1: Tineidae(1-2), Pterophoridae(3-5), Tortricidae(6-8), Pyralidae(9-12)



1. Opogona flavofasciata



2. Opogona theobroma



3. Buckleria paludum



4. Deuterocopus socotranus



5. Diacrotricha fasciola



6. Clepsis sp.



7. Homana sp



8. Dynatocephala omophaea



9. Macalla sp.



10. Lista haraldusalis



11. Epicrocis hilarella



12. Dyloxia fimbriata

Plate 2: Pyralidae(1-4), Crambidae(5-12)



1. Endotricha olivacealis



2. Orybina flaviplaga



3. Sacada discinota



4. Orthopygia igniflualis



5. Cymoriza ustalis



6. Eoophyla peribocalis



7. Herpetogramma luctuosale



8. Hyaloplaga pulchralis



9. Euchromius ocellea



10. Ancylolomia sp.



11. Cirrhochrista brizoalis



12. Cotachena histricalis

Plate 3: Crambidae(1-12)



1. Dichocrocis definita



2. Dysallacta negatalis



3. Endocrossis flavibasalis



4. Glyphodes crithealis



5. Glyphodes bivitralis



6. Goniorhynchus signatalis



7. Lamprosema commixta



8. Nomophila noctuella



9. Omiodes noctesense



10. Pleuroptya balteata



11. Pleuroptya quadrimaculalis



12. Pleuroptya ruralis

Plate 4: Crambidae(1-7), Zygaenidae(8), Cossidae(9-10), Limacodidae(11-12)



1. Polygrammodes sabelialis



2. Sameodes cancellalis



3. Spoladea recurvalis



4. Syllepte verecunda



5. Syngamia alsidicalis



6. Terastia egialialis



7. Dichocrocis punctiferalis



8. Chalcosia suffusa



9. Xyleutes strix



10. Zeuzera multistrigata



11. Altha subnotata



12. Chalcoscelides castaneipars

Plate 5: Limacodidae(1-4), Uraniidae(5-7), Geometridae(Ennominae)(8-12)



1. Miresa albipuncta



2. Phocoderma velutina



3. Scopelodes unicolor



4. Scopelodes venosa



5. Micronia aculeata



6. Orudiza protheclaria



7. Epiplema bicaudata



8. Abraxas peregrina



9. Abraxas irrorata



10. Abraxas sylvata



11. Abraxas picaria



12. Anonychia lativitta

Plate 6: Ennominae (Geometridae)(1-12)



1. Anonychia violacea



2. Biston bengaliaria



3. Biston falcata



4. Buzura suppressaria



5. Psilalcis inceptaria



6. Phthonandria atrilineata



7. Menophra bicornuta



8. Menophra subplagiata



9. Medasina interruptaria



10. Medasina albidaria



11. Medasina cervina



12. Thinopteryx crocoptera

Plate 7: Ennominae (Geometridae)(1-12)



1. Elphos pardicelata



2. Erebomorpha fulguraria



3. Fascellina plagiata



4. Hirasa muscosaria



5. Ourapteryx convergens



6. Ourapteryx sciticaudaria



7. Ourapteryx ebuleata



8. Arichanna tenebraria



9. Gnophos albidior



10. Heterolocha phaenicotaeniata



11. Hypomecis ratotaria



12. Loxaspilates hastigera

Plate 8: Ennominae (Geometridae)(1-12)



1. *Semiothisa nora*



2. *Semiothisa sufflata*



3. *Xandrames latiferaria*



4. *Odontopera heydena*



5. *Odontopera lentiginosaria*



6. *Odontopera obliquaria*



7. *Odontopera kametaria*



8. *Heterocallia temeraria*



9. *Peratophyga hyalinata*



10. *Percnia belluaria*



11. *Plagodis inustaria*



12. *Plagodis reticulata*

Plate 9: Ennominae (Geometridae)(1-12)



1. Pseudomiza cruentaria



2. Pseudopanthera himaleyica



3. Psyra similaria



4. Psyra debilis



5. Psyra falcipennis



6. Psyra angulifera



7. Hyperythra lutea



8. Ophthalmitis herbidaria



9. Opisthograptis sulphurea



10. Opisthograptis tridentifera



11.Sirinopteryx rufivinctata



12. Stenorumia sp.

Plate 10: Ennominae(1-6), Geometrinae(7-12) (Geometridae)



1. Tanaoctenia haliaria



2. Luxiaria sp.



3. Zeheba sp.



4. Krananda sp.



5. Lomographa sp.



6. Heterostegane subtessellata



7. Agathia hemithearia



8. Chlorissa gelida



9. Chlorissa tritonaria



10. Chlorissa distinctaria



11. Chlorochaeta inductaria



12.Chlorochaeta quadrinotata

Plate 11: Geometrinae (Geometridae)(1-12)



1. *Chlorochaeta pictipennis*



2. *Comostola subtiliaria*



3. *Anisozyga gavissima*



4. *Herochroma cristata*



5. *Aporandria specularia*



6. *Mixochlora vittata*



7. *Ornithospila avicularia*



8. *Pingasa rubicaunda*



9. *Pingasa alba*



10. *Pingasa ruginaria*



11. *Tanaorhinus reciprocata*



12. *Thalassodes veraria*

Plate 12: Larentiinae (Geometridae)(1-12)



1. Photoscotocia miniasota



2. Photoscotosia multilinea



3. Photoscotosia amplicata



4. Photoscotosia metachryseis



5. Laciniodes plurilinearia



6. Cidaria aurata



7. Docirava aequilineata



8. Docirava pudicata



9. Ecliptopera postpallida



10. Electrophaes recta



11. Euphyia coangulata



12. Eupithecia rajata

Plate 13: Larentiinae (Geometridae)(1-12)



1. Eustroma chalcoptera



2. Hydrelia bicolorata



3. Stamnodes pamphilata



4. Trichopterigia rufinotata



5. Triphosa rubrodotata



6. Colostygia albigirata



7. Perizoma albofasciata



8. Perizoma seriata



9. Euphyia stellata



10. Xanthorhoe hampsoni



11. Venusia crassisigna



12. Venusia roseicosta

Plate 14: Larentiinae(1-4), Sterrhinae(5-11), Desmobathrinae(12)



1. Heterothera dentifasciata



2. Dysstroma sp.



3. Chartographa sp.



4. Rheumaptera sp.



5. Scopula pulchellata



6. Timandra griseata



7. Rhodostrophia pelloniaria



8. Rhodometra sacraria



9. Problepsis vulgaris



10. Problepsis albidior



11. Chrysocraspeda olearia



12. Eumelea rosalia

Plate 15: Drepanidae(1-12)



1. *Agnidra discispilaria*



2. *Auzata semipavonaria*



3. *Drepana pallida*



4. *Tethea oberthueri*



5. *Teldenia vestigiata*



6. *Cyclidia substigmaria*



7. *Gaurena dierli*



8. *Habrosyne conscripta*



9. *Macrocilix mysticata*



10. *Nordstromia duplicata*



11. *Oreta pavaca*



12. *Thyatira batis*

Plate 16: Bombycoidae: Bombycidae(1-2), Euptreotidae(3-6), Lasiocampidae(7-12)



1. Triuncina religiosae



2. Mustilia sphingiformis



3. Apona caschmirensis



4. Eupterote sp. Morph.1



5. Eupterote sp. Morp.2



6. Eupterote sp. Morph.3



7. Trabala vishnou ♂



8. Trabala vishnou ♀



9. Estigena pardalis



10. Euthrix laeta



11. Malacosoma indicum



12. Paralebeda plagifera

Plate 17: Brahmaeidae(1), Saturniidae(2-5), Sphingidae(6-12)



1. Brahmaea wallichii



2. Antheraea assamensis



3. Caligula thibeta



4. Antheraea paphia



5. Loepa katinka



6. Acosmeryx anceus



7. Daphnis nerii



8. Hippotion boerhaviae



9. Hippotion rosetta



10. Macroglossum bombylans



11. Rhopalopsyche nycteris



12. Theretra alecto

Plate 18: Sphingidae(1-10), Notodontidae(11-12)



1. Theretra nessus



2. Theretra oldenlandiae



3. Nephele comma



4. Ambulyx sp.



5. Amplypterus panopus



6. Clanis stenosema



7. Leucophlebia lineata



8. Marumba sperchius



9. Psilogramma increta



10. Agrius convolvuli



11. Allodonta sikkima



12. Cyphanta xanthochlora

Plate 19: Notodontidae(1-12)



1. Bireta longivitta



2. Formofentonia orbifer



3. Gazalina apsara



4. Oligoclona chrysolopha



5. Ginshachia gemmifera



6. Homocentridia concentrica



7. Neodrymonia sp.



8. Phalera grotei



9. Phalera sangana



10. Pheosia fasciata



11. Ptilodon saturata



12. Semidonta biloba

Plate 20: Notodontidae(1-3), Lymantriinae(4-12)



1. Rachia plumosa



2. Damata longipennis



3. Tarsolepis remicauda



4. Arctornis comma



5. Somena scintillans



6. Artaxa vitellina



7. Laelia exclamationis



8. Dasychira cerebosa



9. Lymantria concolor



10. Lymantria mathura



11. Himala argentea



12. Leucoma clara

Plate 21: Arctiinae (Erebidae) (1-12)



1. *Amsacta lactinea*



2. *Areas galactina*



3. *Areas imperialis*



4. *Argina astrea*



5. *Asura calamaria*



6. *Chrysorabdia bivittata*



7. *Chrysorabdia viridata*



8. *Creatonotos gangis*



9. *Creatonotos transiens*



10. *Agylla beema*



11. *Agylla prasena*



12. *Eilema caniola*

Plate 22: Arctiinae (Erebidae) (1-12)



1. Eilema antica



2. Estigmene quadriramosa



3. Utetheisa lotrix



4. Macrobrochis pallens



5. Miltochrista cuneonotatas



6. Panaxia principalis



7. Panaxia similis



8. Sidyma albifinis



9. Spilosoma melli



10. Spilosoma casigneta



11.Spilosoma erythrozonata



12. Spilosoma obliqua

Plate 23: Arctiinae(1-9), Catocaliinae(10-12) (Erebidae)



1. Spilosoma strigatula



2. Spilosoma unifascia



3. Spilosoma punctaria



4. Spilosoma melanostigma



5. Spilosoma leopardina



6. Chionaema coccinae



7. Chionaema peregrine



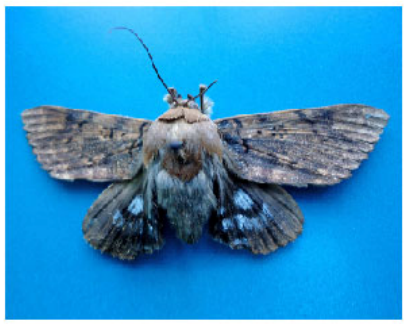
8. Chionaema signa



9. Ceryx imaon



10. Catocala armandi



11. Arcte coerula



12. Bastilla acuta

Plate 24: Catocaliinae(1-9), Calpinae(10-12) (Erebidae)



1. Bastilla crameri



2. Catocala armandi



3. Dysgonia latifascia



4. Hypopyra vespertilio



5. Ophiusa tirhaca



6. Mocis discios



7. Spirama retorta



8. Lagoptera juno



9. Trigonodes hyppasia



10. Bamra lepida



11. Calesia haemorrhoa



12. Cymatophoropsis sinuata

Plate 25: Calpinae(1-4), Euteliidae(5), Nolidae(6-8), Noctuidae(9-12)



1. Ericeia pertendens



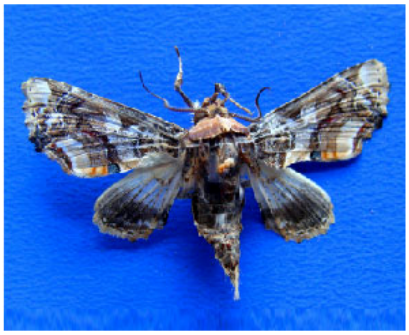
2. Lacera procellosa



3. Oraesia emarginata



4. Othreis fullonia



5. Eutelia adulatrix



6. Gabala argentata



7. Risoba prominens



8. Xanthodes transversa



9. Autographa nigrisigna



10. Autographa purpureofusa



11. Chrysodeixis acuta



12. Erythroplusia pyropia

Plate 26: Noctuidae(1-12)



1. Plusiopalpa sp.



2. Thysanoplusia orichalcea



3. Pseudeustrotia dimera



4. Auchmis indica



5. Diphtherocome fasciata



6. Diphtherocome pallida



7. Nacna malachite



8. Cucullia pullata



9. Valeriodes heterocampa



10. Amphipyra monolitha



11. Amphipyra cupreipennis



12. Mimeusemia peshwa

Plate 27: Noctuidae(1-12)



1. Episteme lectrix



2. Aegocera bimacula



3. Helicoverpa armigera



4. Aspila peltigera



5. Pyrrhia umbra



6. Anapoma albicosta



7. Apamea aquila



8. Callopistria albolineola



9.Callopistria placodoides



10. Callopistria repleta



11. Callopistria rivularis



12. Euplexia plumbeola

Plate 28: Noctuidae(1-12)



1. Euplexia semifascia



2. Euplexia tibetensis



3. Ebertidia haderonides



4. Haderonia culta



5. Heliophobus texturata



6. Leucania compta



7. Lophotyna albosignata



8. Phlogophora subpurpurea



9. Polia scotochlora



10. Prospalta leucospila



11. Spodoptera littoralis



12. Chersotis sp.

Plate 29: Noctuidae(1-12)



1. Diarsia albipennis



2. Diarsia nigrosigna



3. Hermonassa consignata



4. Hermonassa incisa



5. Hermonassa sinuata



6. Ochropleura triangularis



7. Ochropleura flammatra



8. Trichoridia hampsoni



9. Xestia bdelygma



10. Xestia angara



11. Xestia junctura



12. Estimata clavata

Plate 30: Noctuidae(1-6)



1. Euxoa hypochlora



2. Agrotis ipsilon



3. Axylia renalis



4. Bryopolia centralasiae



5. Dasypolia atrox



6. Anaplectoides perviridis

CHAPTER IV

ALPHA DIVERSITY PATTERN OF MOTH ASSEMBLAGES IN DIFFERENT ALTITUDE AND VEGETATION ZONES

4.1 Introduction

Knowledge of spatial diversity patterns is a key prerequisite for the development of effective strategies in biodiversity conservation (Cabeza *et al.* 2004, Gaston 2000, Lamoreux *et al.* 2006). While such knowledge is already widely available for many vertebrate and plant taxa, it is less so in case of invertebrates, especially insects. On current knowledge, insects are by far the most species-rich group, with their estimated share in global macro-biodiversity exceeding 50%, but huge knowledge gaps currently prevail in relation to their diversity and distribution. Not least due to their enormous species richness, insects perform a multitude of fundamental roles in ecosystems. It seems logical to conclude that the great knowledge gaps relating to insect diversity, their distribution patterns and the factors causing these patterns need to be addressed to enable the effective conservation of the global species pool and ecosystem functioning (Leather & Quicke 2010). Lepidoptera are among the most speciose and taxonomically tractable groups of insects and have important functional roles in forests as selective herbivores, pollinators, detritivores, and food resource for organisms at higher trophic levels. Furthermore, the Lepidoptera show promise as indicators of forest health (Kitching *et al.* 2000) and as surrogates for the diversity of other insect groups such as the Hymenoptera (Kerr *et al.* 2000). Thus, the Lepidoptera comprise a critical fauna for answering questions concerning spatial scale and biodiversity in forests.

Another interesting aspect to study the spatial pattern of highly diverse insect assemblage is along altitudinal gradient in a mountain habitat. Mountains offer a unique scenario to unravel the influence of environment on the spatial variation in the taxonomic composition of insect species assemblages. They represent a kind of ‘natural experiment’ whereby to examine the extent to which substantial changes in environment may be associated with evolutionary adaptation of organisms and biodiversity maintenance over

relatively short spatial distances (Lomolino 2001, Ko¨rner 2007). Main altitudinal climatic trends usually co-vary with other factors at local and regional scale, such as variation in vegetation, regional climatic trends (e.g. seasonality and precipitation), land surface orientation and soil characteristics (Ko¨rner 2007). Nonetheless, although it is well documented that insect species composition varies along altitudinal gradients (e.g. dung beetles in South Africa: Davis *et al.* 1999; geometrid moths in Ecuador: Brehm & Fiedler 2003; dung beetles in the Alps: Errouissi *et al.* 2004; ground spiders in Greece: Chatzaki *et al.* 2005; beetles in Spain: Gonza´lez- Megıas *et al.* 2008), the extent to which local and regional factors influence the spatial variation in species composition is still inconclusive. In this first study of its kind in the Himalaya, the diversity of a "mega-diverse" group of herbivorous insects, nocturnal Lepidoptera in a Western Himalayan altitudinal gradient was investigated. This chapter focuses on patterns of intra-habitat diversity (alpha-diversity) along an altitudinal gradient ranging from 1400m to 3600m. The extensive coniferous, broadleaf and mixed forests and alpine grassland patches, with intermediate subalpine forests of this landscape is one of the last resort for many naturally occurring insect assemblages.

Samples taken from tropical arthropod communities are always a methodological challenge for diversity measures. They are almost always incomplete and the numbers of specimens available for analyses often vary considerably between sites (e.g. Schulze & Fiedler 2002). Moreover, tropical arthropod communities are characterized by a high proportion of rare species that cannot be excluded as artefact or a group of marginal importance (Price *et al.* 1995, Novotný & Basset 2000). So, suitable diversity measures should be able to discriminate between samples of different diversity and be independent of sample size in order to avoid misleading bias in the results. Here I present a description of diversity and species composition as well as contrast between sites found in different habitat types within a Himalayan altitudinal gradient in Gangotri Landscape Area. Analyses were carried out at the level of altitude as well as at the level of different habitats found throughout the gradient. The aim of the study was to investigate the moth species composition in different habitat types within a Himalayan temperate ecosystem and to compare sites in terms of their family and species composition. The objective was to describe the diversity and characteristics of species assemblages found in different

habitat types. Using this information, the communities of moth assemblages in different vegetation types was compared and the possible effect of habitat characteristics on species occurrence and observed pattern was explained.

4.2 Materials and Methods

4.2.1 Sampling Design

A stratified random sampling framework was employed, i.e., random samples were taken from a gradient or stratum ranging from the lowest to the highest altitude zones at every 200m. Moths were sampled in sites across four altitudinal zones; viz. Subtropical zone, 1400m-1900m, Moist Temperate Zone, 1900-2400m, Dry Temperate Zone, 2400m-2900m and Subalpine Zone, 2900m-3400m, and five vegetation types that contained contiguous and relatively homogeneous areas of each vegetation community. These were identified subjectively based on apparent differences in vegetation type, physiographic and soil characteristics according to Champion and Seth (1968), viz. Subtropical Pine Broadleaved Mixed forest, Moist Temperate Deciduous forest, Western Mix Coniferous forest, Western Himalayan Upper Oak forest and Subalpine forest.

Sampling occurred during five years (2008-2012) in three distinct seasons viz, spring (April-May), summer and monsoon (June-July) and post-monsoon (October-November). Moths were collected using a light trap running for 4 hours, in two sessions at a particular site for two consecutive nights, e.g. first night from 8 pm to 12'O clock midnight and second night from 12'o clock midnight to 4 am. This was to ensure record all the moths flying in a particular site or habitat in different quarters of night. Light traps were set using a solar powered lantern equivalent to 80 Watt white Actinic bulb or gas petromax equivalents to 160 Watt Mercury Vapour (MV) bulb. The light sources or combination of them were placed in front of a white 10′ x 6′ cloth sheet hung between two vertical poles in such a way that it touches the surface and extends forward over the ground slightly. This was to ensure enough resting place for an individual moth after they were attracted to light for live photography and collection. Some species were very active around a light trap and never used to sit on the white sheet. They were collected using insect net. The specimens were first sorted into morphospecies and later identified with the help of the

available literature and by comparison with the reference collections available at the Zoological Survey of India, Jabalpur and Kolkata. The classification used mainly follows Hampson (1892, 1894, 1895 and 1896) and subsequent changes in the families based on Kirstensen (1999). The voucher specimens were submitted to the national repository at the Zoological Survey of India.

4.2.2 Data Analysis

Moths captured by light trapping at a single site for 2-3 nights were pooled for quantitative analysis. The species richness of moths of each vegetation zone, as well as of the regional data set, was measured according to the following four methods.

(i) Species number: The absolute species number can never be the measure of diversity, particularly for such hyperdiverse taxa such as moths as it never incorporates different sampling sizes or efforts (Colwell & Coddington 1994).

(ii) To avoid sample size dependence, using an extrapolation method, non-parametric estimators such as Chao 1 and Jackknife were estimated. Chao1 gives an estimate of the absolute number of species in an assemblage based on the number of rare species (singletons and doubletons) in a sample. Chao1 estimation of species richness is recommended for inventory completeness values, completeness being the ratio between the observed and estimated richness (Sørensen *et al.* 2002, Scharff *et al.* 2003). Jackknife estimators in general, and Jackknife2 in particular, have been found to perform quite well in extrapolation of species richness, with greater precision, less bias and less dependence on sample size than other estimators (Palmer 1990, 1991, Baltanás 1992, Brose *et al.* 2003, Petersen *et al.* 2003, Chiarucci *et al.* 2003).

(iii) An individual based rarefaction curve was used to obtain an idea about the species richness and sampling success across different habitat categories. This method is particularly useful if assemblages are sampled with a different intensity or success. These curves standardize different data sets on the basis of the number of individuals and not on the number of samples. The curves were rarefied to the lowest number of individuals recorded in a vegetation type (198) to ensure valid comparisons of species richness between different sites (Gotelli & Colwell 2001). Rarefaction was used as a diversity

index because it considers the number of individuals collected and species richness (Magurran 2004), allows comparison of diversity between sites with a similar sample size, and, by showing the rate of new species accumulation, allows verification that enough samples were collected to make proper comparisons of diversity (Gotelli & Colwell 2001, Magurran 2004, Buddle *et al.* 2005).

(iv) The most reliable method for calculating the alpha diversity when it is impossible to obtain a complete inventory due to the presence of maximum singletons and doubletons is the use of Fisher's alpha of the log series distribution (Fisher *et al.* 1943). It has been widely used in tropical arthropod diversity studies. It is efficient in discriminating between habitats and is mainly influenced by the frequencies of species of medium abundance (Kempton & Taylor 1974).

The similarity across sites was depicted as Bray-Curtis similarities (Krebs 1989), using species composition. Multidimensional scaling (MDS) plots were constructed based upon similarity values of species composition across habitat types in program PAST (Hammer *et al.* 2007). Analysis of similarities, ANOSIM (Clarke 1993) was performed between each pair of habitat types to determine whether there were significant differences between the moth assemblages in the five main habitat types. The ANOSIM procedure is a nonparametric permutation procedure applied to rank similarity matrices underlying sample ordinations (Clarke 1993). This method generates a global R-statistic, which is a measure of the distance between groups. An R-value that approaches one indicates strongly distinct assemblages, whereas an R-value close to zero indicates that the assemblages are barely separable (Clarke 1993). These R-values were used to compare moth assemblages between habitat types. Where ANOSIM revealed significant differences between groups, SIMPER analyses were used to identify those species that contributed most to the observed assemblage differences (Clarke & Gorley 2001). Similarity percentages (SIMPER) allowed identification of species and guild important in discriminating between groups that differed significantly from each other. Cumulative contributions were cut arbitrarily at 50%. The species with the highest dissimilarity to standard deviation ratios were identified as good discriminators for each comparison (Clarke 1993). ANOSIM and SIMPER were performed in program PAST.

4.3 Result

The aim here was to look into the diversity pattern in both different altitudinal zones and in various broad habitat categories found within a typical Western Himalayan landscape. Whereas the wide altitudinal range was subdivided into four groups from low to high, the habitats were categorized on the basis of dominant vegetation characteristics.

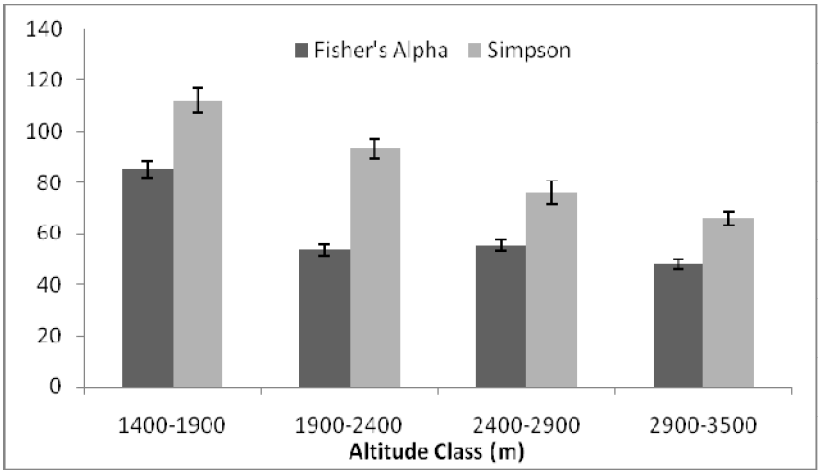
4.3.1 Species and Individuals

Altogether 96 trapping nights were performed to record 670 morphospecies and 10,869 individual moths representing 22 families. The number of moth species and the number of individuals trapped varied considerably between the altitude classes and different vegetation zones.

4.3.2 Diversity in different Altitudinal Level

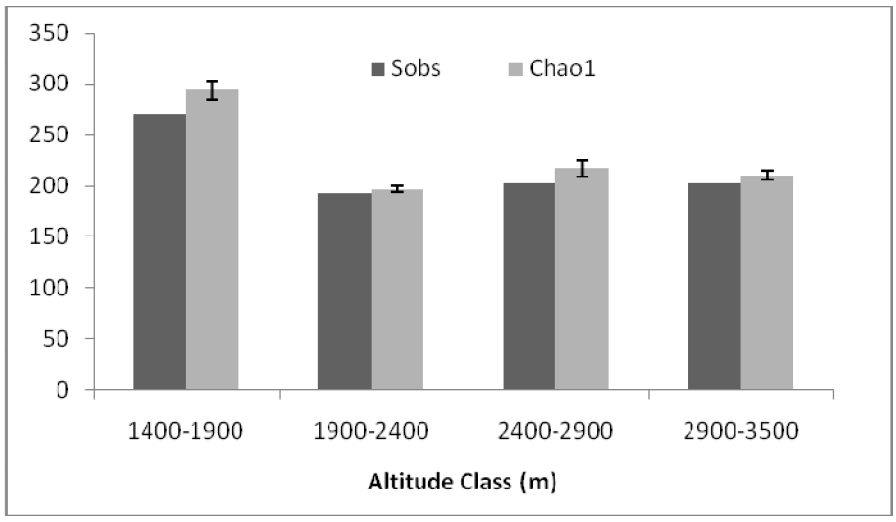
The diversity was maximum in lower altitude zone and decreased gradually in three subsequent zones (Fig 4.1). Fisher's alpha was highest, 85.37±3.31 in 1400m-1900m, and lowest 48.02±1.75 in 2900-3400m. Simpson's Index was 112.14±4.56, 93.27±3.84, 76.04±4.73, 65.89±2.74 in 1400-1900m, 1900-2400m, 2400-2900m and 2900-3400m respectively.

Fig 4.1: Diversity indices of moth assemblage in different altitude classes in GLA (2008-2012)



As nonparametric estimator of asymptotic species richness, Chao1 was used which is based on the frequencies of rare species in the sample. Observed and estimated species richness using Chao1 did not vary much, signifying that sampling was almost complete at local scale. Observed species richness and estimated species richness (Fig 4.2) was 271, 293.54±9.37 for 1400m-1900m, 193, 196.76±3.07 for 1900m-2400m, 203, 217.8±8.26 for 2400m-2900m and 203, 211.09±5.17 for 2900m-3500m. The percent completeness, represented as ratio between observed species richness and estimated species richness was 92%, 98%, 93%, and 96% respectively for the four altitudinal zones studied.

Fig 4.2: Number of observed species (Sobs) and estimated species richness (Chao1) of moth assemblage in different altitude classes in GLA (2008-2012)



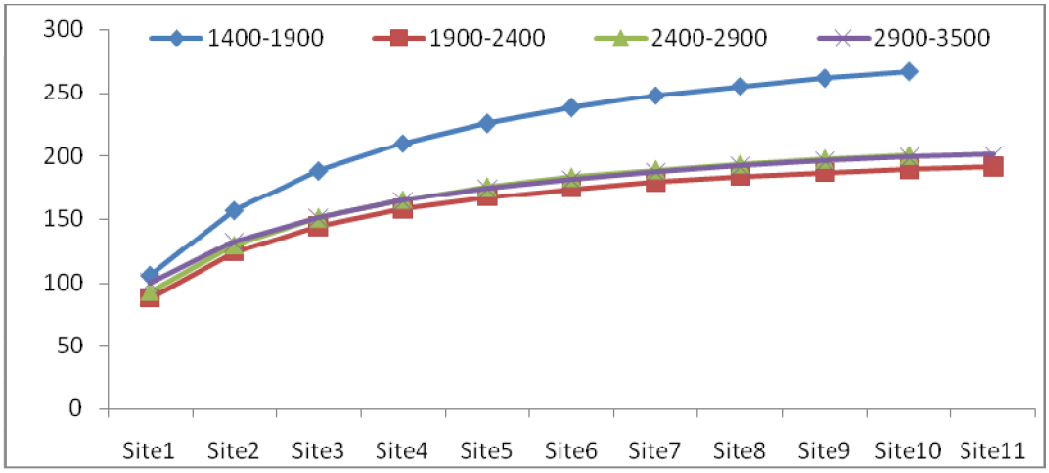
As all the sites were sampled with different intensities, the rarefaction method was used as a suitable alternative for the diversity measure. Although rarefaction can be useful, it is very sensitive to the underlying pattern of species abundance, such that collections with much lower species evenness will often give lower estimates of species diversity than those with very even abundances, regardless if species diversities in reality are equal. I used three rarefaction curves to compare diversity between four altitudinal zones, viz. Coleman Rarefaction curve (Fig 4.3a), which is an empirical measure of the rarefied number of individuals, using Chao 1 as nonparametric species richness estimator (Fig 4.3b), and individual based rarefaction curves (Fig 4.3c) to see the species richness and

sampling success across different altitudinal zones. Curves were rarefied to the lowest number of individuals recorded in an altitude zone (198) to ensure valid comparisons.

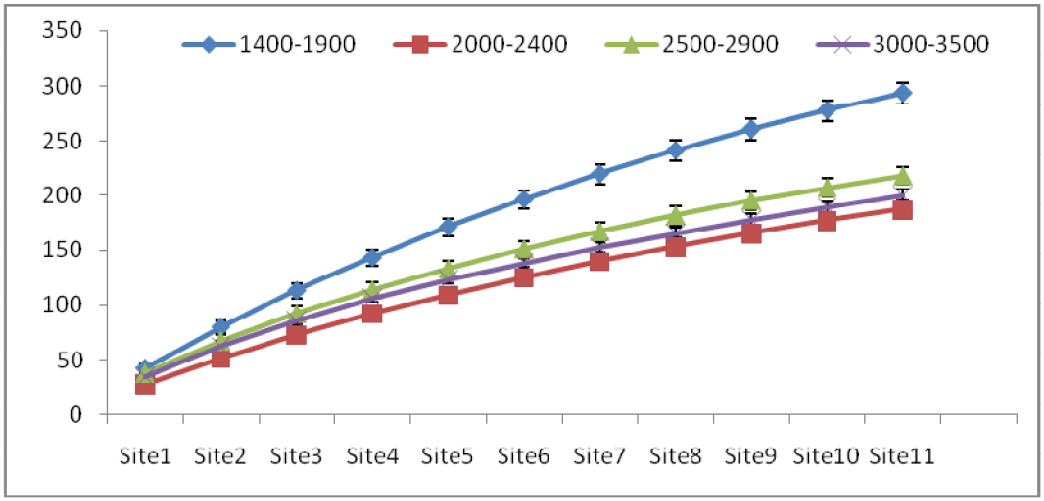
While asymptotes were reached for all the altitudinal zones in Coleman rarefaction curves showing highest species diversity in 1400-1900m zone and almost similar diversity pattern in subsequent zones, while in other two species accumulation curves, asymptotes were not reached in for any of the four zones, showing that a complete inventory had not been achieved. All the curves lay within a relatively narrow band, and no clear pattern was visible. Sampling inadequacy was evident in all the altitudinal zones, recoding highest number of species and individuals in 1400-1900m zone and in the 3000-3500m zone respectively.

Fig 4.3: Rarefaction curves of moth assemblage in different altitude classes in GLA (2008-2012) (a) Coleman, (b) Estimated species richness (Chao1) and (c) individual based

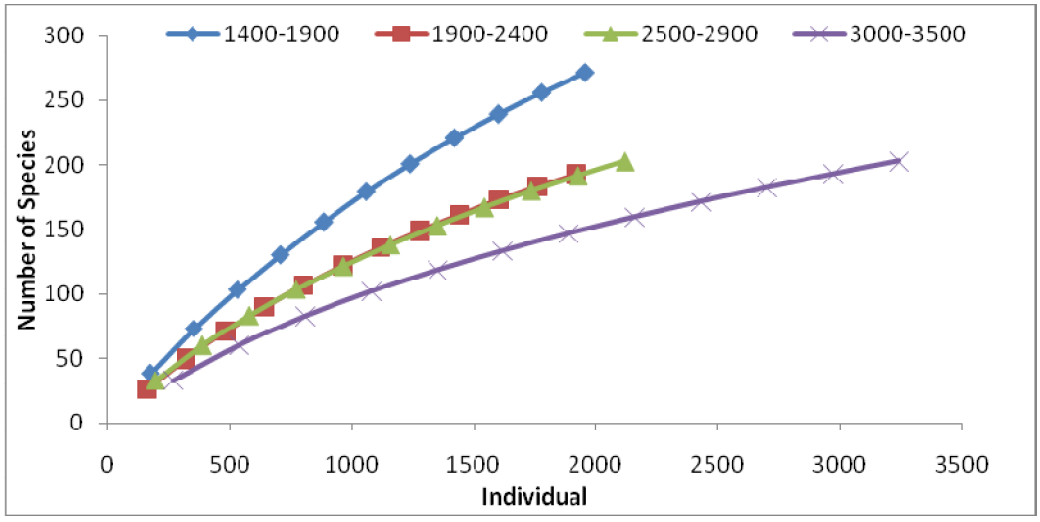
(a)



(b)



(c)

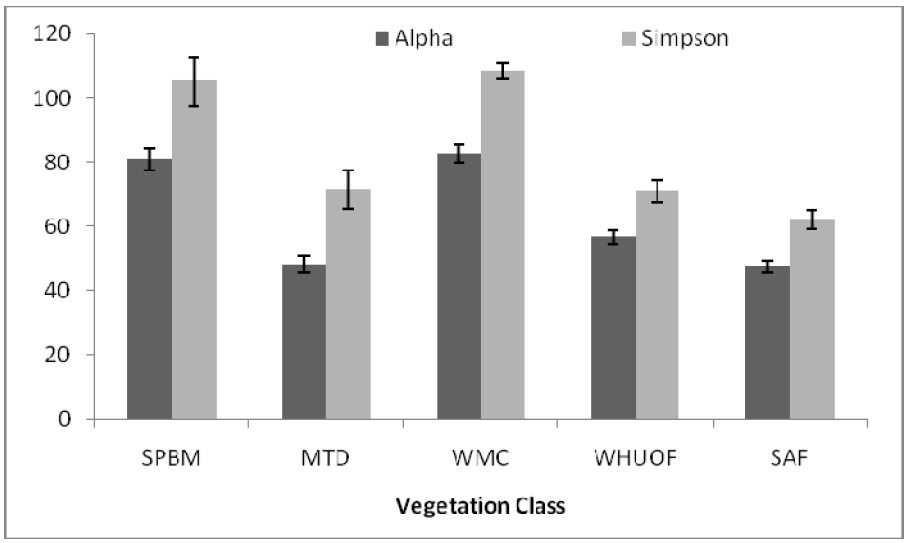


4.3.3 Diversity in different Vegetation Types

Light trappings were done in total 38 sites which were grouped together in five main vegetation types based on dominant tree species according to Champion and Seth: (i) Subtropical Pine Broadleaved Mix forest (SPBM) which included Subtropical Chir Pine forest and Pine Broadleaved mix forest, (ii) Moist Temperate Deciduous forest (MTD) which included Riverine forests also, (iii) Western Mixed Coniferous forest (WMC) including Mohru Oak forests, (iv) Western Himalayan Upper Oak forest (WHUOF) which included Kharsu oak forests and Himalayan Temperate Parkland, (v) Subalpine Forest (SAF) which included Western Himalayan Birch-Fir forest, Birch-Rhododendron Scrub forest and Deciduous Alpine Scrubs.

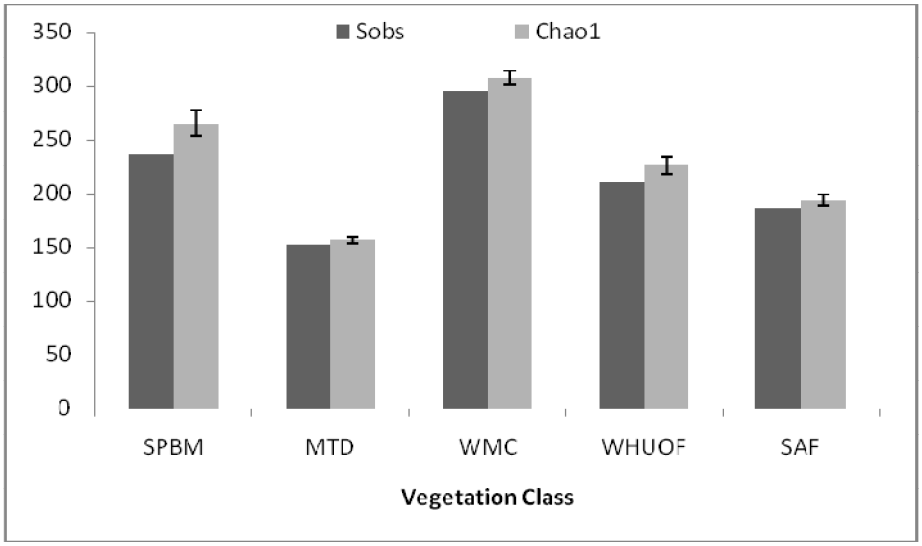
Alpha diversity (Fisher's alpha) and Simpson's index were highest (Fig 4.4) in Subtropical Pine Broadleaved Mix forest (80.89±3.56, 105.18±7.56) and Western Mix Coniferous forest (82.66±2.84, 108.23±2.4) and lowest in Subalpine forest (47.47±1.9, 62.36±2.94). Almost similar diversity patterns were recorded in Moist Temperate Deciduous forest (48.21±2.51, 71.43±5.74) and Western Himalayan Upper Oak forest (56.69±2.24, 70.97±3.38).

Fig 4.4: Diversity indices of moth assemblage in different vegetation types in GLA (2008-2012)



At habitat level also, relatively, sampling success was achieved with no major difference in observed species richness and estimated species richness using Chao 1. Observed and estimated species richness was highest (Fig 4.5) in Western Mixed Coniferous forest (294, 306.99±6.11) and lowest in Moist Temperate Deciduous forest (152, 156.26±3.24). The values for observed and estimated species richness for other vegetation types were like 237, 264.84±11.56 for Subtropical Pine Broadleaved mix forest, 210, 226.13±8.29 for Western Himalayan Upper Oak forest and 187, 193.86±4.67 for Subalpine forest.

Fig 4.5: Number of observed species (Sobs) and estimated species richness (Chao1) of moth assemblage in different vegetation types in GLA (2008-2012)

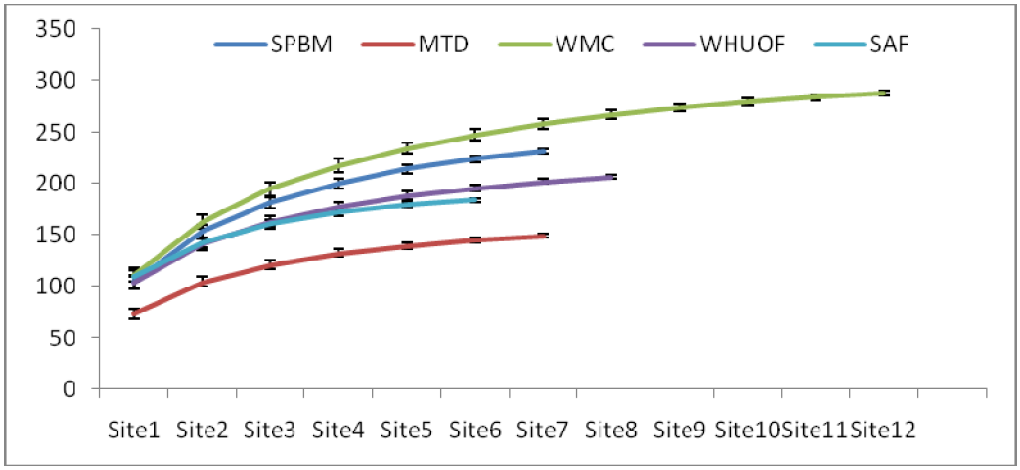


Coleman rarefaction curves reached almost asymptotes in all the vegetation types considered (Fig 4.6a), while curves were never asymptotic in rarefactions using Chao 1 (Fig 4.6b) and individual based (Fig 4.6c). In all three rarefactions, Western Mixed Coniferous forest had highest species diversity and highest number of individuals as well.

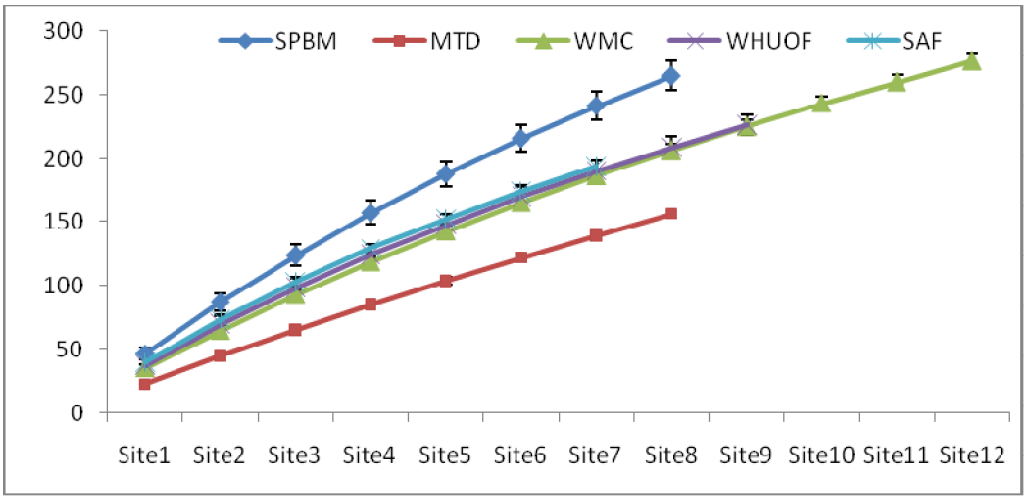
Fig 4.7 shows individual based rarefaction curves for all the plots sampled in entire Gangotri Landscape area. Plot level differences in number of species and individuals captured were apparent and in majority of the plot level curves, asymptotes were reached and highest number of species and individuals were recorded in T2800A and in CH2400 respectively.

Fig 4.6: Rarefaction curves of moth assemblage in different vegetation types in GLA (2008-2012) (a) Coleman, (b) Estimated species richness (Chao1) and (c) individual based.

(a)



(b)



(c)

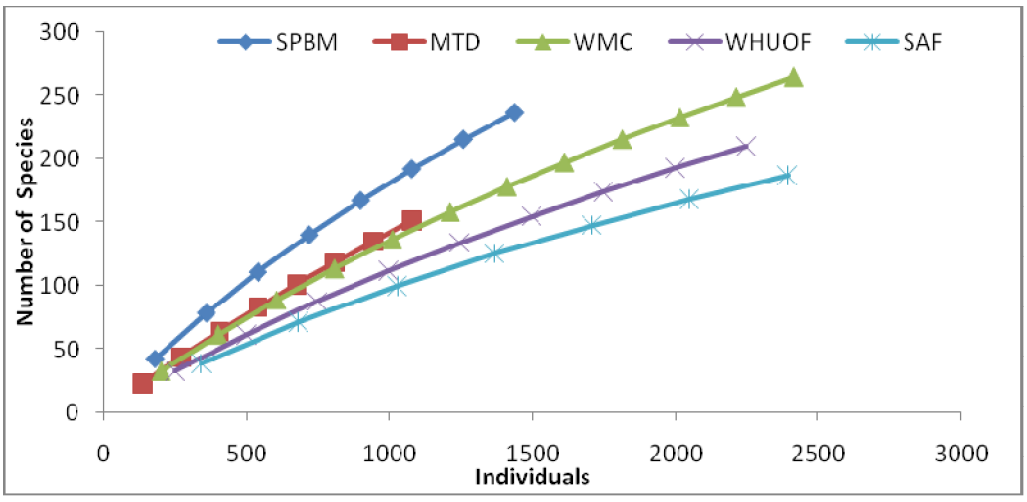
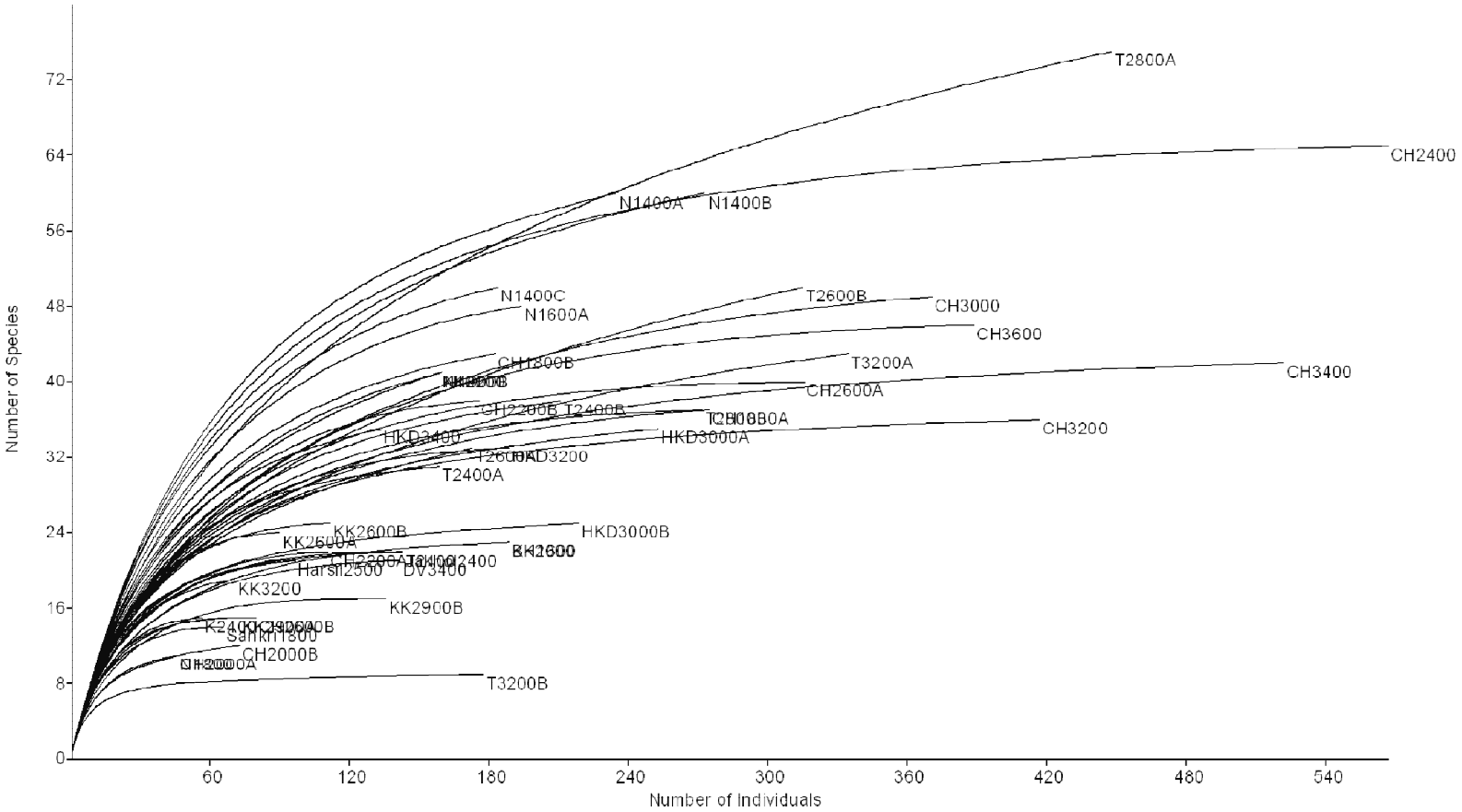


Fig 4.7: Plot-level individual based rarefaction curves for the entire moth assemblage in GLA (2008-2012)



The estimated total species richness using Chao1 was 673 ± 7.43 (SD), and using Jacknife2 691±5.29 (SD) for the complete sample. The ratio of observed to estimated (Chao1) number of species was 94% suggesting that at least 6% more species are to be expected in the area than were actually collected. At local level, in different vegetation zones also, the sampling was almost complete and highest in Moist Temperate Deciduous forest sites and subalpine forest sites. I failed to collect such a high percentage of species (11% missing) in Subtropical Pine Broadleaved Mixed forest sites compared with other habitat types (Table 4.1).

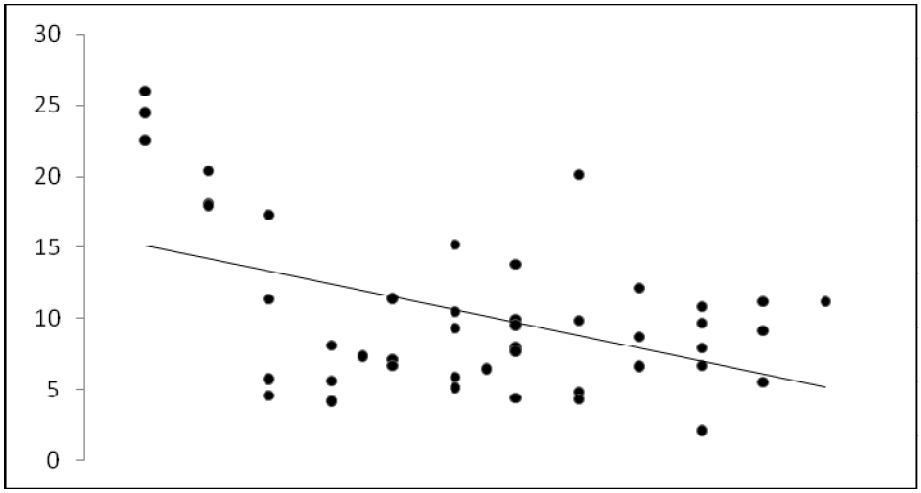
Table 4.1: Diversity Indices of moth assemblages in different vegetation zones in GLA (2008-2012)

	SPBM	MTD	WMC	WHUOF	SAF
Species	237	152	294	210	187
Individuals	1434	1080	2814	2246	2392
Singletons	44	17	34	30	19
Doubletons	33	31	44	26	24
Chao-1	264.80	156.30	306.50	226.10	193.80
Jacknife 2	243.182	154.156	306.682	215.109	194.438
Uniques	172.00	130.00	200.00	156.00	132.00
Dominance_D	0.01	0.01	0.01	0.01	0.02
Simpson_1-D	0.99	0.99	0.99	0.99	0.98
Shannon_H	5.02	4.58	5.09	4.69	4.55
Evenness_e^H/S	0.64	0.64	0.55	0.52	0.51
Fisher_alpha	80.89	48.21	82.67	56.69	47.47
% Completeness	89.77%	97.43%	96.07%	92.92%	96.89%

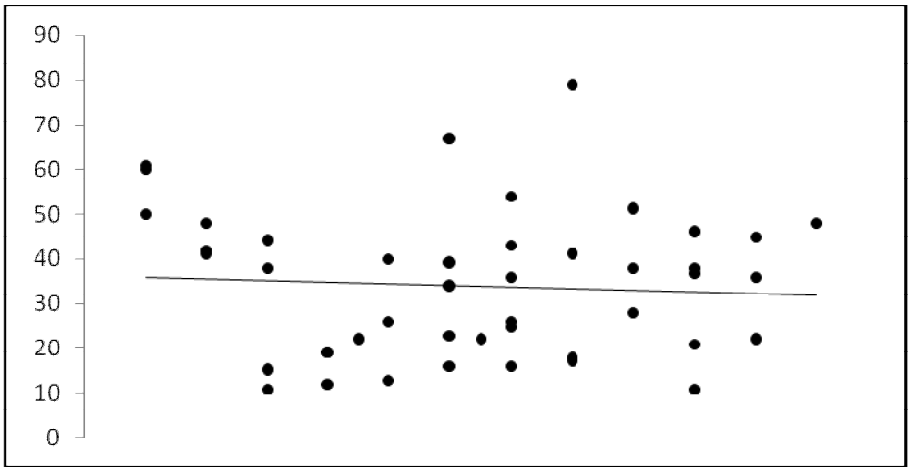
From all species recorded, 144 were singletons (21% of all species) and 158 were doubletons (23% of all species) (Table 4.1). Highest number of species and individuals were recorded from Western Mixed Coniferous forest sites, while lowest species richness was in the Temperate Deciduous forest sites. The highest contribution of singletons was found in Pine Broadleaved mixed forest sites. Values of Fisher's alpha were high at all sites, but varied considerably (range= 47.4 to 82.6). Alpha diversity was highest recorded in Western Mixed Coniferous habitat, followed by Subtropical Pine Mixed, while it was significantly lower in the subalpine and Moist Temperate Deciduous habitat.

Fig 4.8: Distribution of (a) Fisher's Alpha, (b) Observed Species richness and (c) Abundance of entire moth assemblage along altitudinal gradient in GLA (2008-2012)

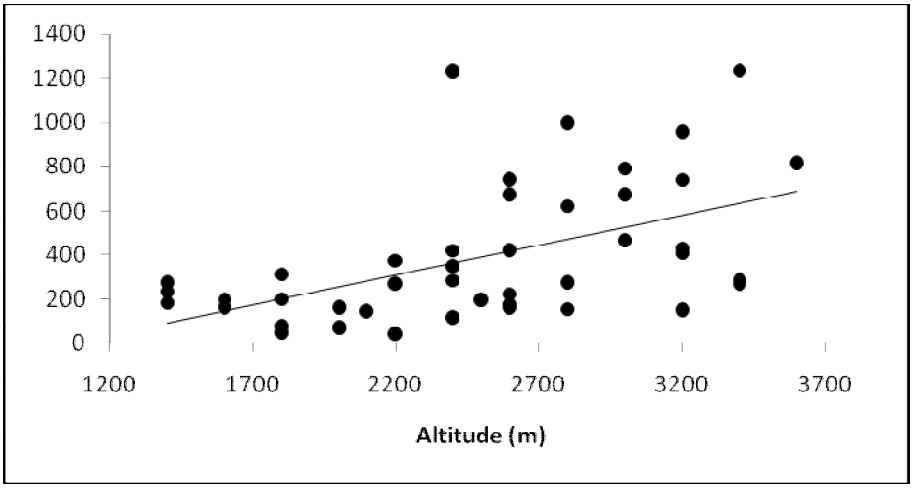
(a)



(b)



(c)



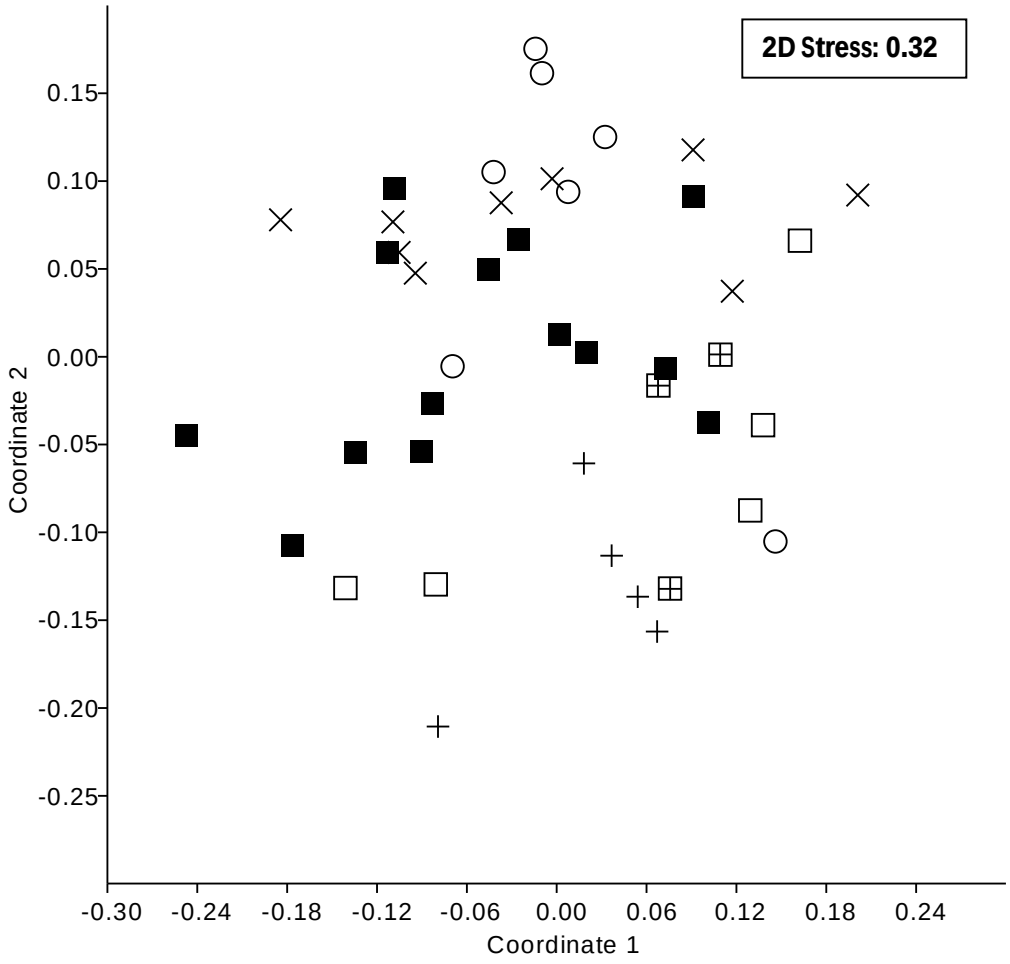
4.3.4 Diversity along Altitudinal Gradient

In an attempt to throw light on the diversity pattern along the entire altitudinal gradient sampled, I plotted Fisher's Alpha, species observed and individuals recorded for entire moth assemblage with increasing altitude. All the three patterns diverged from each other with Fisher's Alpha showing a continuously decreasing trend except a diversity peak in around 2700m (Fig. 4.8). Observed species richness showed a mid altitude hump in 2200m to 2700m range, although the trend line signifying almost equal diversity pattern along the entire gradient sampled. The most interesting picture came in case of abundance pattern which was lowest in lowest altitudinal levels sampled while it showed a continuously increasing trend with increasing altitude and having double peaks at around 2400m and 3300m. So, it was evident that while lower altitudinal sites were occupied by diverse set of species assemblage, numbers of individuals constituting high altitude populations were higher compared to their low altitude counterparts.

4.3.5 Species Composition and Site Similarity

Comparing among different sites revealed that on average, species composition was much more similar within the same habitat type than among different habitat types. NMDS plot generated from relative abundances of different moth species in each habitat type showed that sampling sites from each habitat type clustered together, though the resolution of clustering was not accurately fine (Fig. 4.9). Sampling sites of Pine Broadleaved mixed forest has little overlap with Montane Temperate Deciduous forest sites, whereas Western Mixed Coniferous forest sites formed the most separated cluster from the rest of the habitat types. Whereas, Western Himalayan Upper oak forest sites clustered among Coniferous forest sites, the subalpine forest sites made a separate cluster of their own. Overall the moth species assemblage was successful enough to tell apart one habitat type from other and their positioning reflected a gradual transition from lowest altitude habitat to higher ones with little overlapping with habitat types at next altitude level.

Fig. 4.9: MDS ordination plots of sampling sites in GLA, generated by species composition sorted according to habitat types (Plus: Subtropical Pine Broadleaf Mix, Open Square: Moist Temperate deciduous, Filled Square: Western Mix Coniferous, Cross: Western Himalayan Upper Oak Forest, Open Circle: Subalpine Forest**)**



The Global R statistics from ANOSIM from 1% threshold level was 0.27 with p=.0001 demonstrating that the overall difference between sites were large and statistically significant. Pair wise ANOSIM test (Table 4.2) showed most difference in species composition occurred between Pine Broadleaved Mixed forest and Subalpine Forest (R = 0.58, P = 0.0007), while the least difference was seen between Western Mixed Coniferous forest and Montane Temperate Deciduous forest (R = 0.11, P = .0904),

although this difference was not significant. The least significant difference was between Subalpine forest and Western Himalayan Upper Oak forest (R=0.18, P = .0469). Further comparisons of dissimilarity in composition were made to identify the species contributing to the difference between groups of sites that differed most.

Table 4.2: Pair wise comparison of similarity of moth assemblages in different vegetation types from ANOSIM (Analysis of Similarity) [Highlighted cells represent significance level (bold: p<0.05); Non-highlighted cells are R values)

	SPBM	MTD	WMC	WHUOF	SAF
SPBM		0.2045	0.3277	0.5115	0.5842
MTD	**0.0219**		0.1107	0.3051	0.3841
WMC	**0.0015**	0.0904		0.1273	0.2522
WHUOF	**0.0002**	**0.0059**	0.058		0.1891
SAF	**0.0007**	**0.0019**	**0.0064**	**0.0469**	

Eighteen species contributed around 50% to the difference between groups of sites of two most dissimilar habitats, i.e., Pine Broadleaved mixed forest and Subalpine forest (Table 4.3). These species differed in mean abundance, which was reflected in the degree of group association. Among them, ten species were almost absent from Pine Broadleved Mixed forest, but present in high abundance in Subalpine Forest. Among these ten species, four were from Geometridae (*Rheumaptera* sp., *Photoscotosia amplicata*, *Abraxas* sp. and *Opisthograptis tridentifera*), four were from Noctuidea (*Diphtherocome fasciata*, *Haderonia culta*, *Xestia bdelygma* and *Heliophobus texturata*), and one species from family Notodontidae (*Rachia plumosa*) and family Erebidae (*Spilosoma sp.*) each. There were only two species, *Perizoma albofasciata* and *Euproctis* sp., which were present in Pine Broadleaved mix forest, but absent from Subalpine forest. Results of SIMPER analysis (Table 4.3) revealed that family Geometridae contributing mostly in group difference between Pine and Subalpine habitats with 10 species altogether, while other significantly contributing families were Noctuidae and Erebidae respectively.

Table 4.3: SIMPER result of differences in the species of moth assemblage contributing to the dissimilarity (96.01%) between most dissimilar habitat types, Subtropical Pine Broadleaf Mix and Subalpine forest

Taxon	Av. dissimilarity	Contrib. %	Cumulative %	Mean abundance	
				SPBM	SAF
Diphtherocome fasciata	2.881	3.001	3.001	0	17.4
Rheumaptera sp.	2.646	2.756	5.757	0	14.9
Colostygia albigirata	2.139	2.228	12.71	2.13	12.4
Photoscotosia amplicata	1.99	2.073	16.92	0	11.7
Triphosa sp.	1.971	2.053	18.97	0.625	12
Haderonia culta	1.662	1.731	20.7	0	10
Spilosoma erythrozonata	1.599	1.665	22.37	2.13	4.86
Perizoma seriata	1.449	1.509	23.88	5.5	1.29
Ecliptopera postpallida	1.175	1.224	26.42	2	4.14
Psilalcis inceptaria	0.9549	0.9945	28.44	3.13	1.29
Abraxas sp.	0.947	0.9864	29.43	0	5.57
Perizoma albofasciata	0.9234	0.9618	30.39	4	0
Euproctis sp.	0.8948	0.932	31.32	4	0
Rachia plumosa	0.8566	0.8922	33.12	0	4.86
Xestia bdelygma	0.8477	0.8829	34	0	5
Spilosoma sp.	0.8408	0.8757	34.88	0	4.57
Heliophobus texturata	0.8332	0.8678	35.75	0	2.86
Opisthograptis tridentifera	0.7718	0.8038	37.36	0	4.86

4.4 Discussion

The scale at which to look into the diversity pattern of a hyperdiverse taxa like moth is very important to decide, more so in a Himalayan landscape which is not only poorly studied previously, but also difficult to sample from the logistic point of view due to a wide altitudinal range as well as inaccessibility issues. There is also long-standing debate in choosing for appropriate alpha diversity measure for taxa like moth, assemblage structure of which is always dominated by rare species which renders the dataset to look ever-inadequate. In this backdrop, the aim of the current chapter was to look for suitable scale to sample as well as choosing for proper alpha diversity measures which will not

only be sample-size independent, but also robust enough to discriminate between different levels of sampling units.

The present study, a systematic inventory of moths, is the first of its kind in Gangotri Landscape and is one of the few studies on moth communities in India and more importantly in a Himalayan landscape. As there is no previous species list available for this area, it is difficult to know precisely what proportion of the actual local and regional species richness the study captured. However, based on the estimated richness, the inventory was almost complete at the regional scale (90%). In spite of the relative success of this study, it still cannot be described as comprehensive – undoubtedly species were missed at local scales. Sampling additional sites or using different methods would capture more species. Additionally, lacking access to the modern equipments for light-trapping, species predominantly or exclusively occurring in the canopy or dense forest vegetation were under-sampled. However, using a sample-size independent diversity measure such as Fisher's alpha (Hayek & Buzas 1997) should minimize distortions of between-zone comparisons. Nevertheless, the inventory protocol utilized here provided sufficiently thorough samples of local and regional moth species to permit an accurate comparison of species richness of different altitude and vegetation zones.

The moth diversity captured was not similar in the different altitude and vegetation zones, although the altitude zonation was little unrealistic and not flawless, mirroring the underlying changes in vegetation composition. Overall, the assemblages varied among zones and revealed a pattern of assemblage response in relation to altitude and the related microclimatic regime. The Subtropical Pine Broadleaved mix forest, comprising excellent stands of Chir Pine and mix diversity of associated broadleaved species showed second highest alpha diversity and Simpson's, second highest numbers of species observed (Sobs) and estimated species richness. The estimated species richness curves and individual based rarefaction curves were most asymptotic for this habitat and at local level the sites of 1400m, 1600m and 1800m (NT14, NT16, NT18, Fig. 2.5) were most incompletely sampled. Maximum number of singletons and second highest numbers of doubletons were recorded from these habitats, all these signifying a rather incompletely sampled assemblage (89%). The reason may be that the Pine forests are open kind of

forest with high but open canopy and relatively less dense understory vegetation rendering light trapping little unsuccessful and to capture an assemblage with cross-attracted species from adjacent habitats like Riverine and Moist Temperate Deciduous forests. Moist Temperate Deciduous habitats stretching from 1800m to 2200m, also including the riverine habitats were least diverse among all the major habitat types with lowest Fisher's Alpha, lowest number of species observed and estimated species richness. Though sampling was complete with lowest number of singletons, the low number of species and individuals captured signifying a comparatively less diverse assemblage. The Western Mixed Coniferous forests stretching from 2200m to 2600m were the hub of most diverse assemblage with highest values of Alpha diversity and Simpson's index, highest numbers of species and individuals collected, second highest numbers of singletons and highest numbers of doubletons recorded. These were the most extensive and intact habitats in the study area and characteristics of typical Western Himalayan vegetation community. Above these, were the Western Himalayan Upper Oak forests, mainly dominated by Kharsu Oak forest between 2800m and 3200m which harbors a diverse and unique moth assemblage with second lowest alpha diversity and Simpson's index, third highest observed and estimated species richness with considerable number of local singletons and doubletons. The subalpine forests constituting Western Himalayan Birch-Fir forest, Birch-Rhododendron scrub forest and Deciduous Alpine scrublands were one of the least diverse habitats in terms of Alpha diversity and Simpson's index, second lowest observed and estimated species richness and low singletons and doubletons recorded. The individuals recorded were high signifying a characteristic assemblage which is adapted and very successful to harsh climatic conditions associated with this highest altitude vegetation community.

Studies on different insect and invertebrate taxa along elevational transects reveal that there is large variation in diversity patterns, with most study depicting a hump-backed distribution (Holloway *et al.* 1990, McCoy 1990, Olson 1994, Holloway 1997, Pyrcz & Wojtusiak 2002), whereas Wolda (1987) found a general decrease with increasing elevation. Brehm (2002) recorded a broad maximum diversity plateau in the Andean mountain rainforest between 1040 and 2670 m. Schulze (2000) likewise showed that high levels of diversity in geometrid moth communities occur over a broad elevational range

in the tropical mountain rainforest of Mt. Kinabalu, Borneo. But till date, no comparable studies have been performed in the Himalayan elevational gradient. In a broad-scale assessment of variation in distribution patterns of foliage-dwelling arthropod orders along elevational gradients located across an extensive precipitation gradient in the Himalayas, Ghosh-Harihar (2013) had found that relative abundances of foliage-dwelling arthropods peaked at intermediate elevations along elevational gradients. The aim of my study was to investigate the diversity of moth communities along elevational transect in Gangotri Landscape, Western Himalaya. Furthermore, I was interested in diversity changes across different broad habitat categories. Although local diversity showed a general decreasing trend, with Fisher's alpha highest (28) in lowest altitude sites and declining to around 15 in highest altitude sites, diversity was more or less similar across the altitudinal gradient surveyed. Observed species richness showed a diversity plateau around 2200m to 2700m representing a mid-elevation peak concordant with general elevational diversity trend worldwide. The increasingly high number of individuals along the gradient probably reflected occurrence of specialized species assemblage consisting of *Abraxas*, *Colostygia*, *Diphtherocome*, *Haderonia*, *Photoscotocia*, *Rheumaptera* etc. which survives the harsh climatic condition with population flushes in suitable season in forests of higher elevations. While intra-specific competition for suitable resources may check the population of lower altitude assemblages, the low species diversity in subalpine forest along with low level of predation may cause high abundance of specially adapted species assemblage.

Alpha diversity of moths remains remarkably stable with changing altitude across the entire altitudinal belt. Furthermore, the species composition within the coniferous forest habitat is more homogeneous than outside this habitat type, as revealed by the ordination and ANOSIM analyses. Thus within the whole forest belt covering an elevational range of more than 2000m, the species pool changes more slowly than outside the forest. The moth ensembles of forest sites are positioned according to their elevation in the ordinations. While the assemblage structure for different habitat categories showed a gradual transformation, the assemblage of Western Mixed Coniferous habitat showed most dissimilar assemblage in comparison with those of other habitat types. It can

therefore be concluded that these gradual faunal changes are mainly related to gradual changes in the environment with altitude.

In conclusion, despite gradual and small distances between various habitat types studied, each one had significant resources to support its own characteristic moth assemblage. Overall, local diversity among moth communities were high all through the gradient signifying enough resource availability at every altitude and vegetation zones studied. The high diversity documented for the first time of a major herbivorous insect community in this typical Western Himalayan altitudinal gradient can be instrumental enough to ascertain its conservation significance. The results confirm that unless sampled extensively over a large temporal scale, the recorded species number is an unreliable measure of diversity because of its dependence on the number of specimens collected. Use of a set of sample size independent diversity measures like Fisher's alpha, Chao I and Jackknife should complement each other in different aspects of diversity as well as mathematical assumptions underlying their usage. Concordant diversity picture yielded by all these different measures should also minimize the possible risk of misinterpretations. The diversity pattern emerged at fine taxonomic resolution should raise important issues regarding driving factors behind it, which is tried to be answered in next two chapters. The results provided in this chapter emphasize need for a better understanding of the natural histories of Himalayan moth fauna, as well as the enormous importance of Himalayan coniferous and subalpine forests in conservation issues.

CHAPTER V

FACTORS DETERMINING DISTRIBUTION PATTERN OF MOTHS IN GANGOTRI LANDSCAPE

5.1 Introduction

Herbivorous insects account for a major fraction of global biodiversity (Novotny *et al.* 2006, Lewinsohn & Roslin 2008) as well as any regional diversity pool. Their intermediate position in trophic cascades makes them ideal objects with which to study the effects of environmental gradient on the diversity of faunal communities. Moths have a particularly high potential to serve as a model system in this respect. Being one of the most species-rich groups of insect, their potential as 'biodiversity indicators' has been extensively explored by studies in Southeast Asia (Holloway 1985, Chey *et al.* 1997, Intachat *et al.* 1997, 1999a, b, Willott 1999, Beck *et al.* 2002), South and Central America (Brehm *et al.* 2003b, 2007; Hilt *et al.* 2006), Australia (Kitching *et al.* 2000) and Africa (Axmacher *et al.* 2004a,b). But such kind of study was long overdue in Himalayan landscape. In this first attempt to look into diversity pattern of this species-rich group of herbivorous insect in a typical Western Himalayan landscape of Gangotri area, my primary attempt in this chapter is to look into various factors structuring the observed diversity pattern as well as finding meaningful ways to use this result in conservation monitoring purposes.

The species richness of many organisms changes along environmental gradients: altitude (Holloway 1987, McCoy 1990); disturbance (Lawton *et al.* 1998; Beck *et al.* 2002, Schulze *et al.* 2004); and productivity (Bonn *et al.* 2004, Gaston & Evans 2004) are often important at a local scale, whereas area size (Rosenzweig 1995, Ulrich & Buszko 2003); climate and geographic position (Chown & Gaston 2000, Willig *et al.* 2003; Currie *et al.* 2004) become increasingly important at larger spatial scales. Variables operating at local scales however, may be more important than regional factors in determining the number and types of lepidopteran species sampled at a given site. Traditionally, local processes have always been studied in terms of species interactions (e.g. competition, predation), which, most of the times, are unable demonstrating significant local control of community

structure (Ricklefs 1987). In contrast, studies specifically aimed at forest insects suggest that local factors such as disturbance (Hamer & Hill 2000, Summerville & Crist 2002), patch size (Usher & Keiller 1998, Davies *et al.* 2001) can regulate the numbers or types of species found within a habitat patch by altering stand structure or floristic composition.

Gangotri Landscape in Western Himalaya has an unique altitudinal gradient characterized by successive vegetation gradient. Govind National Park and Sanctuary, an essential part of this landscape is dominated at lower altitudes by pure stands of Chir Pine forest and Western Himalayan Pine-Broadleaved mix forest. Most of the human settlements (32 out of total 42 villages in the landscape) come under this vegetation type. Next, the Moist Temperate Deciduous forest and Riverine forests (1800-2200m) in the landscape is devoid of any human disturbance with pristine riverine forests in Changsil Gradient (Fig.5.1). The next major vegetation type was Western Mixed Coniferous forest which stretches from 2220m to 2800m intact with minor human disturbance in terms of lopping and grazing resulted from annual livestock herding practiced by local villagers and Gujjar parties. The coniferous forests give way to Upper Himalayan Oak forests dominated mainly by Kharsu (*Quercus semicarpifolia*) which was present in good health in Taluka-Pustara gradient. The Subalppine Forest was dominant in all the three altitudinal gradients with combination of Birch-Fir forest with *Abies*, and Birch-Rhododendron forest of *Rhododendron campanulatum* (3200m-3500m). The highest vegetation type, the deciduous alpine scrub was not very extensive in the landscape with associated issues of unsuccessful light-trapping. All through the forested patches in the gradient, livestock grazing and related activities including minor fires were prevalent. The open habitat of alpine pastures was affected by major grazing. This typical Western Himalayan altitudinal vegetation gradient, along with low to high disturbance intensity made the gradient perfect to look into the effects of broad scale factors like altitude, habitat, energy as well as local factors like disturbance shaping assemblage structure of a typical herbivorous insect.

The better-known groups of Lepidoptera have been advocated as preferred indicators of environmental impact (Ehrhart 1985, Ehrhardt & Thomas 1991, Daily & Ehrlich 1995, Hill *et al.* 1995, Hill & Hamer 1998), although usually this has referred to butterflies

and/or day-flying moths. Butterflies are not easily trapped and are often only poorly represented in forest environments. In contrast, the nocturnal families of macrolepidoptera, though taxonomically more challenging, are sufficiently speciose and diverse to offer powerful discrimination in detecting ecosystem level impacts (Holloway 1977, 1985). The predominantly herbivorous habit of the order leads to the expectation that they will represent a measure of the quality of the vegetation in any location. Most families of moths are readily attracted to light traps; resulting abundance data if used with care, can provide a standard measure of the fauna flying in a particular period. One method used to quantify the 'bioindicator value' of a range of taxa is the indicator value (IndVal) method developed by Dufrêne & Legendre (1997). This method combines measurements of the degree of specificity of a species to an ecological state, for example a habitat type, and its fidelity within that state (Dufrêne & Legendre 1997). Species with a high specificity and high fidelity within a habitat will have a high indicator value. High fidelity (frequency of occurrence) of a species across sample sites is generally associated with large abundance of individuals (Brown 1984). Both these characteristics facilitate sampling and monitoring, which is an important requirement for a useful bioindicator (Jenkins 1971, Kremen *et al.*1994).

The Ind Val method as proposed by Dufrene and Legendre (1997), identifies indicator species as those 'characteristic' of a particular habitat (i.e. with high specificity and fidelity to the habitat and thus a high percentage IndVal). However, species with other combinations of specificity and fidelity may also be useful indicators, for example detector species. When monitoring environmental change, species that span a range of ecological states (i.e. do not have high specificity) may be more useful indicators of direction of change than highly specific (characteristic) species restricted to a single state. Because habitat specificity is likely to be relatively resistant to change over time in comparison with population abundance levels, the abundance, and thus the fidelity of characteristic species may decline rapidly under changing environmental conditions to the point where they are regarded as vulnerable.

Therefore, if detector species can be identified in assemblages, they will provide information complimentary to that provided by characteristic indicator species. Detector

species will facilitate longer-term assessment, as well as indicate the direction in which ecological change is taking place. The two objectives of ecological bioindication outlined above are best addressed separately, i.e. the identification of characteristic, indicator species for monitoring within a particular ecological state, and the identification of detector species for monitoring within and across states to detect the direction in which change is occurring. In this study, I tried to identify the sets of Indicator-Detector species assemblage for each broad vegetation types as well as different disturbance categories using the IndVal method (Dufrêne & Legendre 1997). As conservation status of different moth species in Western Himalayan context is largely unavailable, in this first kind of such study, my aim was to identify characteristic species assemblage for different vegetation and disturbance level, so that the baseline information about their abundance pattern can be documented which can be further used in species-specific monitoring as well as rapid habitat evaluation.

My broad research questions for this chapter are:

i) How the vegetation gradient shaped major assemblage structure (four major moth families were selected for analysis: Pyralidae, Geometridae, Erebidae and Noctuidae).

ii) Effect of topographic, vegetation structure and composition, microclimatic and local anthropogenic disturbance factors shaping diversity pattern of these four major families. (Another very important modular of moth assemblage structure in a mountainous habitat is season, discussion about which is made separately in next chapter).

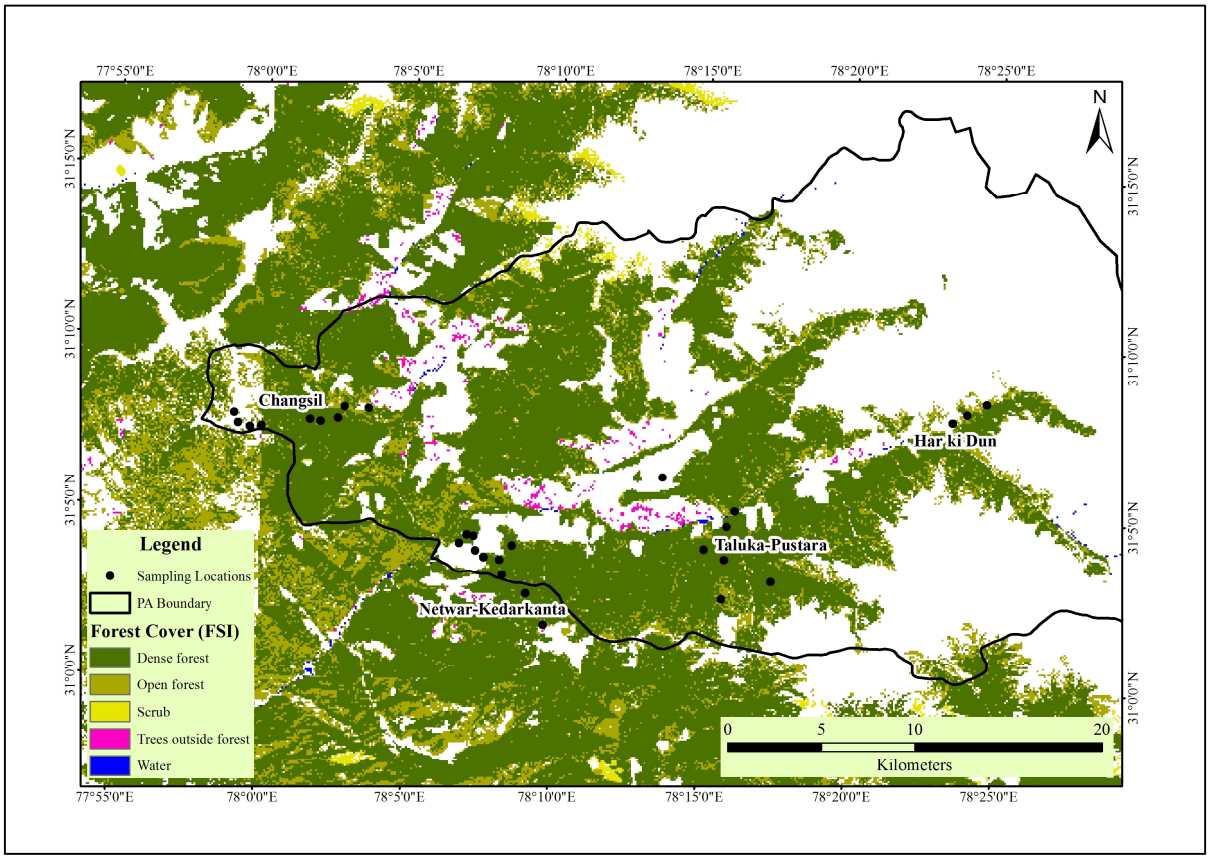
iii) Detector-Indicator species assemblage typical of every vegetation type and disturbance regimes to target out species of conservation importance.

5.2 Methods

5.2.1 Study Area and Site Selection

The study area was located in the Govind National Park and Sanctuary (GNPS), western part of Gangotri Landscape Area, a typical Western Himalayan landscape (Fig.5.1). In GNPS, three gradients were selected: The Changsil gradient, Taluka-Pustara gradient and Netwar-Kedarkanta gradient. Some additional high altitude sites were selected in Har-Ki-Dun gradient. On these slopes, the vegetation changes from large-scale Chir Pine and Pine-Broadleaved mixed forest interspersed with agricultural lands below 1400m up to 1800m, to a mosaic of Moist Temperate Deciduous forests and Riverine forest up to 2200 m.

Fig. 5.1: Vegetation cover map of Govind Wildlife Sanctuary & National Park showing four altitudinal gradients sampled: Changil, Netawar-Kedarkanta, Taluka-Pustara and Har-ki-Dun



Above this zone, secondary and mature forest of coniferous forests covers the slopes between 2200m and 2800m, with temperate parklands replacing the forests above this elevation. In moister areas Upper Himalayan Kharsu Oak forests dominate up to the elevation of 3200m which is then replaced by large tracts of subalpine forest from 3200m to 3600m. Detailed descriptions of these vegetation types are given in Chapter II. Fifty-two plots of 20 x20 m^2 each were established in clusters at elevations ranging from 1400m to 3600m at intervals of c. 200 m. These clusters represent the respective ranges of typical habitats occurring at the various elevations. In plot selection, it was ensured that the vegetation was homogeneous at each of the plots. Plots at same elevation zone were established at a minimum distance of 50m from each other, and the weak light sources used in this study were invisible from neighboring plots in order to minimize cross-habitat attraction ensuring that moth samples were independent.

5.2.2 Recording of Moth and Vegetation-Disturbance data

Moths were sampled manually using a light trap running for 4 hours, in two sessions at a particular site for two consecutive nights, e.g. first night from 8 pm to 12'O clock midnight and second night from 12'o clock midnight to 4 am. This was to ensure record all the moths flying in a particular site or habitat in different quarters of night. Light traps were set using a solar powered lantern equivalent to 80 Watt White Actinic bulb and gas petromax equivalents to 160 Watt Mercury vapour (MV) bulb. At some nights, particularly in lower altitude sites where electricity was available, 80 Watt Tungsten Filament bulbs were used instead of MV light. The combination of light sources were placed in front of a white 10′ x 6′ cloth sheet hung between two vertical poles in such a way that it touches the surface and extends forward over the ground slightly. This was to ensure enough resting place for an individual moth after they were attracted to light for live photography and collection. Some species were very active around a light trap and never used to sit on the white sheet. They were collected using insect net. No sampling occurred in the period 5 days before to 4 days after the full moon, as light trapping is much less effective during these periods (McGeachie 1989, Yela & Holyoak 1997). All plots were visited between two and eight times to ensure a minimum sample size of at least 50 individuals. In 40 cases, the overall sampling size exceeded 100 individuals.

Moths were later classified and identified at the Zoological Survey of India in Jabalpur and Kolkata. 48% of the specimens were identified to species level, with the remainder identified to genus level and sorted as morphospecies.

Plant community of each vegetation types was sampled using a series of nested quadrates. Initially, each series was designed such that, within a vegetation type, one set of quadrates was centered on the position of the light trapping station and the remaining two were randomly located 50 m from the centre. 20x20m^2 quadrate was used to quantify species richness and abundance of trees. Within 20x20m^2 quadrate two 5x5m^2 quadrate was used to quantify species richness and abundance of shrubs and saplings. Two 1 $meter^2$ quadrate nested within each shrub plot was taken account to measure species richness, abundance, and percent cover of herbaceous layer. Furthermore, data on vegetation structure, including information on stratification in terms of Foliage Height Diversity and cover were obtained from each plot. The percentage cover of the various strata was estimated. Additionally following variables were considered as site-covariates:

(a) **Topographic**:

(i) Altitude: noted from Altimeter reading, later confirmed by GPS. Data used to denote broad altitude zone, not exact altitudinal position (like 1400m, not 1460m).

(ii) Slope: Using Clinometer

(b) **Vegetation structure & composition**:

(iii) Canopy Cover: it was measured using a Spherical Densitometer at 8 points spaced at 10m intervals along the perimeter of each 20x20m^2 quadrate.

(iv) Tree Species Richness: Number of tree species and individuals of each species were recorded for each 20x20m^2 quadrate

(v) Tree Height: Height of each tree was measured using clinometer

(vi) Tree DBH: Diameter at breast height of all trees greater than 10cm were recorded for each individual tree using meter tape.

(vii) Shrub Cover, shrub species richness and shrub height: While cover was measured as the percent area within the 5x5m^2 box covered with shrubs, all individuals of each species of shrubs were counted and height measured with meter tape.

(viii) Tree density and shrub density: Total number of trees and shrubs per quadrate area (20m x 20m and 5m x 5m respectively) were summed and density was calculated for site.

(ix) Herb Cover and species richness: Percent herb cover was estimated visually in four sub-quadrates (1x1m^2) within each 20x20m^2 quadrate. Individuals of each herb species were also counted.

(x) Percentage litter cover, bare soil and grass cover at ground were estimated visually in 20x20m^2 quadrate.

(xi) Dominant flowering plants for tree, herb, shrub and grass layer were recorded in each 20x20m^2 quadrate.

(c) **Microclimatic Variables**:

(xii) Ambient temperature and relative humidity were measured using digital Thermo-Hygrometer during light trapping at every one hour and averaged for one trap night.

(xiii) Monthly Mean Precipitation data at district level was obtained from Indian Metereological Department.

(xiv) Wind Speed at every one hour during light trapping was measured using hand-held Digital Anemometer.

(xv) Atmospheric Pressure was measured using barometer while percentage Cloud Cover was estimated visually.

(d) **Disturbance Variables**:

(xvi) Logging & Lopping Signs Present: Number of large and small branches cut from a tree was counted in each 20x20m^2 quadrate.

(xvii) Presence of felled and dead trees were counted in each quadrate.

(xviii) Number of Fire signs were counted as an index of Fire Intensity, and

(xix) Number of pellets and dung were counted and signs of grazing were counted in each 20x20m^2 plot as an index of Livestock presence and Grazing intensity.

5.2.3 Data Analysis

The altitude-diversity patterns of major families of moths and their diversity pattern in major vegetation types were first explored using simple box-plots with error bars. Correlation matrix was developed from overall diversity measures (Species observed, Individuals and Fisher's alpha) and abundance of important families (Erebidae, Geometridae and Noctuidae) with major topographical features, microclimate variables, vegetation structural and compositional parameters and disturbance variables. Pair wise correlation graphs were used to show the significant relationships.

Multicollinearity within data sets as well as species-abundance data matrix with multiple zeroes potentially distorts the results of many commonly used statistical techniques like regression. To avoid such distortions and on account for the large number of environmental parameters investigated, ordination techniques have been recommended for variable reduction of predictor variables. Nonmetric multidimensional scaling (NMDS) is an iterative ordination method which does not assume linearity or monotonicity of the underlying data structure, and thus appropriate with the kinds of ecological data in this study (Fasham 1977, Minchin 1987, McCune & Grace 2002). To reduce the dimensionality of the environmental, vegetation structure and composition and disturbance data matrices, I used NMDS with the Bray-Curtis distance measure (PC-ORD 4, 1999, MjM Software Design, Gleneden Beach, Oregon). The statistically significant NMDS axes were then used as predictor variables and the alpha diversity

(Fisher's Alpha), abundance and species observed (raw estimate of species richness) of moth diversity as dependent variables were plotted against the three synthetic NMDS axes and were visually represented as scatter plots.

The numbers of mobile insects sampled in light traps depend on a variety of factors, including sampling effort, background illumination, general visibility and weather conditions. These factors often render the observed number of species a poor measure of alpha diversity (Gotelli & Colwell 2001). Various methods have therefore been developed to allow the interpretation of differences in the numbers of species and specimens between light-trap samples from different habitats and sampling events (Hayek & Buzas 1997, Southwood & Henderson 2000). In this study, Fisher's alpha (Fisher *et al.* 1943), a parametric index based on the assumption of a logarithmic series distribution of specimens per species, was calculated as a measure of alpha diversity of moths using the computer program EstimateS 8.0 (Colwell 2006). Fisher's alpha has been widely used and has proved to be a robust measure with which to assess tropical arthropod diversity (Brehm *et al.* 2003b, Schulze & Fiedler 2003, Axmacher *et al.* 2004a).

Furthermore, the pattern of variation in the species and family composition of moth assemblage was examined by Canonical Correspondence Analysis (CCA). Effect of each of the habitat variables belonging to environmental, vegetation and disturbance on species composition was explored using CCA (using PC-ORD software, McCune and Grace 2002). CCA is a direct ordination method that positions sites (i.e. forest stands) along an environmental gradient based on both the observed similarity in species composition (i.e. moths) and shared environmental variables. Briefly, algorithm for CCA seeks to define linear combinations of environmental variables that maximize the separation among site scores on synthetic ordination axes. In ordination space, site scores are calculated as weighted averages of species abundances and are plotted in the center of the cluster of species occurring at that site. Similarly, the species scores are the weighted average of their abundances across sites. Thus, species scores that are close to a given site score in the space defined by the ordination axes are more abundant at that site compared to other sites. The positions of site scores in the area created by the ordination axes show

how overall community structure varies with the combination of measured environmental variables. The influence of the environmental variables on community structure can be depicted on the ordination figure through the use of bi-plot vectors, which are graphic renderings of species-environment correlations (ter Braak 1995).

Characteristic moth species were identified for each vegetation type and disturbance categories (High, Medium, Low) using the indicator value method (Dufrêne & Legendre 1997) using program PC-ORD. This method combines measures of specificity and fidelity and provides an indicator value (*IndVal*) for each species, as a percentage, as follows (Dufrêne & Legendre 1997):

$$\text{specificity measure: } A_{ij} = N\ individuals_{ij}/N\ individuals_{i}$$

where $Nindividuals_{ij}$ is the mean number of species *i* across sites of group *j*, and $Nindividuals_{i}$ is the sum of the mean numbers of individuals of species *i* over all groups:

$$\text{fidelity measure: } Bij = Nsites_{ij}/Nsites_{.j}$$

where $Nsites_{ij}$ is the number of sites in cluster (habitat) *j* where species *i* is present, and $Nsites_{.j}$ is the total number of sites in that cluster. The percentage indicator value for species *i* in cluster (habitat) *j* is then:

$$IndVal_{ij} = A_{ij} \times B_{ij} \times 100$$

Dufrêne & Legendre's (1997) random reallocation procedure of sites among site groups was used to test the significance of the *IndVal* measures for each species. Each species has a percentage *IndVal* with an associated measure of significance, with high and significant percentages designating good indicator species. Those species with significant *IndVal*s of greater than 70% were regarded as characteristic indicator species for the habitat in question. Species that were predicted to act as detectors of a change in habitat were identified as those species with *IndVal*s of between 50% and < 70%. These species were therefore not characteristic species, as they did not have high IndVals of ≥ 70% for any particular habitat (McGeoch *et al.* 2002). Apart from NMDS, CCA and *IndVal*, all other statistical tests were performed in SPSS 21, XLSTAT and PAST.

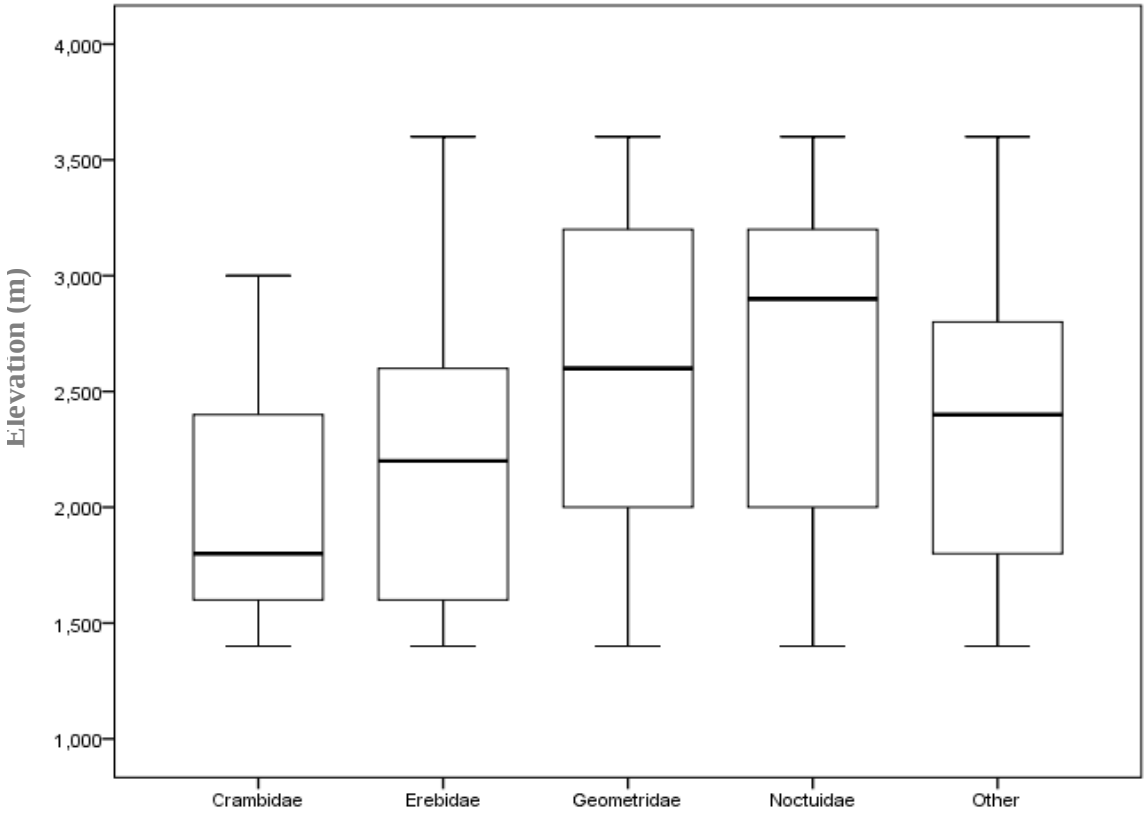
5.3 Result

5.3.1 Distribution of Moth Families in different Altitude & Vegetation

A total of 583 morphospecies belonging to 303 genera and 22 families were collected during entire sampling periods. Fisher's alpha values for the moth assemblages varied between 5.68 and 39.98, with a mean value of 16.21 and a standard deviation of 5.77 within stands, highest recorded in CH3200 (39.16), lowest in Sankri1800 (5.68). Mean species observed was 34.18 (SD 16.20), highest in T2800 (79) and lowest in N1800B (11). Highest number of individuals were recorded in CH3400A (1234), lowest in N1800B (46), with mean value 383.13. The diversity of vascular plants (all tree, herb and shrub) varied between 26 and 92 species per plot. Although overall regional moth species richness was high, species evenness was low. Most species were rare, as indicated by the steep initial gradient in the rarefaction curves (Fig. 4.6); From all species recorded, 144 were singletons (21% of all species) and 158 were doubletons (23% of all species).

Among 22 families of moth recorded, four major families were selected for analysis: majority of individuals were from family Geometridae (n=3646), Erebidae (n=1621), Noctuidae (n=1492) and Crambidae (n=498). These families had different diversity pattern along altitudinal gradient (Fig 5.2):

Fig 5.2: Altitudinal distribution of most abundant families of moth in Govind WLS & NP (2008-2012)



Mean distribution of the family Crambidae was recorded around 1800m, while most of the species were recorded between 1600m to 2400m (Fig. 5.2), and species range extends from 1400m to 3000m. Mean species distribution of the family Erebidae was around 2200m, while most of the species and individuals were abundant between 1600m and 2600m (Fig.5.2), however species range extends from 1400m to 3600m. The most speciose and diverse family recorded from the study plots was Geometridae with mean species abundance at around 2600m, while most of the species were recorded between 2000m and 3200m. Family was diverse all through the altitudinal gradient sampled from 1400m to 3600m. Mean species distribution of the Noctuidae was around 2900m, while most of the species and individuals were abundant between 2000m and 3200m, however species range extends from 1400m to 3600m.

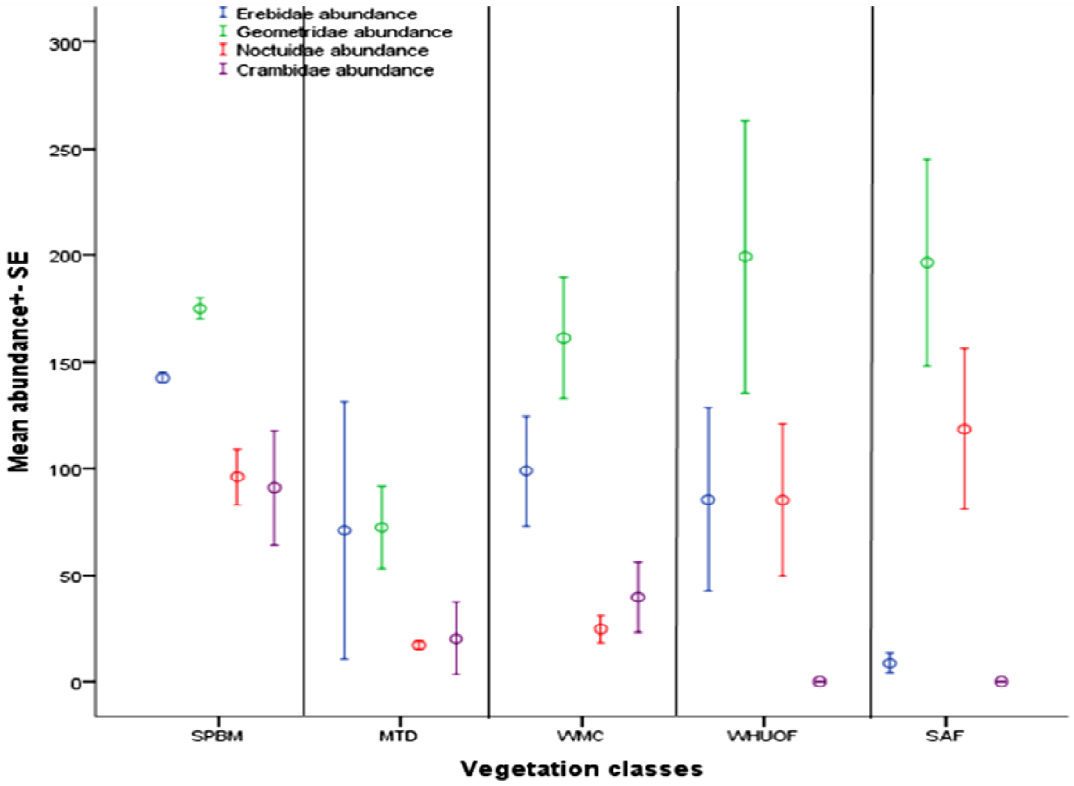
The 48 sampling plots were grouped into five major vegetation types based on dominant tree species: Subtropical Pine Broadleaved Mix forest (SPBM), Moist Temperate

Deciduous forest (MTD), Western Mixed Coniferous forest (WMC), Western Himalayan Upper Oak forest (WHUOF) and Subalpine Forest (SAF). Abundance pattern of the four major families varied greatly among different vegetation types (Fig 5.3): Family Erebidae had highest mean abundance in SPBM (142.5) and lowest in SAF (8.8). Geometridae did not vary much between the vegetation types except in MTD where lowest abundance (72.33) was recorded, whereas high abundance in all other classes with highest abundance recorded in WHOUF (199.2). Noctuidae abundance varied much between different vegetation types with high mean abundance in two altitudinally extreme classes, in SPBM (96) and SAF (118.6) and lowest abundance in MTD (17.33). The family Crambidae was absent from two highest altitudinal classes WHUOF and SAF. Highest mean abundance of this family was recorded in altitudinally lowest vegetation types SPBM (91) and lowest in MTD (20.33).

5.3.2 Correlation between Moth Diversity and Habitat Variables

Spearman correlation test was performed to see the main effects of all the major topographic, microclimatic, vegetation structural, compositional and disturbance variables on the diversity measures of overall moth assemblage like species observed, individuals and Fisher's Alpha, and abundance of three major families, Erebidae, Geometridae and Noctuidae (Table 5.1, Fig 5.4a to n). Altitude was one of the major governing factors for some vegetation structural parameters as well as moth diversity and family abundance. It had significant negative effect on average temperature (-0.864) and canopy cover (-0.686) whereas alpha diversity of entire assemblage (-0.455) and Erebidae abundance (-0.475) decreased significantly with increasing altitude.

Fig 5.3: Mean abundance of four major families, viz. Erebidae, Geometridae, Noctuidae and Crambidae in different vegetation types sampled in Govind WLS & NP



Total numbers of individuals increased significantly (0.450) with increasing altitude. Average temperature had significant positive association with Erebidae abundance (0.565) and Fisher's Alpha (0.444). Number of individuals increased (0.576) as average humidity rose. As altitude increased, associated average temperature decreased significantly, which in combination has a significant negative association with canopy cover. The canopy cover in turn had a positive expression on Erebidae species richness (0.713) and abundance (0.565) and Crambidae species richness (0.847) and abundance (0.810), diversity of overall moth assemblage (0.444). Average Humidity had positive association with Shrub Cover (0.582), which was positively correlated with total number of individuals caught per light trap. Although tree abundance had no significant correlation with any of the diversity measure, Average height and Average GBH of tree had significant effect on moth assemblage structure. Both of these structural parameters of vegetation layer had significant negative effect on Noctuidae species richness (with

Avg. Height: -0.565, with Avg. GBH: -0.639) and abundance (with Avg. Height: -0.484, with Avg. GBH: -0.494) which signifies preference of this particular family for open type of habitat, not dense forest. Among disturbance parameters, logging sign had no significant effect on any of the diversity statistics, but intensity of grazing, i.e., number of grazing sign had significant negative effect on Crambidae species richness (-0.524) and abundance (-0.477). As distance to nearest village, an anthropogenic disturbance indicator increased, Herb species abundance (0.490) and grazing intensity (0.519) increased, whereas overall moth diversity (-0.486), Crambidae (-0.544) and Erebidae (-0.530) species richness and Crambidae abundance (-0.505) decreased significantly, while surprisingly, number of individuals captured increased significantly (0.538).

Table 5.1: Correlation matrix of overall diversity measures (Species observed, Individuals and Fisher's alpha) and family abundance with important habitat variables.

Variables	Sobs	Individuals	Fisher's Alpha	Erebidae Abundance	Geometridae Abundance	Noctuidae Abundance
Altitude	-0.090	**0.427**	**-0.466**	**-0.433**	0.240	0.310
Slope	0.192	0.109	-0.309	-0.161	-0.173	-0.021
Avg. Temp	0.241	-0.266	**0.451**	**0.525**	-0.318	-0.236
Avg.Humidity	0.242	**0.547**	0.004	0.061	0.178	0.255
Canopy Cover	0.328	0.141	**0.507**	**0.471**	0.104	-0.136
Tree Abnd	0.149	0.247	0.105	0.142	-0.216	0.187
Avg.Tree Height	0.101	0.074	0.278	0.309	-0.006	**-0.475**
Avg.Tree Gbh	0.093	0.140	0.132	0.311	-0.219	**-0.511**
Shrub Cover	0.349	0.382	0.309	0.275	0.082	0.237
Herb Sp.	-0.054	0.027	0.047	0.037	0.070	0.064
Herb Abnd.	0.037	0.226	-0.035	-0.130	0.220	0.249
Logging Sign	0.374	**0.475**	-0.038	0.092	-0.141	0.194
No. of Grazing Sign	0.179	0.266	-0.180	-0.175	-0.046	0.096
Nearest Village	-0.023	**0.509**	**-0.526**	-0.400	0.184	**0.463**
Values in bold are different from 0 with a significance level alpha=0.05						

Fig 5.4: Pair wise correlation graph between (a) Altitude vs. individual, (b) Altitude vs. Fisher's alpha, (c) Altitude vs. Erebidae abundance, (d) Average temperature vs. Erebidae abundance, (e) Average temperature vs. Fisher's alpha, (f) Average humidity vs. individual.

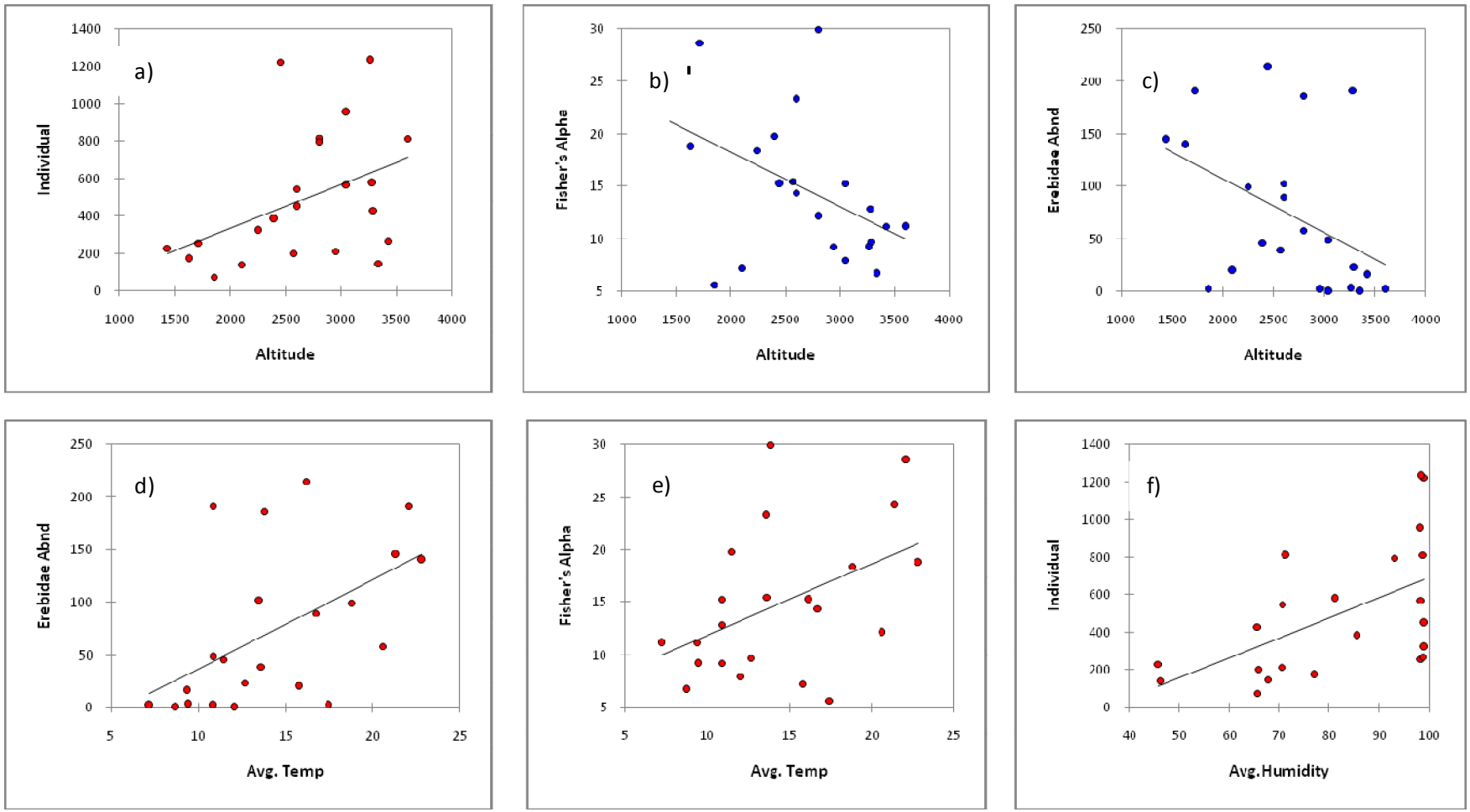


Fig 5.4: Pair wise correlation graph between (g) Canopy cover vs. Erebidae abundance, (h) Canopy cover vs. Fisher's alpha, (i) Average tree height vs. Noctuidae abundance, (j) Average tree GBH vs. Noctuidae abundance, (k) No. of grazing sign vs. individual, (l) Nearest village vs. individual.

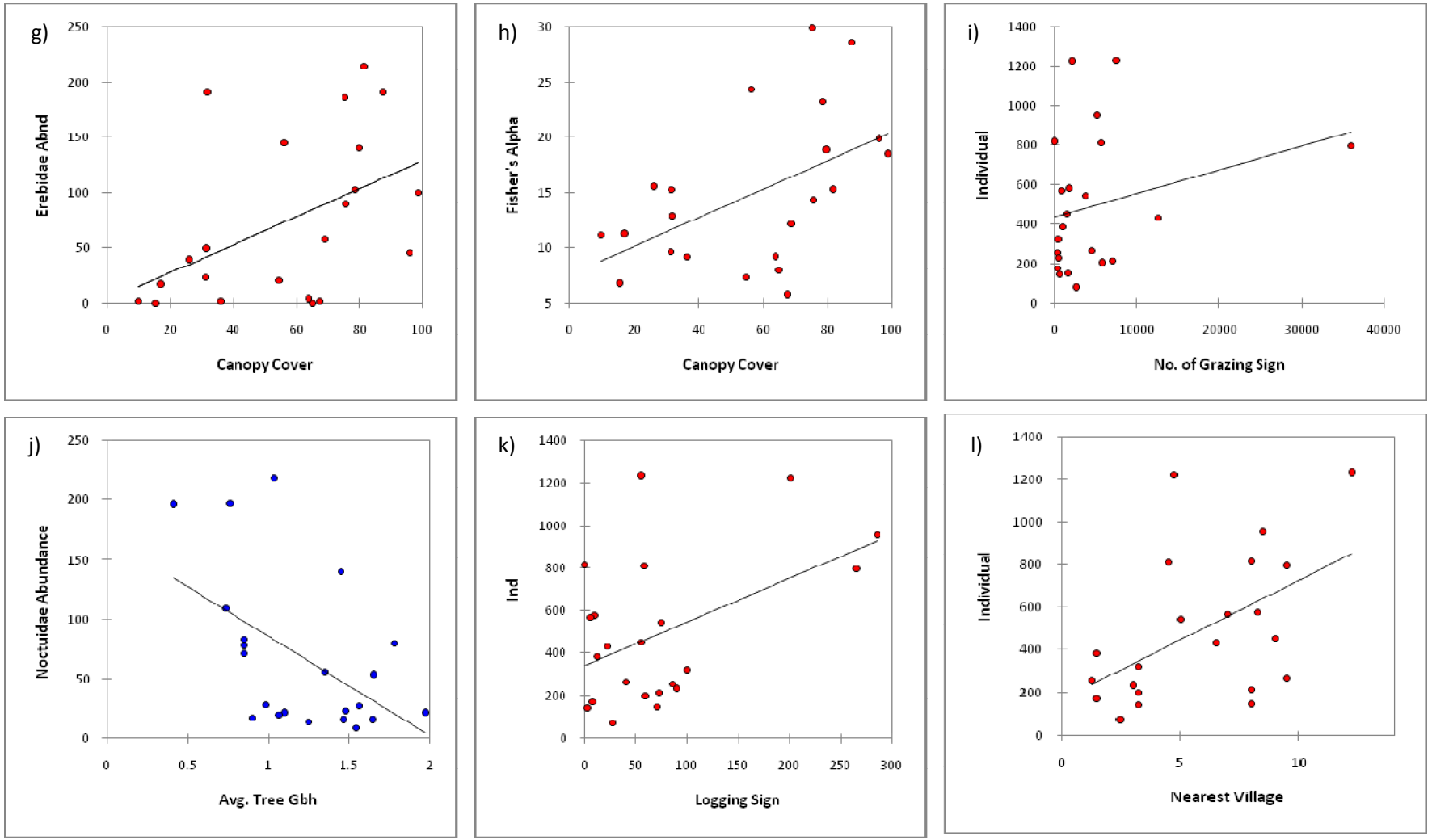
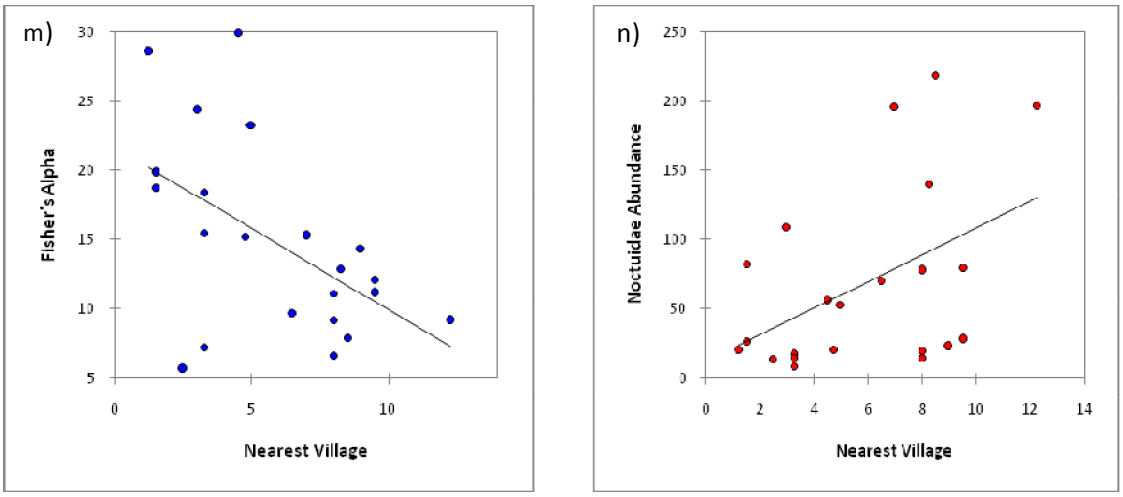


Fig 5.4: Pair wise correlation graph between (m) Nearest Village vs. Fisher's Alpha, (n) Nearest Village vs. Noctuidae abundance



5.3.3 Nonmetric Multidimensional Scaling of Habitat Variables

As initial NMS with all 48 plots indicated separation of habitats based on all the major data matrices, environmental, vegetation and disturbance, I analyzed the data with plots. Details of the NMS ordination results are given in Table 5.3. Seven environmental variables (both topographic and microclimatic), fourteen vegetation variables and twelve disturbance variables were included in the analysis. The main influential environmental variable was altitude with maximum loading constructing the major axes. Among vegetation structure and composition axes variables, Tree Abundance was most significant explaining 76% of the variability constituting the major axes, other influential variables being Average GBH (46%), Herb Abundance (38%) and Canopy Cover (33%). No. of grazing signs (42%) and Logging Sign (31%) were the most significant disturbance variables.

All the synthetic environmental, vegetation and disturbance variables obtained from NMDS were correlated with abundance of four major families encountered in light trapping. The environmental axes had significant negative effect (Table 5.7, Fig. 5.8) on the abundance of family Erebidae. This signifies a negative effect of altitude on abundance of moths of family Erebidae. All other relationships were weak and non-significant.

Table 5.2: Axis scores of NMDS of all environmental (microclimatic and topographic), vegetation and disturbance variables for all 48 plots

Axes		**Variable Names**	**Axis Scores**	
			Axis 1	**Axis 2**
Environmental		Altitude	0.67486	-0.26734
Stress	0.02315	Slope	-0.16721	0.39899
R^2		Barometric Pressure	-0.1366	-0.09847
Axis 1	0.9817	Cloud Cover	0.21575	-0.00928
Axis 2	0.0334	Average Temperature	-0.66856	0.22338
		Average Humidity	-0.01561	-0.29124
		Average Wind speed	0.14756	0.065138
Vegetation		Tree Abundance	0.76321	-0.10488
Stress	0.074	Average GBH	0.46116	0.052582
R^2		Herb Abundance	0.38224	-0.37114
Axis 1	0.7892	Canopy Cover	0.33718	-0.16933
Axis 2	0.3731	Shrub Cover	0.31733	-0.48731
		Herb Species Richness	0.31483	-0.23798
		Herb Average Height	0.31252	-0.17409
		Shrub Species Richness	0.28018	-0.17655
		Tree Species Richness	0.22165	0.028018
		Litter Cover (%)	0.078612	-0.02827
		Herb Cover	0.03798	-0.33327
		Grass Cover (%)	-0.0546	-0.35052
		Shrub Abundance	-0.26194	-0.53499
		Shrub Height	-0.47662	0.43586
Disturbance		No. of Grazing Sign	0.42051	0.027227
Stress	0.09385	Logging Sign	0.31913	-0.07418
R^2		Nearest Village	0.20733	-0.01919
Axis 1	0.7298	No. of Pellets	0.17967	0.27495
Axis 2	0.1339	Nearest Cropland	0.15976	-0.01028
		Felled Trees	0.14935	0.19591
		No. of Dead Trees	0.095708	0.12868
		Lopping Sign	0.007707	-0.49685
		Evidence of Fire	-0.06767	-0.18345
		No. of Dung	-0.12847	-0.09855
		Bare Soil	-0.25528	-0.03184
		Nearest Water source	-0.60162	0.11541

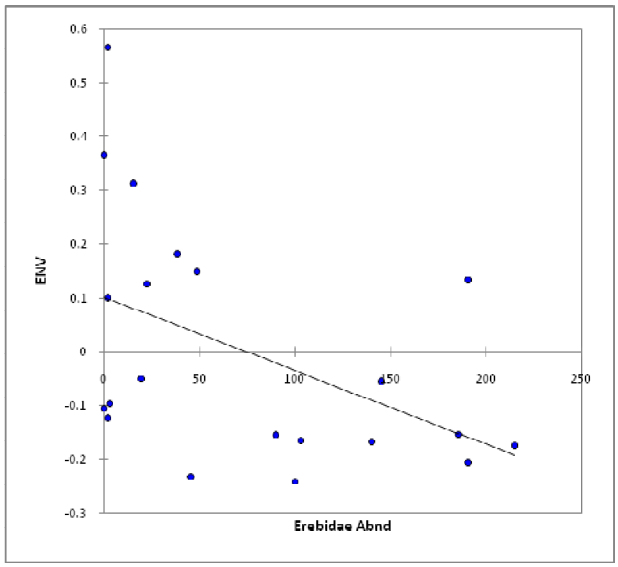
Table 5.3: Correlation between family abundance (Erebidae, Geometridae and Noctuidae) and different axes (environmental, vegetation and disturbance) derived from NMDS scores

Correlation matrix (Pearson):

Variables	ENV	VEG	DIST
Erebidae Abundance	**-0.466**	0.236	0.192
Geometridae Abundance	-0.059	-0.243	0.003
Noctuidae Abundance	0.064	-0.058	0.179

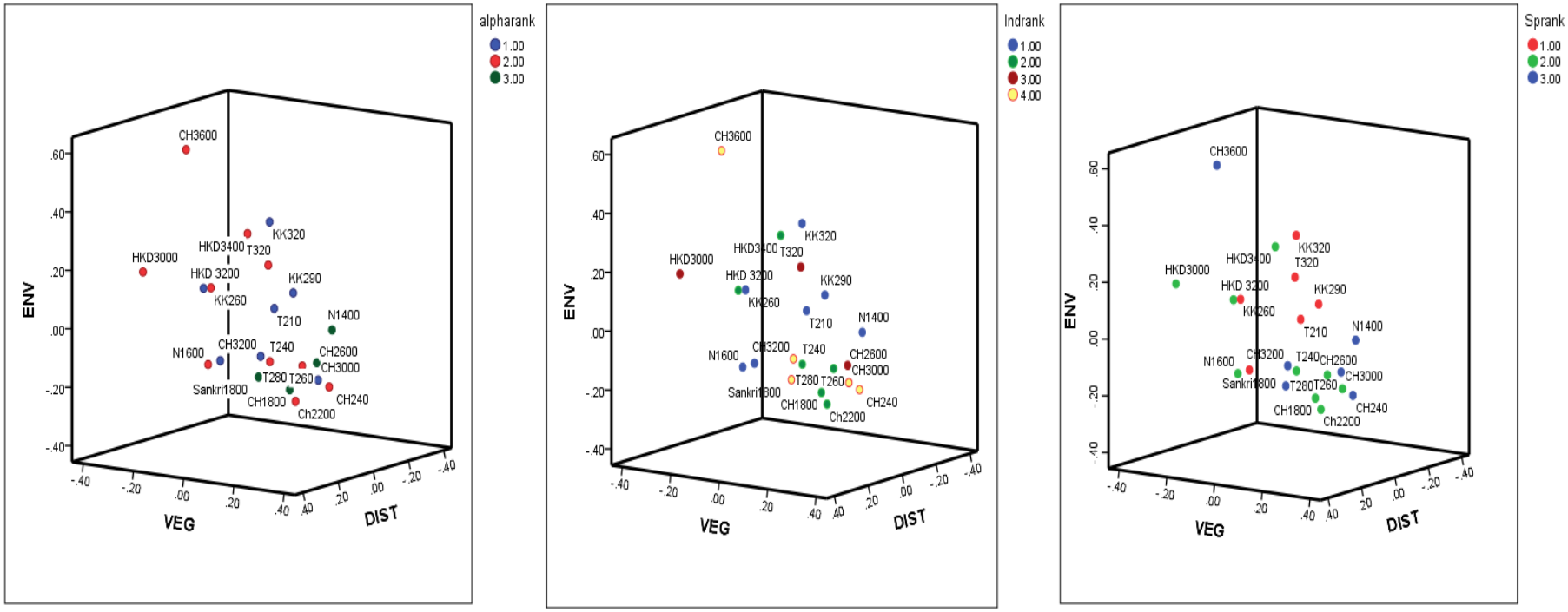
Values in bold are different from 0 with a significance level alpha=0.05

Fig 5.5: Scatter plot showing relation between environmental axes scores and Erebidae abundance



High Fisher's alpha were observed in dense vegetations with medium disturbances in low altitudes (low value of environmental variables) in 3-D scatter plot (Fig.5.5). Greater number of individuals was recorded in dense vegetation, low altitude and less disturbance, except one particular plot (CH3600), where highest number of individuals were recorded in high altitude. Species observed showed almost similar trend except plot CH3600. In all three cases, low environmental score, i.e., lower altitude, high vegetation score and low disturbance level supported high diversity and richness of moth, although very clear-cut pattern was lacking in general.

Fig 5.6: 3D scatter plot showing distribution of (a) Fisher's alpha, (b) Individual and (c) Species observed along three axes of environmental, vegetation and disturbance variables synthesized according to NMDS scores. Fisher's alpha rank: 1<10, 2<20, 3>20; Individual rank: 1<250, 2<500, 3<800, 4>800; Species Observed: 1<30, 2<45, 3>45



(a) (b) (c)

5.3.4 CCA with Environment and Moth Family Richness & Diversity

CCA using environmental, topographical, vegetation and disturbance variables (major variables obtained from NMDS) revealed significant pattern for all canonical axes. CCA was performed with habitat variables for two data matrices: one for major family richness and abundance, another for moth diversity indices like species observed, individuals, Fisher's Alpha, Shannon, Simpson and Pielou's index etc.

Table 5.4: Summary of the Canonical Correspondence Analysis (CCA) for moth family richness and abundance with axes related to environmental variables

Axis	Eigenvalue	% explained	p
1	0.23939	72.4	0.0198
2	0.056408	17.06	0.2079
3	0.022177	6.708	0.802
4	0.009578	2.897	0.009901
5	0.002336	0.7064	0.09901
6	0.00053	0.1602	0.8515
7	0.000208	0.06299	0.6931

In the CCA for family-environmental data matrix, the first two axes represented 89% variation (Table 5.5), while for the diversity-environmental data, the first two axes represented 97% of variation (Table 5.6). For family richness and abundance, the first CCA axes was strongly influenced by average temperature (r=0.74), canopy cover (r=0.59) and average GBH (r=0.36), which represented closed primary forest sites, and negatively influenced by altitude (r=-0.65). The first CCA axes were highly positive for Erebidae species richness (r=1.30) and abundance (r=1.23), Crambidae species richness (r=2.01) and abundance (2.26). Noctuidae species richness (r=-0.42) and abundance (r=-0.1.03), were negatively influenced by axes 1.The second axes of CCA was strongly influenced by tree abundance (r= 0.42), logging sign (r=0.46) and shrub cover (r=0.36), which was associated with Noctuidae abundance (r=1.63) and Crambidae species richness (r=2.01). The second axes was negatively influenced by average tree height (r=-0.45) and average GBH (r=-0.37), which had moderate negative influence on Geometridae species richness (r=0.55), which was not particularly related to any variable.

Fig 5.7: CCA biplot based on species richness and abundance of major families (Geometridae, Erebidae, Noctuidae and Crambidae) & environmental variables with sites.

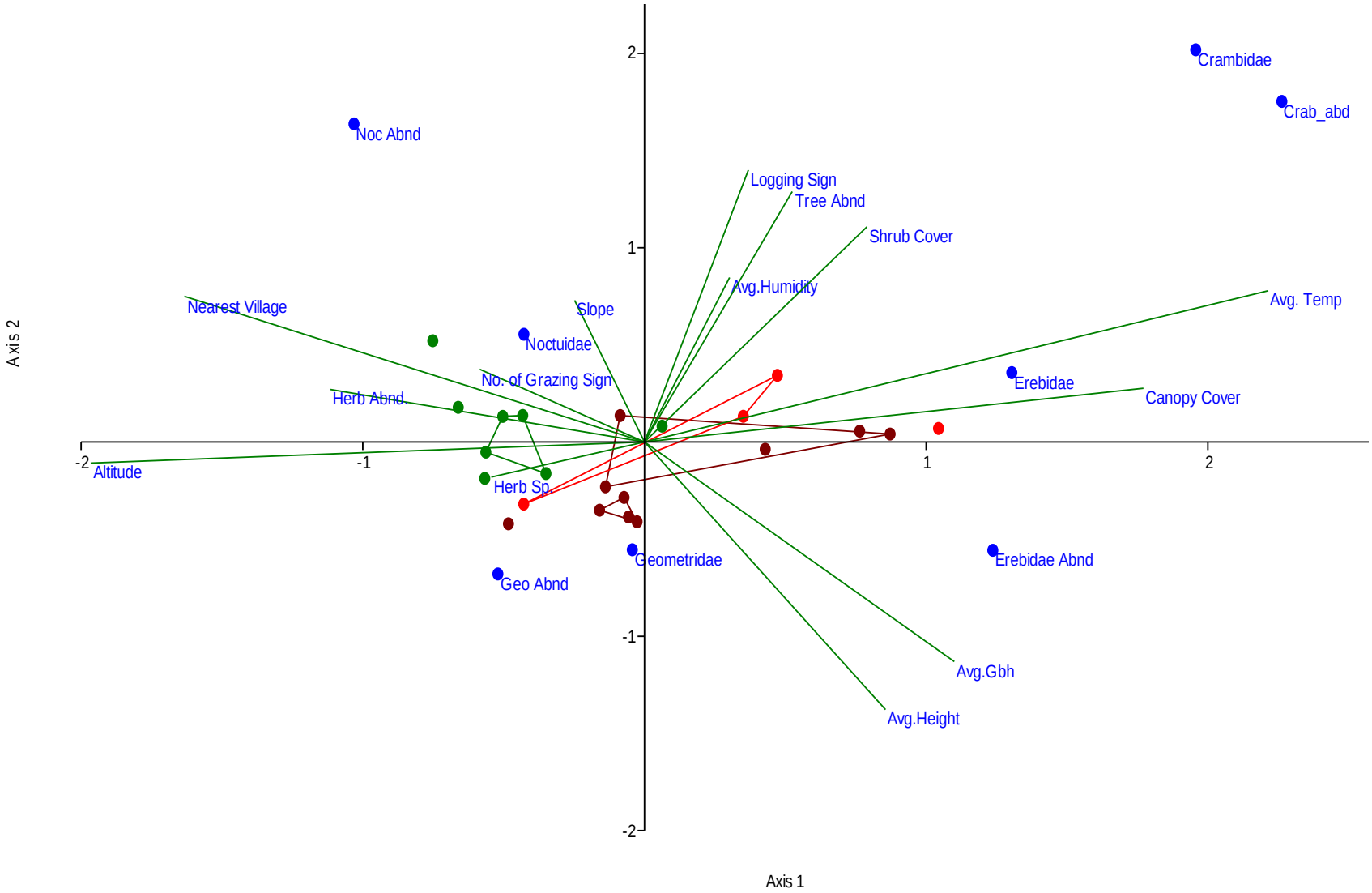


Table 5.5: Intraset correlations between explanatory variables and ordination axes resulting from the CCA, describing the relative magnitude and importance of each environmental variable in structuring the moth family richness and abundance ordination

Explanatory Variables	Correlations	
	Axis 1	**Axis 2**
Altitude	-0.655427	-0.0361731
Slope	-0.0827251	0.243004
Avg. Temp	0.738071	0.259627
Avg.Humidity	0.100609	0.282157
Canopy Cover	0.590371	0.0922276
Tree Abnd	0.174801	0.429546
Avg.Height	0.285159	-0.459038
Avg.Gbh	0.366607	-0.376683
Shrub Cover	0.263133	0.369151
Herb Sp.	-0.181275	-0.0602208
Herb Abnd.	-0.371698	0.0901254
Logging Sign	0.122867	0.466757
No. of Grazing Sign	-0.195013	0.124759
Nearest Village	-0.54453	0.249946

In the second CCA with different diversity indices of moth assemblage and environmental data, the first axes alone represented 94% (Table 5.6) variance in the data. The first axes was positively associated with average temperature (r=0.61) which had in turn positively influenced observed species richness (r=1.45), Fisher's Alpha (r=2.19), Simpson (r=3.21) and Shannon index (r=1.91). This axes was negatively associated with altitude (r=-0.78) and average humidity (r=-0.56) and had negative influence on number of individuals captured (r=-0.41). The second axes only explained 3% data variation which was positively associated with slope (r=0.51).

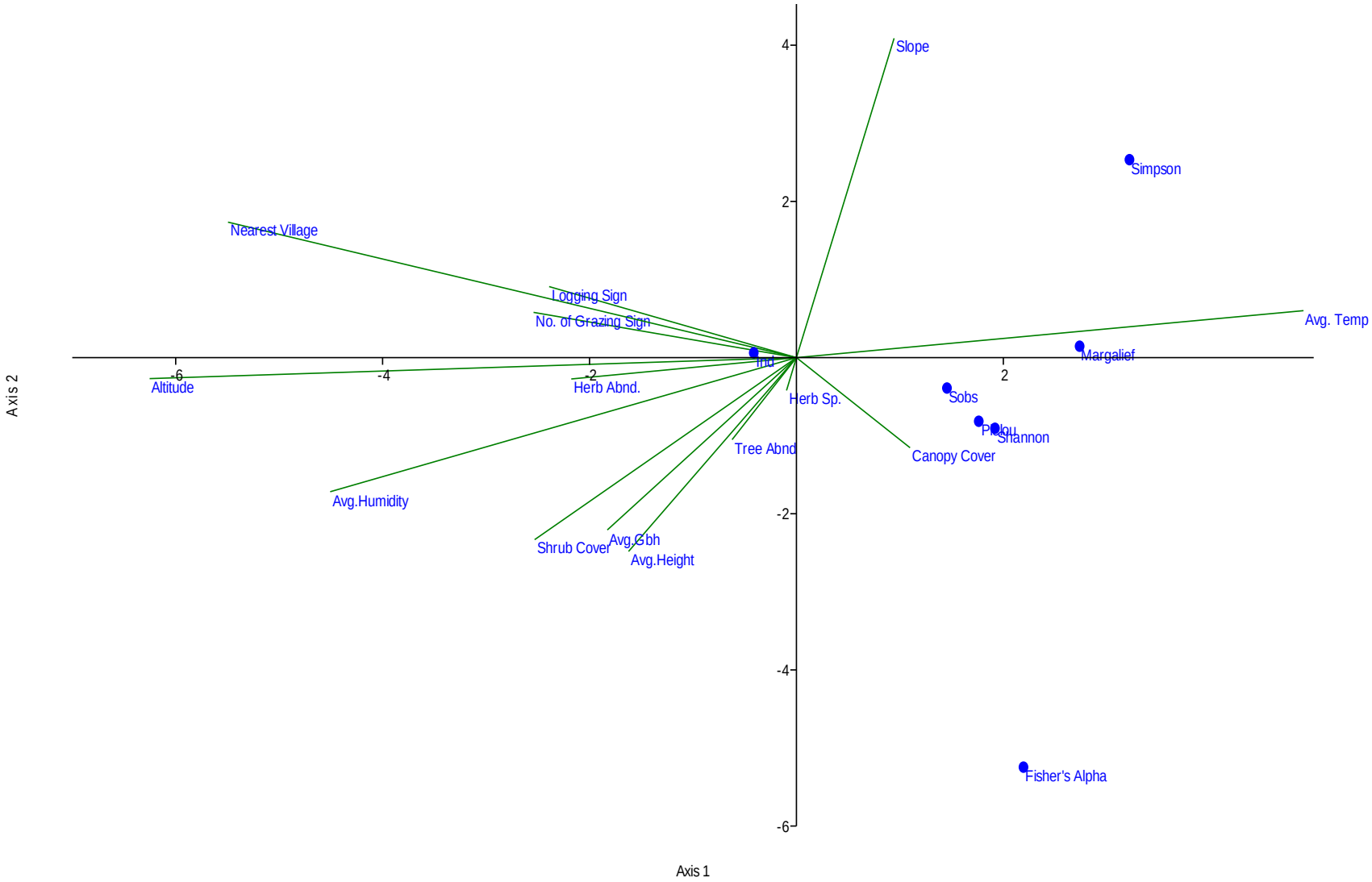
Table 5.6: Summary of the CCA for different diversity measures of moth species richness (Species observed, Individual, Fisher's Alpha, Margalief, Simpson, Shannon and Pielou's index) with axes related to environmental variables

Axis	Eigenvalue	%	p
1	0.07005	94.79	0.0297
2	0.002902	3.926	0.3366
3	0.0007	0.9473	0.604
4	0.000186	0.2521	0.901
5	5.92E-05	0.08014	0.8119
6	9.11E-07	0.001233	0.3861

Table 5.7: Intraset correlations between explanatory variables and ordination axes resulting from the CCA, describing the relative magnitude and importance of each environmental variable in structuring the moth diversity ordination

Explanatory Variables	Correlations	
	Axis 1	Axis 2
Sobs	1.45489	-0.39043
Ind	-0.412528	0.061748
Fisher's Alpha	2.19421	-5.2449
Simpson	3.21912	2.53489
Shannon	1.91911	-0.90515
Altitude	-0.781557	-0.03363
Slope	0.117954	0.511176
Avg. Temp	0.612616	0.075141
Avg.Humidity	-0.563366	-0.21476
Canopy Cover	0.137305	-0.14436
Tree Abnd	-0.0778411	-0.13146
Avg.Height	-0.202918	-0.31034
Avg.Gbh	-0.228537	-0.27604
Shrub Cover	-0.316372	-0.29147
Herb Sp.	-0.0120295	-0.05267
Herb Abnd.	-0.272077	-0.0343
Logging Sign	-0.298827	0.113608
No. of Grazing Sign	-0.317722	0.072306
Nearest Village	-0.686909	0.216724

Fig 5.8: CCA biplot based on moth species-diversity measures (Species observed, Individual, Fisher's Alpha, Margalief, Simpson, Shannon and Pielou's index) & environmental variables with sites.



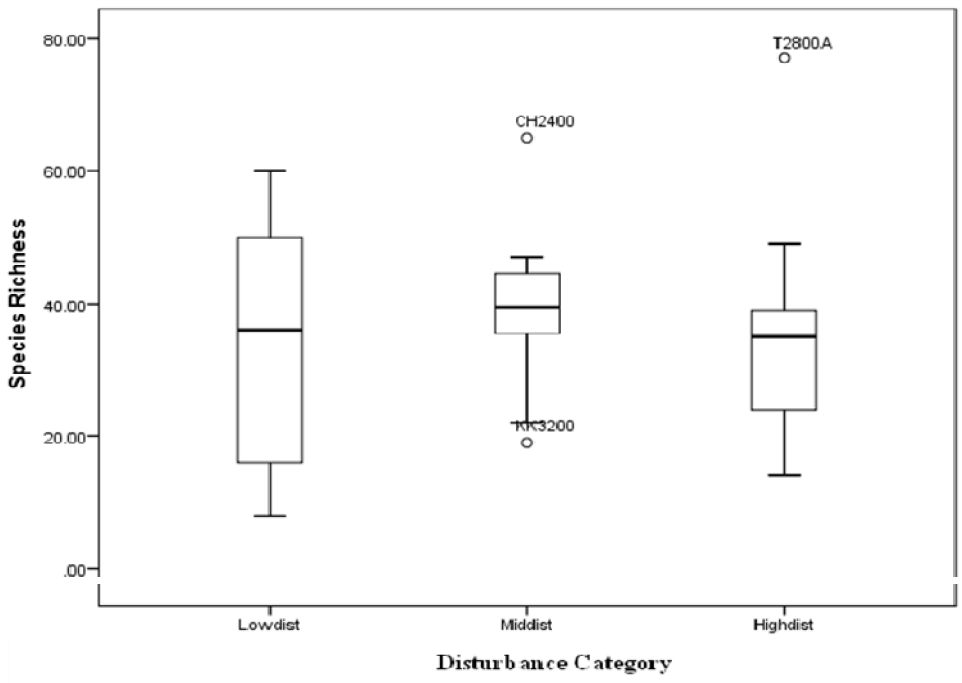
The overall result of CCA was encouraging since it clearly explained the suits of environmental, vegetation and disturbance parameters which influenced the community composition and assemblage structure of moths. Although there was no clear determinants recognized to influence the Geometridae richness and abundance, Erebidae, Crambidae and Noctuidae species richness and abundance were precisely predicted from the habitat variables considered.

5.3.5 Effect of Anthropogenic Disturbance on Moth Assemblage Structure

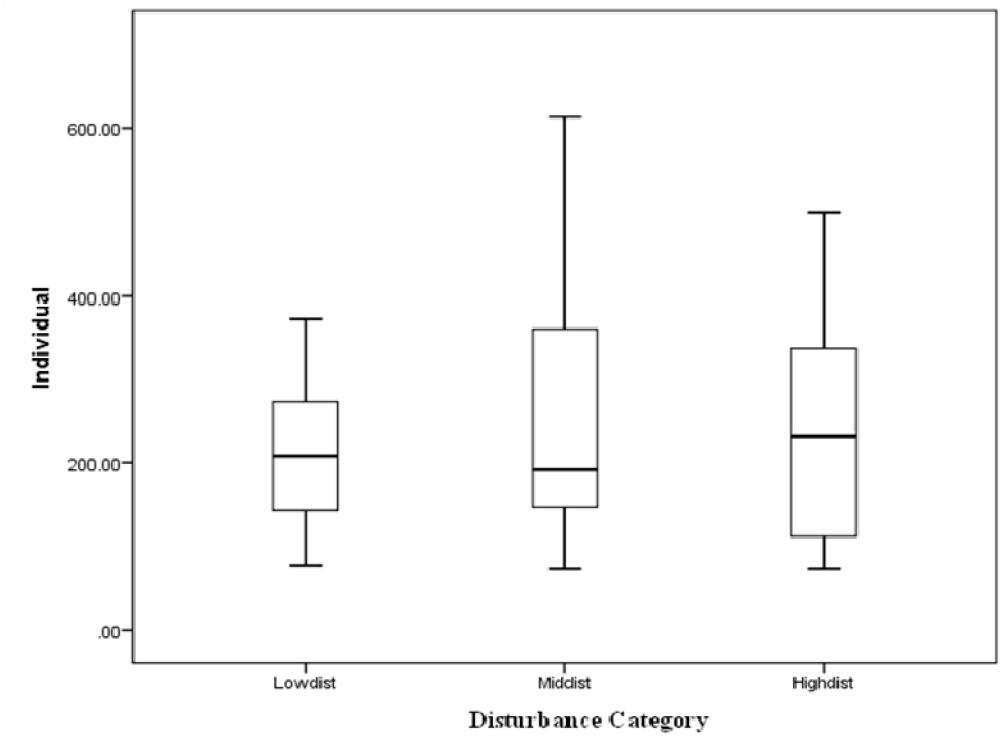
The 48 sampling plots were categorized into low, medium and high disturbance level according to the NMDS axes scores. The major variables explaining the NMDS disturbance axes were number of grazing sign, logging sign and distance to nearest village. I wanted to see how moth diversity and family composition differed in different disturbance categories. Although distribution of species richness and number of individuals captured among different disturbance categories did not differed significantly (Fig. 5.9, a, b), suggesting no subtle effect of anthropogenic disturbance on overall richness and diversity of moth assemblage.

Fig 5.9: (a) Species richness and (b) abundance of moths in three disturbance category, viz. low, medium and high

(a)

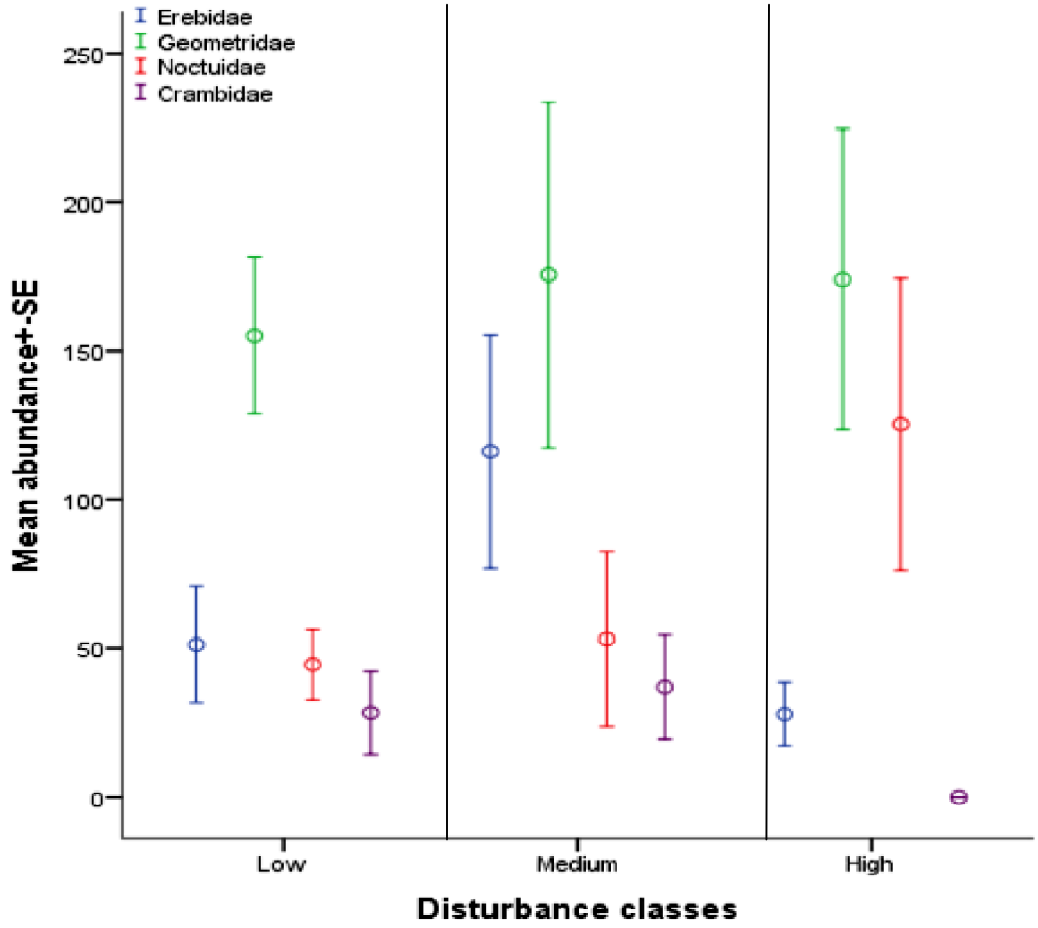


(b)



On the contrary, different families of moth responded to different disturbance intensities on a finer scale (Fig.5.10). While Geometridae, the largest family of moth recorded from the study area was equally abundant in all three categories of disturbance intensity, the other three responded differentially. The next largest family Erebidae was most dominant in mid-intensity category, the mean abundance of this family being lowest in high disturbance sites. Noctuidae responded in opposite manner being highly abundant in high disturbance sites, which is also congruent with the CCA result, associating this family with sites having less complexity in vegetation structure. The family Crambidae preferred sites with low to medium disturbance, the mean abundance of them being negligible in high disturbance category.

Fig 5.10: Mean abundance of four major families (Geometridae, Erebidae, Noctuidae and Crambidae) in three disturbance classes, viz. low, medium and high



5.3.6 Indicator Species of Moth for Different Vegetation and Disturbance

In general, the gradient in species and family composition across these habitat patches that range widely in variation to heterogeneity and disturbance, provides opportunity to identify species or species group i.e., family that respond to vegetation and microclimate attributes that change along the gradient. Apart from Indicator species, whose Ind Val percentage was above 70%, Detector species are also presented here, whose indicator score are between 50% and 70% (McGeoch *et al.* 2002). Only those species with statistically significant values ($P < 0.001$) were selected as suitable indicators or detectors from a list of 583 confirmed species (unidentified morphospecies were not considered for analysis) and are presented here (Table 5.8).

Table 5.8: Indicator species of moths for different habitat types sampled in GLA

Habitat Types	Species	Family	Ind Val	Sig. (P)
SPBM	*Semiothisa sufflata*	Geometridae (Ennominae)	81.6	0.001
SPBM	*Menophra subplagiata*	Geometridae (Ennominae)	78.4	0.0008
SPBM	*Scopula pulchellata*	Geometridae (Sterrhinae)	75.4	0.0013
SPBM	*Callopistria albolineola*	Noctuidae (Hadeniinae)	69.3	0.0091
SPBM	*Creatonotos transiens*	Erebidae (Arctiinae)	67.5	0.0098
SPBM	*Dyloxia fimbriata*	Pyralidae	67.5	0.009
SPBM	*Ericeia pertendens*	Erebidae (Calpiinae)	67.5	0.01
SPBM	*Hemithea sp.*	Geometridae (Geometrinae)	67.5	0.0087
SPBM	*Oraesia emarginata*	Erebidae (Calpiinae)	57.5	0.009
SPBM	*Spodoptera littoralis*	Noctuidae (Hadeniinae)	57.5	0.01
SPBM	*Dasychira cerebosa*	Erebidae (Lymantriinae)	56.4	0.0121
SPBM	*Helicoverpa armigera*	Noctuidae (Heliothinae)	53.5	0.0154
MTD	*Sirinopteryx rufivinctata*	Geometridae (Ennominae)	77.5	0.009
MTD	*Cotachena histricalis*	Crambidae	56.6	0.01
MTD	*Odontopera kametaria*	Geometridae (Ennominae)	56.4	0.0048
WMC	*Hyaloplaga pulchralis*	Crambidae	72	0.0204
WMC	*Cotachena histricalis*	Crambidae	68.6	0.0363
WMC	*Pseudopanthera himaleyica*	Geometridae (Ennominae)	56.9	0.0577
WHUOF	*Odontopera lentiginosaria*	Geometridae (Ennominae)	81	0.0051
WHUOF	*Spilosoma leopardina*	Erebidae (Arctiinae)	81	0.011
WHUOF	*Diphtherocome fasciata*	Noctuidae (Acronictinae)	78.9	0.006
WHUOF	*Mustilia sphingiformis*	Bombycidae	73.3	0.013
WHUOF	*Stenorumia* sp.	Geometridae (Ennominae)	53.3	0.0319
SAF	*Arichana tenebraria*	Geometridae (Ennominae)	87.1	0.0004
SAF	*Hermonassa consignata*	Noctuidae (Noctuinae)	87.1	0.0003
SAF	*Xestia sp.*	Noctuidae (Noctuinae)	77.1	0.0003
SAF	*Diphtherocome pallida*	Noctuidae (Acronictinae)	75.1	0.0009
SAF	*Photoscotosia amplicata*	Geometridae (Larentiinae)	74.6	0.0009
SAF	*Hermonassa incisa*	Noctuidae (Noctuinae)	70.6	0.0006
SAF	*Haderonia culta*	Noctuidae (Hadeniinae)	69	0.0048
SAF	*Opisthograptis tridentifera*	Geometridae (Ennominae)	64.7	0.0033
SAF	*Photoscotosia multilinea*	Geometridae (Larentiinae)	62.9	0.0024
SAF	*Valeriodes heterocampa*	Noctuidae (Cuculliinae)	62.9	0.0024
SAF	*Venusia classisigna*	Geometridae (Larentiinae)	62.9	0.0024
SAF	*Abraxas gunsana*	Geometridae (Ennominae)	62.4	0.0032
SAF	*Triphosa rubrodotata*	Geometridae (Larentiinae)	60.1	0.0166
SAF	*Eustroma chalcoptera*	Geometridae (Larentiinae)	58.4	0.0069
SAF	*Opisthograptis sulphurea*	Geometridae (Ennominae)	57.8	0.0099
SAF	*Malacosoma indicum*	Lasiocampidae	56.8	0.0129

Among 39 species selected from 5 major vegetation types, 15 species met the indicator criteria, while 24 species met the criteria of detector species. Species with highest indicator percentage (87.1) was from subalpine forest. This very specialized habitat was also characterized by highest number of indicators as well as detectors, signifying an assemblage of species with high conservation values typifying the habitat itself. The lowest vegetation type, Subtropical Pine Broadleaved Mix forest was characterized by 3 indicator species and 9 detector species. The Moist Temperate Deciduous forest and Western Mixed Coniferous forests were both characterized by single indicator and two detectors, signifying the assemblage as a mix-up of high and low altitude generalists occupying the entire mid altitude (1800m-2800m) of the gradient sampled. The Western Himalayan Upper Oak Forest sites were inhabited by 4 highly specialized species (with high Ind Val %) and a single detector species.

Table 5.9: Indicator species of moths for different disturbance categories, viz. Low, Medium & High in GLA

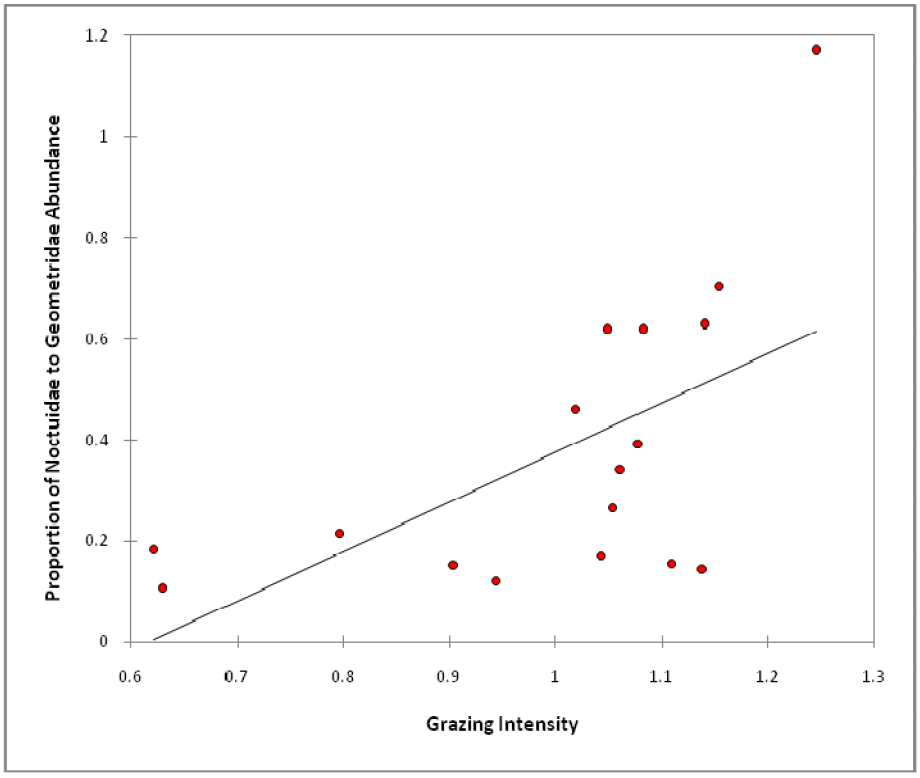
Dist. Level	Species	Family	Ind Val	Significance
Low	*Medasina albidaria*	Geometridae	76.8	0.0335
Low	*Heterolocha phaenicotaeniata*	Geometridae	76.1	0.1899
Low	*Percnia belluaria*	Geometridae	66.1	0.1432
Low	*Amphipyra monolitha*	Noctuidae	64.4	0.0237
Medium	*Panaxia similis*	Erebidae	80.4	0.0155
Medium	*Spilosoma obliqua*	Erebidae	80.2	0.0069
Medium	*Cymoriza ustalis*	Crambidae	65	0.0467
Medium	*Elphos pardicelata*	Geometridae	65	0.0429
Medium	*Hydrelia bicolorata*	Geometridae	65	0.0455
Medium	*Xandrames latiferaria*	Geometridae	65	0.0449
High	*Stenorumia* sp.	Geometridae	84.1	0.0113
High	*Diphtherocome pallida*	Noctuidae	80	0.0417
High	*Anonychia violaceae*	Geometridae	76.3	0.0515
High	*Triphosa sp.*	Geometridae	76.1	0.015
High	*Colostygia albigirata*	Geometridae	71.5	0.131
High	*Heliophobus texturata*	Noctuidae	71.4	0.024
High	*Photoscosia miniasota*	Geometridae	69.7	0.2708
High	*Spilosoma erythrozonata*	Erebidae	68.6	0.404
High	*Electrophaes recta*	Geometridae	68.4	0.0443
High	*Odontopera lentiginosaria*	Geometridae	68.4	0.1063
High	*Euphyia coangulata*	Geometridae	67.5	0.0563
High	*Gaurena dierli*	Drepanidae	67.3	0.1072

ISA was also performed with species-site matrix, sites categorized according to disturbance intensity, viz., low, medium and high, from NMDS score. Specificity and fidelity of all the species were computed to identify species characteristic of each disturbance level (Table 5.9). Three Ennominae species and one Noctuidae were characteristic of low intensity disturbance. Two Erebidae species of subfamily Arctiinae, one Crambidae and three Geometridae were characteristic of sites with medium disturbance. Among these five species, two Arctiinae, *Panaxia similis* and *Spilosoma obliqua* were with high Ind Val %, identifying these two species as ideal indicator of medium intensity disturbance. Maximum numbers of species, twelve in total were characteristic of sites designated as highly disturbed. Among them, *Stenorumia* sp. and *Diphtherocome pallida* were of high indicator score, while four other species met the indicator criteria for high-disturbance category. Six other species, among which four Geometridae and one each of Erebidae and Drepanidae were selected as high disturbance detectors with relatively low Ind Val score. Along with vegetation zone indicators, this set of disturbance indicators has potential to be used in conservation monitoring purpose, where changes in abundance pattern of these species may reflect underlying changes in habitat quality due to anthropogenic modification.

Another very easy and quick way to characterize disturbance in terms of changes in moth family composition is to look into the proportional changes in abundance of family Noctuidae to Geometridae. The ratio of noctuids to geometrids is an excellent disturbance indicator and has been used extensively to assess the quality of rainforest remnants in North Queensland, Australia (Kitching 2007). The more disturbed sites are dominated by "grass" moths (noctuids), whereas the less disturbed sites being dominated by "loopers" (geometrids). In the current altitudinal transect studied in a typical Western Himalayan landscape, livestock grazing was one of the major disturbance factors which varied greatly in intensity measured as number of visible signs of livestock feeding on ground herb layer in a 20 m^2 of nested quadrate plot used for vegetation quantification. I plotted proportion of Noctuidae to Geometridae along increasing grazing intensity represented as NMDS axis score. Except for few sites, the proportion of Noctuidae species to Geometridae species increased significantly (r^2= 0.59, p=0.012) with increasing grazing intensity (Fig. 5.11) validating appropriateness of this particular faunal index to point out

the level of grazing related disturbances in quick habitat assessment program. Overall, the moth assemblage structure and composition had much potential to be used as indicators representing the quality of vegetation zones as well as anthropogenic disturbance altering them.

Fig 5.11: Proportion of Noctuidae to Geometridae abundance along increasing grazing intensity



5.4 Discussion:

The main objective of this study was to document changes in moth assemblages along an altitudinal gradient within continuous Western Himalayan Montane Temperate forest. The data has demonstrated that there are characteristic assemblages of species at each elevation and have identified particular species with indicator potential. In this discussion I examine potential explanations for these patterns.

The occurrence of a species in a particular sample results from a multiplicity of factors. These may be methodological or biological. Methodologically, light trapping samples

only night-flying, light-attracted moths. This is a subset of all moths but, nevertheless, is adequately large to provide a degree of confidence to identify community patterns from which usable management tools can be derived. Light traps are relatively easy to use and produce large number of individuals which can be reliably identified to nullify the species-specific bias in abundance data. The sampling artefact was most likely present in measured total abundance and abundance of individual species, but there is no way of assessing the scale of this bias in the dataset (Bates *et al*. 2014). Poor catches in light trap resulted from their use on cold windy nights or bright moonlit nights (Nowinszky 2004). I had to use a sampling strategy which was flexible enough to substitute additional sampling nights in response to the occasionally unsuccessful trap night.

Ecologically, the presence or absence of a particular species at a particular elevation will be determined by the limiting dimensions of the niche of each species. These may be physico-chemical dimensions such as temperature, moisture and soil chemistry, or biological variables based on interactions with food-plants, competitors and natural predators. The physico-chemical variables are dimensions of the fundamental niche of the species and reflect the evolved physiological tolerances of the species concerned. Biological interactions add dimensions to the niche space which define the realized niche of the species (Hutchinson 1957). Species restricted to particular altitudes presenting more extreme and challenging microclimates, would be more likely to be restricted by their physiological tolerances of climatic extremes, whereas those species spread across altitudes, presumably comfortably within their physiological envelopes, are more likely to be restricted by biological interactions (Ashton *et al.* 2011). Biological interactions that may restrict the spatial distribution of moths are likely to include the presence of food-plants and the suite of predators and parasitoids co-occurring with them.

The present study, a systematic inventory of moths, is the first of its kind in Western Himalayan Landscape. As there is no previous species list available for this area, it is difficult to know precisely what proportion of the actual local and regional species richness the study captured. However, based on the estimated richness, the inventory was almost complete at the regional scale (90%). Methodological challenge of distortion-free abundance data of mobile organism like nocturnal Lepidoptera is always hard to collect,

that too in a previously untested Western Himalayan landscape, where the assemblage structure is affected by the greater abundance of rare species which forms a significant proportion of local assemblage. Although in the current study, the percentage of local singletons and doubletons were not very high, (maximum 21% and 18% recorded in Subtropical Pine Broadleaved Mix habitat respectively), the species pool of local assemblage was sufficiently sampled, with high percentage of sampling sufficiency. Patterns of moth dominance and diversity are more tightly linked to altitude (and the suite of environmental variables like average temperature and humidity that are associated with altitude). Among vegetation variables, the most parsimonious and most ecologically sensible explanation was that moth assemblages are highly influenced by tree and herb abundance. Average GBH of tree and canopy cover moderately influenced assemblage structure but had a strong influence on assemblage composition. The stronger relationship of moth biodiversity with total resource abundance than with resource diversity suggests that a relatively low degree of resource selection (Summerville et al. 2003) may be occurring among moths in these forests .

Light rapping data was analyzed separately for four most speciose groups of nocturnal Lepidoptera: Crambidae, Geometridae, Erebidae and Noctuidae. The advantage of this attempt is these groups represent different phylogenetic clade (Kristensen 1998) which differs substantially in their general biology like feeding guild, host plant-preference, physiology and diversity pattern in the landscape. Crambidae abundance was highest in lower altitudinal forest and considerable in mid-altitude forest like Western Mixed Coniferous forest, but was completely absent from forests above 3000m. Likewise, the family was absent in high-disturbance plots and had its highest abundance in mid-disturbance sites. Canopy cover, average tree GBH, tree abundance, logging sign and shrub cover are among the major determinants strongly influencing Crambidae species richness and abundance. The preference of the members of this family for grasses and herbs as food plants were reflected in the findings that grazing intensity had negatively influenced Crambidae diversity and abundance. Geometridae was the most successful group all through the landscape studied with highly abundant local fauna dominating the assemblage composition. Two most speciose subfamilies of Geometridae, the Ennominae and Larentiinae were abundant throughout the altitudinal gradient, diversity of the latter

one highest in forests above 3000m. Majority of the habitat variables had not successfully predicted Geometridae abundance and diversity except average tree height and average GBH which had negatively impacted species richness of this family. Among altitudinal-vegetation zones, this family had highest mean abundance in West Himalayan Upper Oak forests and subalpine forests, but abundance was not significantly different in three disturbance zones considered. The lack of a significant correlation between overall habitat variables and geometrid diversity indicates that geometrid moths may not be very selective in their food plant choice, as also reported previously in Afro tropical rainforests (Axmacher *et al.* 2009). Family Erebidae including subfamilies Arctiinae, Lymantriinae and Catocaliinae was the most suitable group for studying the environmental correlates, family being most significantly influenced by environmental variables like altitude and average temperature and humidity. Forest canopy is more influential to patterns of Erebidae diversity than are understory and shrub vegetation. This finding highlights the relative importance of abundance of canopy foliage in determining patterns of moth dominance and diversity. As a consequence, natural or anthropogenic changes in tree densities are likely to alter patterns of Erebidae diversity. Because timber harvest alters the distribution and overall abundance of canopy foliage, forest management activities are likely to impact Erebidae diversity in these Western Himalayan forests and they can be good set of indicators in studies assessing impact of logging on biodiversity. Erebidae was also sensitive to anthropogenic disturbance factors and their mean abundance was lowest in high disturbance plots. The family Noctuidae was abundant in altitudes above 2800m and associated forests like Upper Oak forest and subalpine forests. They were most negatively influenced by average tree height and tree GBH, whereas both shrub and understory species richness were dominant environmental gradients responsible for variation in Noctuidae species composition among sites. Strong relationships between species richness of shrubs and richness of moths collectively have been reported in both temperate and tropical forests (Chey *et al.* 1997, Intachat *et al.* 1997, Usher & Keiller 1998, Beck *et al.* 2002). It has been postulated that Lepidopteran species associated with understory and shrubs have more restricted ranges than do species associated with the canopy (Spitzer *et al.* 1993). If this is true, turnover in noctuid species composition would be expected to occur in concert with changes in shrub and understory composition, thus

explaining the linkages observed between moth community structure and the composition of vegetation beneath the canopy (Ober & Hayes 2010). The preference of the family for shrub and understory vegetation was also highlighted in the high mean abundance of the family in high disturbance sites where logging and grazing were intense. The family abundance can be used as an effective indicator of increased grazing pressure in studies assessing the effect of livestock pressure on biodiversity.

The high-elevation moth communities were far more variable inter-annually, whether associated with high-elevation forests, meadows, or alpine pastures. Low-elevation young and old Pine-Broadleaved mix forests and riparian forests had more stable and predictable communities having less inter-annual variability. Low-elevation moth communities are less abundant than high-elevation communities and typically associated with the high species richness with most common, abundant species of macro moths in the study. High-elevation communities, by contrast, are associated with specialized species with high abundance as well as with rare moth species. Nocturnal moths, especially those altitudinally restricted species are good indicators of changing climate conditions in local and regional landscapes because many species have relatively discrete distributional boundaries associated with the distribution of their host-plants and climatic limits. Because they respond to fluctuations in temperatures from year to year via accelerated or delayed maturation, they are effective biological indicators of climate change effects (Highland *et al.* 2013).

The selection of suitable indicator species depends on several criteria. An effective indicator needs to be present in large numbers, be easily recognizable, as well as being sensitive to environmental variables (Holloway 1998, Scoble 1995). Moth groups that are sensitive to floristic change and which have low vagility (Ashton *et al.* 2011) fulfill these criteria and have been demonstrated to be good indicators across a variety of ecological investigations (Beck *et al.* 2002, Holloway 1985, Kitching *et al.* 2000, Scoble 1995). The analyses presented here suggest a set of 15 species of Indicators and 24 species of Detectors which may be useful as part of a multi-taxon predictor set for future monitoring of the impact of global warming on forest biodiversity. The existence of clear cut patterns of altitudinally delimited moth assemblages, with particular species having clearly

restricted altitudinal distributions, suggests that selected moth taxa will be useful in tracking any upward shifts in distribution and invasions of higher altitudes, a likely consequence of global warming. It also suggests that the highly distinctive upper elevation assemblage (the subalpine set of indicators) must be regarded as vulnerable and of conservation concern. Together with disturbance-category indicators, this set of moth species identified can be usefully incorporated as part of a 'predictor set' of arthropod and plant species, reflecting different trophic levels and guilds within the Western Himalayan forest community. This will be significant for the ecological monitoring of future changes in ecosystem composition and function (Kitching 1993, McGeogh 1998).

In conclusion, the analyses I have presented here are among the first, necessarily preliminary results of the nocturnal Lepidoptera studies in Western Himalayan Landscape. This study effectively shows that moth assemblages provide reliable assessment of the habitat condition in response to habitat heterogeneity and disturbance. Moths, as diverse and abundant plant feeders in forest ecosystems, seem well suited to discriminate vegetation type and quality, since many species often rely on a distinct complex of environmental habitat factors with respect to species-specific ecological demands. Further research should explore wider distribution and larval food plant records of identified indicator species and their responses to vegetation and disturbance data collected in a finer spatial scale. These data will be critical to understand the rapid changes taking place in populations of rare and vulnerable species and their habitats. This would help conservation planners and managers in the selection of biodiversity rich areas and by giving attention to remaining fragmented habitats facing human alterations in Western Himalayan Landscape, which will ultimately increase biodiversity conservation efforts in the area and to halt and reverse the biodiversity losses that threaten human welfare.

CHAPTER VI

SEASONAL VARIATION OF MOTH ASSEMBLAGES IN GANGOTRI LANDSCAPE

6.1 Introduction

Patterns in temporal variation of insect population abundances or community composition, and their underlying processes, are of major interest to ecologists. It has commonly been observed that insect abundance changes both in long-term (e.g. years) as well as in short-term cycles (e.g., weeks; Wolda 1978, Cook & Graham 1996). In practice, there are few generalizations that can be made about insect seasonality in the tropics and tropical insects can show a wide array of seasonal patterns, even at the same site (Wolda 1988). Species can be aseasonal, occurring throughout the year, can show one or more seasonal peaks, and those peaks can be short and sharp or spaced over a broad period (Wolda 1988). In the highly seasonal temperate forests there are a range of life-history strategies to deal with the large differences in temperature and rainfall and consequent availability of resources during the year. Some adult insects enter a state of reproductive dormancy in the winter months and sometimes during hot dry periods of the summer. Cues that control the switching from one state to another or from one life stage to the next are thought to include photoperiod, temperature, and moisture (Wolda 1988, Tauber *et al.* 1998, Didham & Springate 2003). Despite the usually low intra-annual variation in temperature and photoperiod in the tropics, the climate of most tropical rain forests is distinctly seasonal particularly with respect to precipitation (Leigh 2004). Consequently tropical insect assemblages have shown strong seasonal patterns, more often associated with changes in precipitation rather than temperature (Denlinger 1980, Wolda 1988, Frith & Frith 1990, Hill 1993). A majority of tropical studies covering a wide range of insect groups support the classic view of tropical entomologists that insect activity and diversity peak during the wettest part of the year (Owen & Chanter 1970, Wolda 1978, Denlinger 1980, Smythe 1982, Novotn´y & Basset 1998, DeVries & Walla 2001) rather than the driest (Boinski & Fowler 1989, Basu 1997, Dibog *et al.* 1998).

However, the cues for changes in activity and reproductive behavior can vary even among closely related species (Jones & Rienks 1987), and can be relatively delicate.

In literature there are not much studies relating to seasonality of moth assemblage, while considerable works have been carried out for butterflies, although the choice of resource for these two Lepidopteran groups are almost alike. Moth assemblage reacts to changing season differently from butterflies owing to their nocturnal habit. In forest ecosystems, moths are mostly herbivores in their larval stage and are thus particularly sensitive to environmental changes that affect plant quality and quantity as their diets. Seasonal patterns of larval moth assemblages have been investigated in relation to foliage quality, weather conditions and natural enemies (Feeny 1970, Niemelä & Haukioja 1982, Yoshida 1985, Butler & Strazanac 2000, Summerville *et al.* 2003; Murakami *et al.* 2005). However, only a few studies have focused on seasonal patterns of adult moth assemblages (Yoshida 1980, Yela & Herrera 1993, Butler *et al.* 2001). Despite pronounced temporal fluctuations in total catch size (i.e., variation in the number of observed species and individuals), diversity of Southeast Asian Pyraloidea (Schulze & Fiedler 2003) and Geometridae (Intachat & Holloway 2000) showed no clear cyclic trends (also Barlow & Woiwod 1990). In more seasonal tropical climates, fluctuations in abundance and species richness have been documented in a number of insect groups (Wolda 1978, Smythe 1982, Wolda & Wong 1988). For example, DeVries *et al.* (1997) observed that both species richness and abundance of Nymphalid butterflies in a lowland forest in Ecuador are depressed during the dry season and increase at the beginning of the rainy season. This seasonal pattern recurs in many other insect groups (such as Coleoptera, Hymenoptera, Homoptera, Lepidoptera, Orthoptera: e.g., Janzen 1984, Wolda & Wong 1988, Brown 1991, Wolda 1992, Pinheiro *et al.* 2002). Yet, the magnitude of intra and inter-annual variation in species richness and abundance of tropical insects remains poorly known. Moreover, temporal dynamics of faunas might vary between more natural and anthropogenically altered habitats (Fiedler & Schulze 2004), or between taxonomic groups. These considerations also have practical consequences, e.g., for conservation-oriented assessment of local faunas or for the purpose of "bioindication." If temporal dynamics lead to strong variation in diversity or species composition, the exact timing of sampling will be essential to warrant

comparability and representativeness of samples in monitoring programs (Hilt *et al.* 2007). Only if species diversity and composition of faunas remain largely stable over time, short-time sampling programs performed at different times will yield data that allow for further comparisons.

Here in this chapter, I analyze the temporal variation in diversity and species composition of diverse ensembles of mobile herbivorous insects, i.e., nocturnal Lepidoptera along an altitudinal gradient in a Western Himalayan landscape. In a typical Western Himalayan landscape, three main seasons can be demarcated: Spring or summer, pre-monsoon (April to June), Monsoon (July-August) and autumn or Post-monsoon (September-November). The winter is prolonged (November to March) and owing to low temperature, night time activity of flying insects are minimal. I chose four different moth families as model groups, namely Geometridae, Erebidae, Noctuidae and Crambidae. Species of these four families were abundant in the altitudinal gradient sampled and taxonomically well-tractable. These four families differ prominently in important life history traits such as body size distribution, host plant relationships, voltinism (the number of generations per year), and adult life span. These varied biology of the different families of moth allowed analyzing the effect of seasonality on a finer scale of resource dependency.

I specifically asked following broad questions:

i) How diversity (alpha diversity) and abundance of moth assemblages in different altitudinal zones varied in different seasons?

ii) How these two governing factors, viz. altitude and season and their interaction affected relative abundance of most common species of moths of dominant families like Geometridae, Erebidae, Noctuidae and Crambidae?

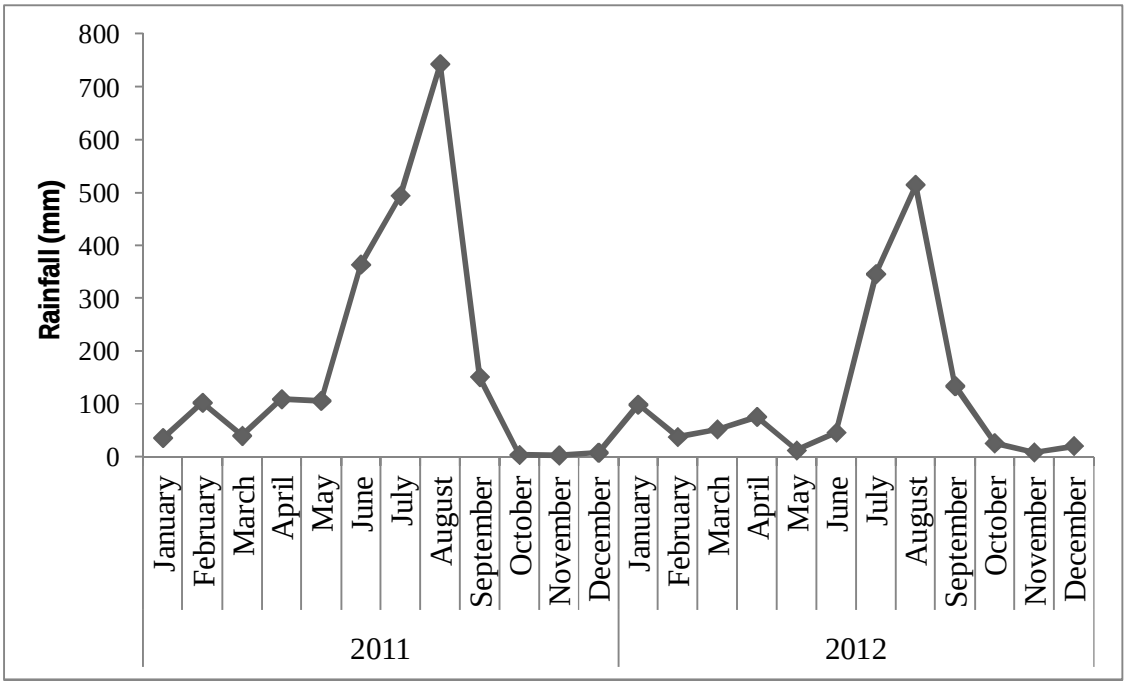
iii) Seasonal trend in species/individual caught per light-trap night.

6.2 Methods

6.2.1 Study Area and Seasonal Pattern

The study area in Gangotri Landscape Area comprising Govind Wildlife Sanctuary and National Park and Gangotri National Park shows typical Western Himalayan climate with Subtropical weather in lower altitudes up to 1600m and temperate climate above. The sampling sites were grouped into three categories according to their altitudinal position: Low (1500m-2000m, N=28 sites), Medium (2100m-2900m, N=29 sites) and High (3000m-3600m, N=25 sites). Broadly the area showed occurrence of four main seasons: Summer or Pre-Monsoon from mid April to mid June. Monsoon sets in from mid June and continues up to mid September. The Post-Monsoon season is from mid September to November. The remaining months of winter from December to March were not considered for analysis as light trapping was not possible in those months due to very low night temperature resulting in absolutely no nocturnal insect activity.

Fig.6.1: Mean monthly rainfall for GLA in the year 2011-12. The data is from Hydro-Met Division, New Delhi, Indian Meteorological Department



Subtropical climate in lower part of the valley is characterized by hot and more or less humid monsoon season from July to September, pleasant autumn and spring and a cool,

dry winter season. The average annual rainfall is 1500mm, with extreme cold and snow during the 3-4 months of winter. The rainfall pattern for the year 2011-12 is depicted in fig. 6.1. Maximum rainfall occurs during month of July and August and minimum rainfall during January and October. In summer maximum temperature reaches 42-43° Celsius in areas below 1600m and 30-32° Celsius at 2000m elevation. At higher elevation the weather remains cool and pleasant even in June and the precipitation being high. The winter is long and severe with heavy snowfall above 2000m. Snow starts falling in November and continues up to February and sometimes in March. The period from month of December to February is the coldest period. The months of April, May and June are warm, marked by occasional thunderstorms, often accompanied by hail and raining, at all elevations.

6.2.2 Sampling and Identification

Moths were sampled manually by attraction to weak light sources (solar powered lantern equivalent to 80 Watt White Actinic bulb and gas petromax equivalents to 160 Watt Mercury vapour (MV) bulb.). Low-power light sources are sufficient to minimize cross-attraction of moths between sampled habitats (Schulze & Fiedler 2003, Beck & Linsenmair 2006). The effective 'radius of attraction' for moths has been estimated to be only between 10 and 30m (Muirhead-Thomson 1991, Beck & Linsenmair 2006). I restricted sampling to the peak time of moth activity during the evening hours between 8pm and 4am, in two sessions. Moths were collected during six periods comprising three seasons, in the years 2011-12 which showed the climatic characters typical for the region. Rainfall was very high in 2011, the pattern of monthly rainfall almost identical in both the years, monsoon arriving one months prior to be expected in 2011 (Fig.6.1). At each site and within each period, 2-4 nightly catches were pooled to provide the data basis for the subsequent analyses. Catches were restricted to phases between four days after full moon until six days before full moon, because the moon phase has an important impact on the efficiency of light traps (McGeachie 1989, Yela & Holyoak 1997). Specimens were sorted to morphospecies and later taxonomically identified as far as possible using published literature and reference collections.

6.2.3 Quantitative Analysis

Box plots with error bars were used to represent the differences in nightly catches of both number of species and individuals caught in light trap in different months and seasons. Numbers of all moth species and individuals and diversity estimates were compared between pooled samples of each of the three seasons in three altitudinal zones. I calculated Fisher's alpha as a measure of local diversity using program EstimateS. Besides, estimated species richness using Chao 1 and species observed for pooled samples were compared between seasons. The extent of temporal abundance variation of individual species of prominent families like Geometridae, Noctuidae, Erebidae and Crambidae was tested in the commonest species only, i.e. species where the total catch (summed over all sites and seasons) was N>50. For rarer species sampling effects are expected to be so pronounced that they weaken reliability of detailed species-level analyses. In these common species, numbers of moths were converted to relative abundances (setting the total catch per each site and sampling period as 1), since light-trap data do not provide sound measures of absolute abundance, but yield useful data of relative abundances for those species that are attracted to light (Fiedler & Schulze 2004). Relative abundances were then analyzed by univariate analysis (General Linear Model) with altitudinal class (low, medium and high) and collecting season (pre-monsoon, monsoon and post-monsoon) as effects. Additionally, error graphs were produced for relative abundance of most common species in different altitudinal zones in different seasons.

The significance of faunal differences between predefined groups of samples in each season was assessed by ANOSIM (Clarke & Warwick 2001) with 1,000 random permutations. The R statistics of ANOSIM was used as a measure of effect size. SIMPER was performed to identify species contributing most (50%) in seasonal turnover of assemblage composition.

6.3 Result

6.3.1 Seasonal Variation in Overall Moth Abundance and Diversity

Daily changes in numbers of moths caught in light traps are more representative of changes in flight activity rather than changes in abundance (Muirhead-Thomson 1991). Environmental conditions are likely to influence light trap catches by altering trap efficiency. Changes in flight activity and trap efficiency in response to weather also cause light trap catches to vary with weather conditions. However, variation in both flight activity and trap efficiency represent forms of sampling error in absolute abundance estimates. With an aim to see the seasonal pattern of moth assemblage along altitudinal gradient, I first analyzed the monthly and seasonal changes in species and individual caught per trap night. In all the four cases (Fig. 6.2 a-d), there was a clear pattern where mean number of species and individuals caught per trap night was highest in the monsoon season and lowest in post-monsoon. In pre-monsoon, numbers of species and individuals caught was higher than post-monsoon season. Monthly trend showed number of moths caught was significantly higher in the month of July and the pre-monsoon months like May-June having higher catches than post-monsoon months like October-November.

Fig 6.2: Monthly trend & Seasonal trend of species (a-b) and individual (c-d) caught per trap night in GLA (2008-2012)

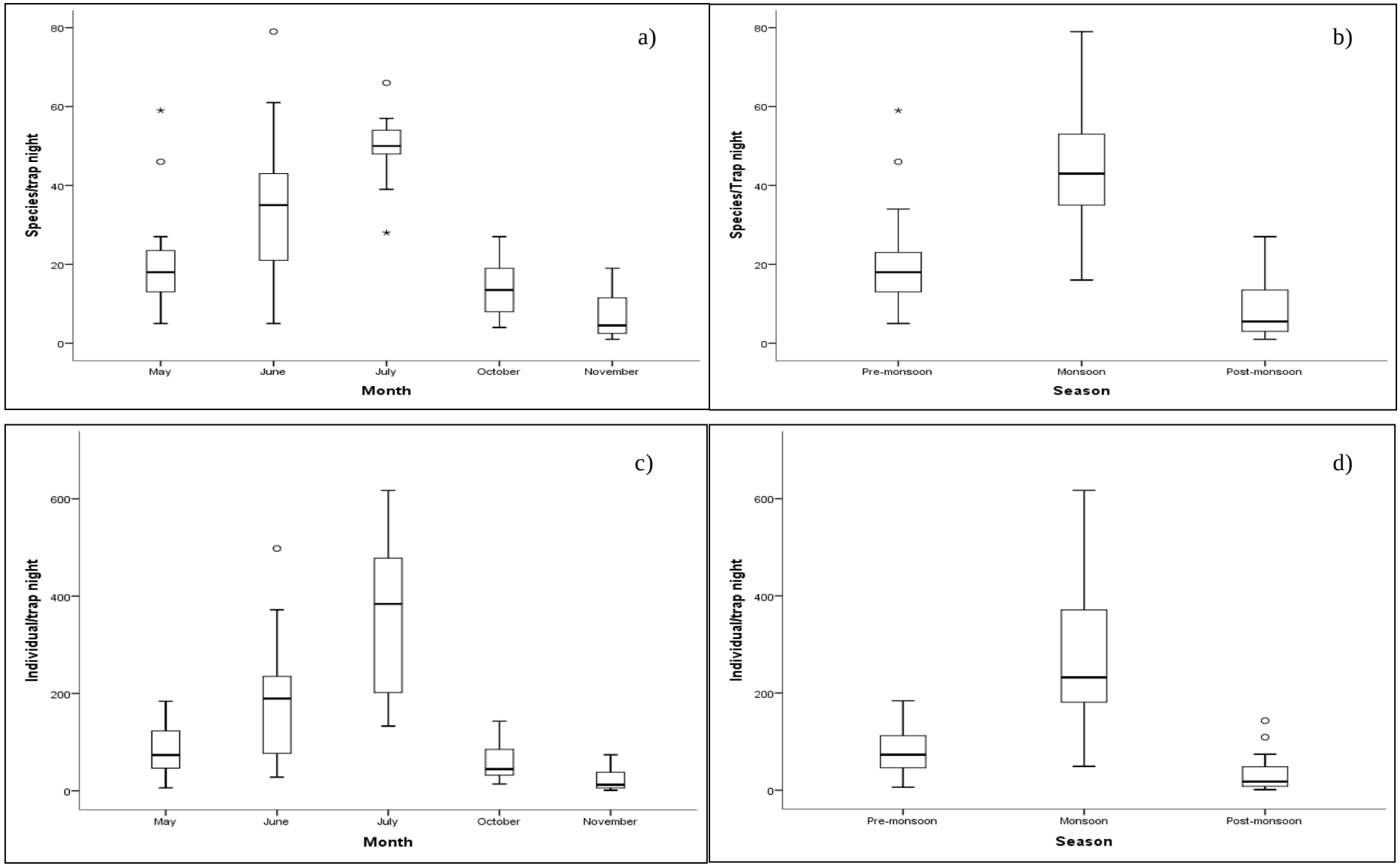


Fig 6.3: Diversity statistics of moth assemblage in three different season, viz. pre-monsoon, monsoon and post-monsoon in three altitudinal zones in GLA (Low : <2000m, Medium: 2000-3000m, High: >3000m)

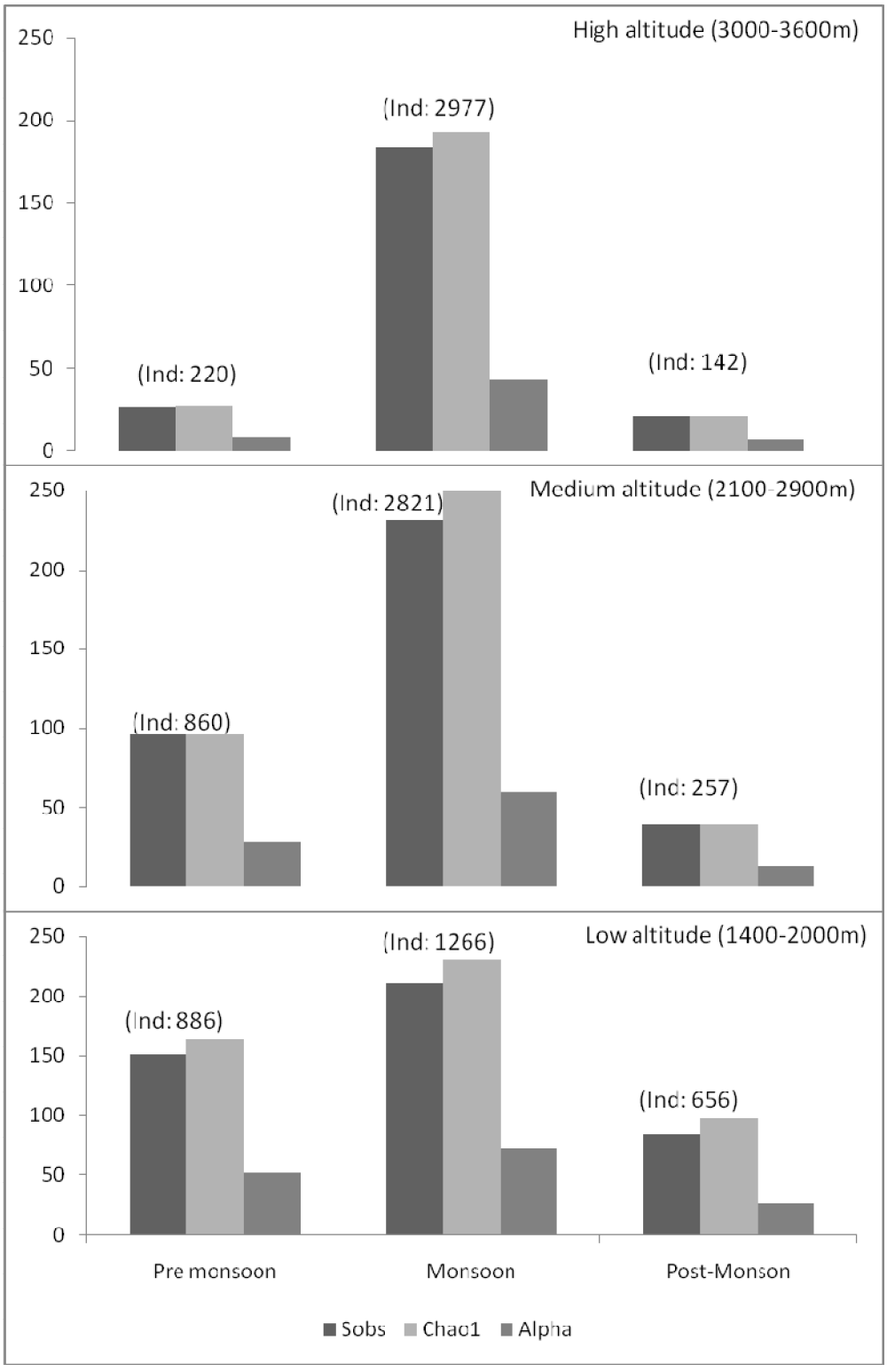
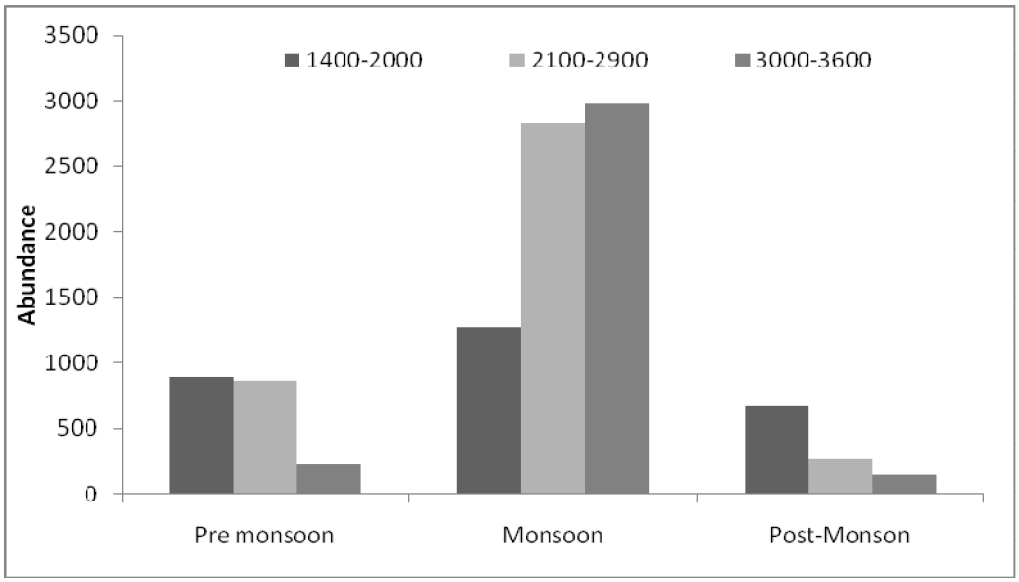


Fig 6.4: Abundance fluctuations of moth assemblages in three altitudinal zones in three seasons



The alpha diversity of moth assemblages was analyzed in three altitudinal zones, viz. low (<2000m), medium (2000-3000m) and high (>3000m) in three seasons. Three measures of alpha diversity were taken into account: the actual number of species observed (sobs), the extrapolated species number (Chao1) and Fisher's alpha. Alpha diversity was highest in monsoon in all the three altitudinal zones (Fig. 6.3) by all measures. There was no significant difference of alpha diversities recorded in high altitude between pre-monsoon and post-monsoon. However, in medium and low altitudes, diversity recorded was higher in pre-monsoon than post-monsoon. In lower altitude zone, the magnitude of difference between three seasons was less pronounced compared to other zones. Among three measures of alpha diversity, sobs and Chao 1 were almost identical in nature, whereas Fisher's alpha values were significantly lower compared to other two. But in all the cases, monsoon season was the time when diversity of moths was highest.

I also analyzed the abundance fluctuations of moths in different season in different altitudinal zones (Fig. 6.4). In pre-monsoon, high moth abundance was recorded in both low and middle altitude, which was significantly higher than abundance in high altitude. On the contrary, the picture was just opposite in monsoon season, when abundance was

highest in high altitudes, which was significantly higher than abundance recorded in low altitude zone. There was not much difference between high and mid altitude during this season. In post-monsoon, the moth abundance again decreased drastically and was higher in low altitude compared to middle and high altitude. Overall, moths were most abundant in monsoon season and population bloom was recorded in high altitude zone in this season.

6.3.2 Contribution of Individual Species to Temporal Dynamics

Relative abundances of most prominent species of major families were analyzed to see the effects of altitude, season or their interaction. For Geometridae, there was a clear temporal effect and a weaker altitudinal effect (two-way ANOVA with repeated measurements: altitude: $F_{2, 11} = 5.61$, $P<0.005$; season: $F_{2, 22} = 22.66$, $P<0.05$; interaction term: $F_{2, 22} = 12.96$, $P<0.005$). Geometridae relative abundance was positively influenced by the interaction of low-altitude class and post-monsoon season whereas in case of mid-altitude the relative abundance was positively influenced in both pre-monsoon and monsoon. Highly significant effect of monsoon on relative abundance of Geometridae was reflected in high-altitudes.

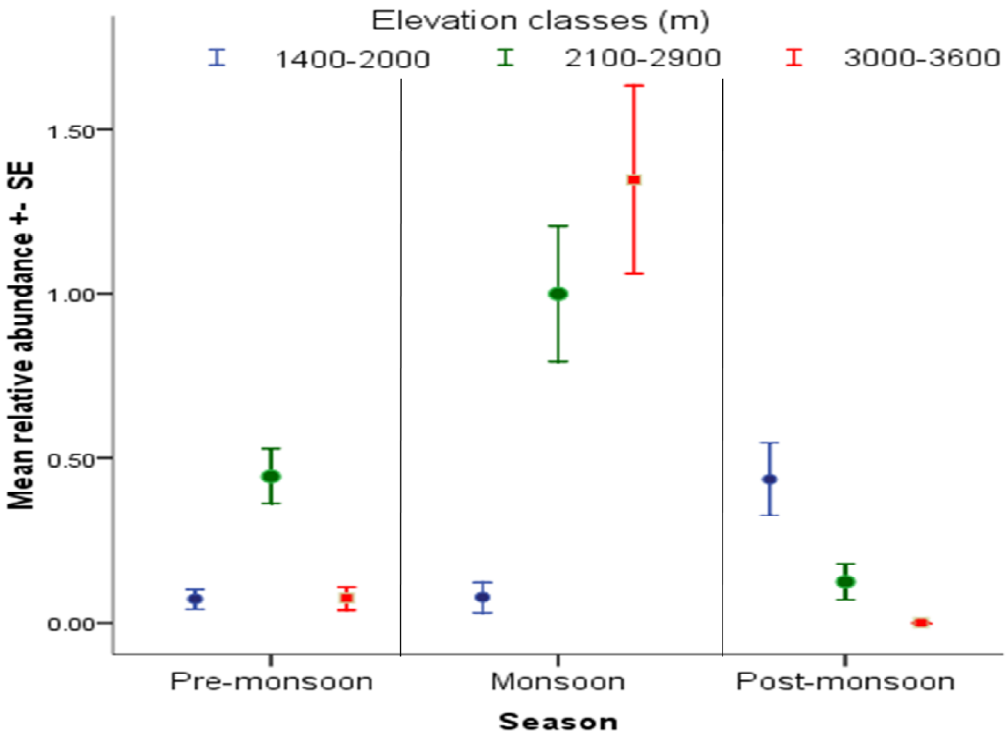
Table 6.1: Univariate analysis (General Linear Model) (a) Anova table, (b) Parameter estimates for effect of altitude class, season and their interaction on relative abundance of most common species of family Geometridae (Significant values are given in bold)

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	Sig.
Corrected Model	50.896a	8	6.362	13.551	0
Intercept	39.683	1	39.683	84.522	0
Alt * Seas	24.346	**4**	6.086	**12.964**	**0.000**
Alt	5.274	**2**	2.637	**5.616**	**0.004**
Seas	21.277	**2**	10.639	**22.66**	**0.000**
a. R Squared = .308 (Adjusted R Squared = .286)					

Parameter	B	Std. Error	t	Sig.
Intercept	-1.14E-15	0.129	0	1
Lowalt*Premonsoon	0.07	0.183	0.384	0.701
Lowalt*Monsoon	0.076	0.183	0.415	0.679
Lowalt*Postmonsoon	**0.436**	0.183	**2.382**	**0.018**
Midalt*Premonsoon	**0.445**	0.183	**2.428**	**0.016**

Midalt*Monsoon	**0.999**	0.183	**5.456**	**0.000**
Midalt*Postmonsoon	0.124	0.183	0.676	0.500
Highalt*Premonsoon	0.073	0.183	0.4	0.690
Highalt*Monsoon	1.348	0.183	7.361	0
Highalt*Postmonsoon	.	.	.	.

Fig 6.5: Mean relative abundance of most common Geometridae species in three altitudinal zones in three seasons



Mean relative abundances of most common Geometridae species were highest in middle altitude in pre-monsoon season (Fig.6.5). There was no significant difference in relative abundances in low and high altitude, but significantly lower than middle altitude. In monsoon, mean relative abundance was highest in high altitude and also high in medium altitude, but significantly lower in low altitude. Among all the seasons and altitude, mean relative abundance of Geometrids was highest in high altitude in monsoon. In post-monsoon, mean relative abundance was highest in low altitude and negligible in high altitude.

For Erebidae also, the temporal effect was more prominent and altitudinal effect was weaker (Table 6.2) (two-way ANOVA with repeated measurements: altitude: F2, 11 = 3.53, P<0.005; season: F2, 22 = 26.01, P<0.05; interaction term: F2, 22 = 12.96, P<0.005). Erebidae relative abundance was most positively influenced by the post-monsoon in all the altitudinal zones. Significant effect of post-monsoon was evident in low altitude, middle altitude and high altitude respectively. All the other interactions between season and altitude were insignificant.

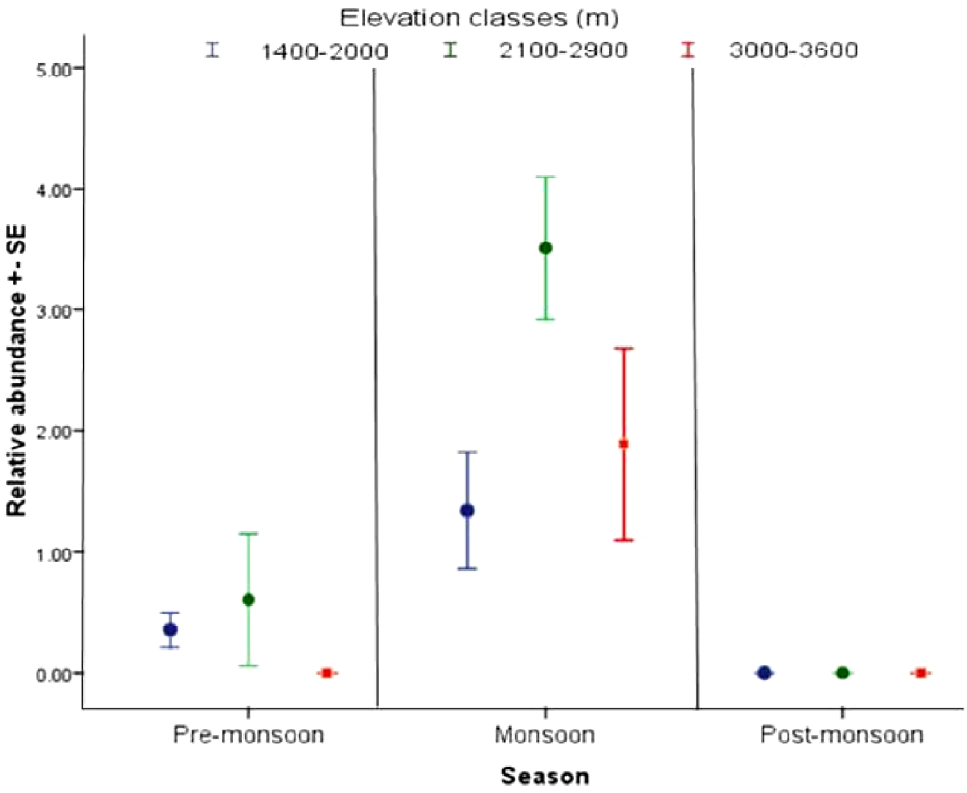
Table 6.2: Univariate analysis (GLM) (a) Anova table, (b) Parameter estimates for effect of altitude class, season and their interaction on relative abundance of most common species of family Erebidae (Significant values are given in bold).

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	150.538a	8	18.817	8.509	0
Intercept	85.504	1	85.504	38.662	0
Alt * Seas	19.841	4	4.96	2.243	0.069
Seas	115.06	**2**	57.53	**26.013**	**0.000**
Alt	15.636	**2**	7.818	**3.535**	**0.033**
Error	238.849	108	2.212		
Total	474.891	117			
Corrected Total	389.387	116			

Dependent Variable:Rab				
Parameter				
Intercept	B	Std. Error	t	Sig.
Lowaltitude* premonsoon	-7.58E-17	0.412	0	1
Lowaltitude*Monsoon	0.355	0.583	0.609	0.544
Lowaltitude*Postmonsoon	**1.338**	**0.583**	**2.295**	**0.024**
Midaltitude*Premonsoon	1.35E-16	0.583	0	1
Midaltitude*Monsoon	0.603	0.583	1.034	0.303
Midaltitude*Postmonsoon	**3.508**	**0.583**	**6.015**	**0.000**
Highaltitude*Premonsoon	3.05E-16	0.583	0	1
Highaltitude*Monsoon	1.94E-16	0.583	0	1
Highaltitude*Postmonsoon	**1.888**	**0.583**	**3.238**	**0.002**
		.	.	.

In pre-monsoon, the mean relative abundance of Erebidae was highest in middle altitude (Fig. 6.6). In lower altitude also, there was considerable relative abundances, but almost nil in high altitude. In monsoon, mean relative abundance was significantly higher than other season, and highest in middle altitude. In low and high altitude, the mean relative abundance was almost similar, but significantly lower than middle altitude. In post-monsoon, the Erebidae presence was just nil and in all the altitudinal zones, the mean relative abundance was zero.

Fig 6.6: Mean relative abundance of most common Erebidae species in three altitudinal zones in three seasons



For Family Noctuidae, both altitude as well as temporal effect, and their interaction was prominent, most significant being the temporal ((Table 6.3) (two-way ANOVA with repeated measurements: altitude: $F_{2,11} = 7.04$, $P<0.005$; season: $F_{2,22} = 9.76$, $P<0.05$; interaction term: $F_{2,22} = 7.87$, $P<0.005$). The diversity and abundance pattern of

Noctuidae assemblage was most strongly influenced by post-monsoon season and high altitude. All the other interactions between season and altitude were non-significant.

Mean relative abundance of most common Noctuid species was highest at high altitude in monsoon (Fig.6.7). The population bloom of Noctuidae at high altitude in monsoon season was evident. In pre-monsoon and post-monsoon, the abundance was low in all the altitude zones, except no presence in mid and high altitude in post-monsoon.

Table 6.3: Univariate analysis (General Linear Model) (a) Anova table, (b) Parameter estimates for effect of altitude class, season and their interaction on relative abundance of most common species of family Noctuidae

Dependent Variable:Rab					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	187.944a	8	23.493	8.136	0
Intercept	65.234	1	65.234	22.591	0
Alt * Seas	90.9	**4**	22.725	**7.87**	**0.000**
Alt	40.675	**2**	20.338	**7.043**	**0.001**
Seas	56.37	**2**	28.185	**9.761**	**0.000**
Error	415.82	144	2.888		
Total	668.998	153			
Corrected Total	603.764	152			

Parameter	B	Std. Error	t	Sig.
Intercept	-2.86E-15	0.412	0	1
Lowaltitude* premonsoon	0.395	0.583	0.677	0.499
Lowaltitude*Monsoon	0.359	0.583	0.616	0.539
Lowaltitude*Postmonsoon	0.474	0.583	0.812	0.418
Midaltitude*Premonsoon	0.126	0.583	0.216	0.83
Midaltitude*Monsoon	0.414	0.583	0.71	0.479
Midaltitude*Postmonsoon	2.64E-15	0.583	0	1
Highaltitude*Premonsoon	0.359	0.583	0.617	0.538
Highaltitude*Monsoon	**3.751**	0.583	**6.435**	**0.000**

For Crambidae, the season's effect was more prominent and altitudinal effect was weaker (Table 6.4) (two-way ANOVA with repeated measurements: altitude: F2, 11 = 4.56, P<0.05; season: F2, 22 = 13.07, P<0.005; interaction term: F2, 22 = 4.84, P<0.005). Crambidae relative abundance was most positively influenced by the low and mid altitude in monsoon. In pre-monsoon, mean relative abundance was highest in lower altitude, but negligible in mid and high altitude (Fig. 6.8). In monsoon, abundance was prominent in all three altitudes, but highest in middle altitude. In lower altitude, abundance was significantly lower than mid altitude, but higher than in high altitude. In post-monsoon, low abundance was recorded in lower altitude, but almost nil in mid and high altitude.

Fig 6.7: Mean relative abundance of most common Noctuidae species in three altitudinal zones in three seasons

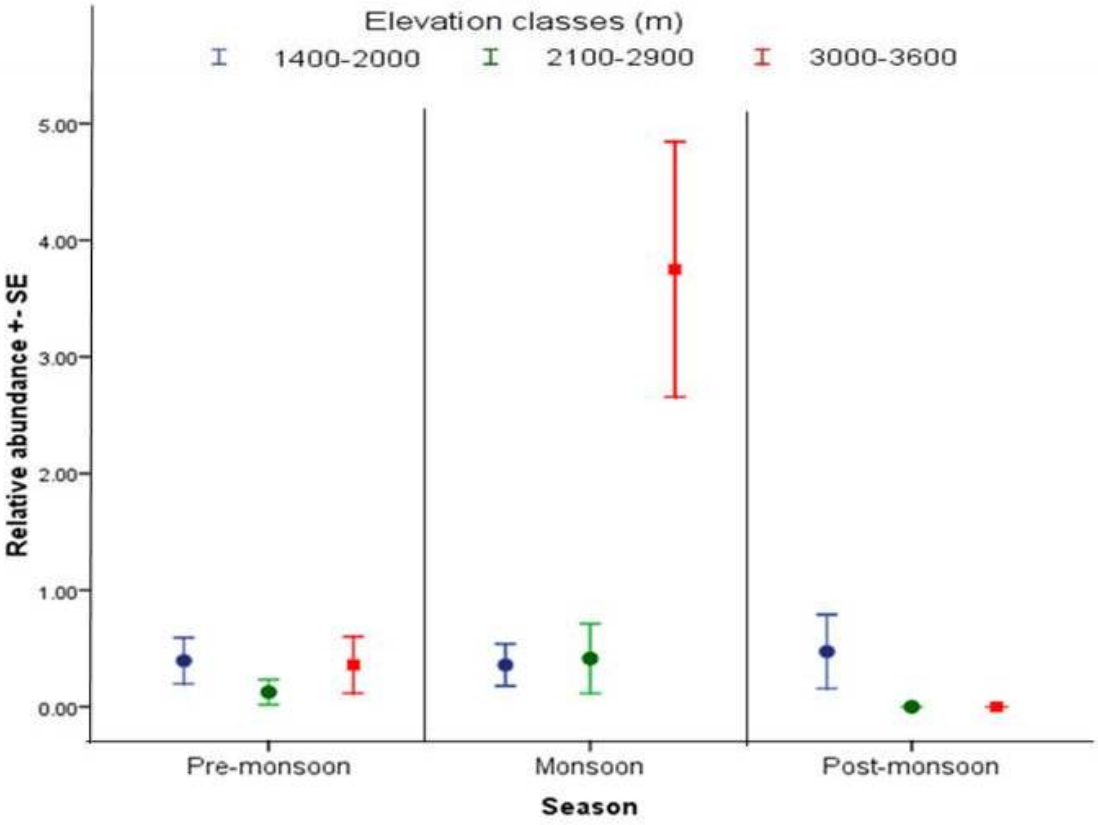
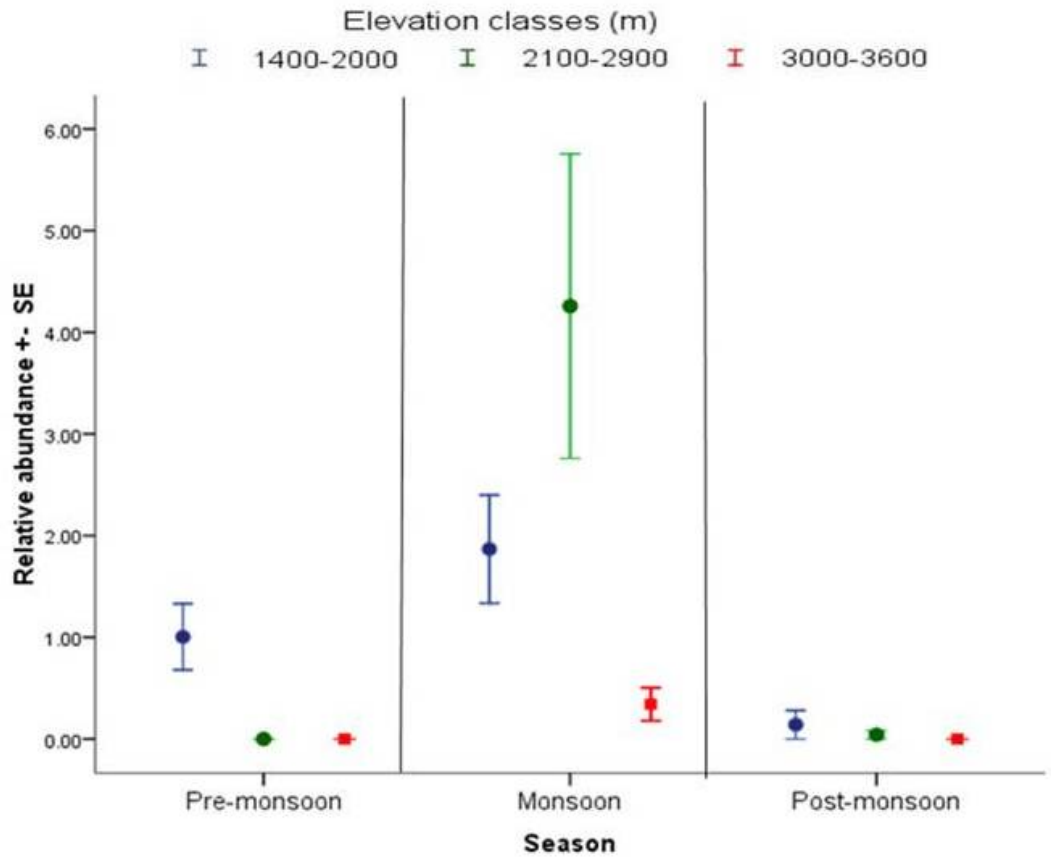


Table 6.4: Univariate analysis (GLM) (a) Anova table, (b) Parameter estimates for effect of altitude class, season and their interaction on relative abundance of most common species of family Crambidae (Significant values are given in bold).

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	211.338a	8	26.417	6.83	0
Intercept	84.556	1	84.556	21.863	0
Altcd * Seascd	74.884	**4**	18.721	**4.84**	**0.001**
Seascd	101.151	**2**	50.576	**13.077**	**0.000**
Altcd	35.302	**2**	17.651	**4.564**	**0.013**
Error	417.703	108	3.868		
Total	713.597	117			

Parameter	B	Std. Error	t	Sig.
Intercept	-2.64E-15	0.545	0	1
Lowaltitude* premonsoon	1.004	0.771	1.301	0.196
Lowaltitude*Monsoon	**1.867**	0.771	**2.421**	**0.017**
Lowaltitude*Postmonsoon	0.141	0.771	0.182	0.856
Midaltitude*Premonsoon	2.76E-15	0.771	0	1
Midaltitude*Monsoon	**4.258**	0.771	**5.52**	**0.000**
Midaltitude*Postmonsoon	0.04	0.771	0.052	0.959
Highaltitude*Premonsoon	2.98E-15	0.771	0	1
Highaltitude*Monsoon	0.341	0.771	0.442	0.659
Highaltitude*Postmonsoon	0a	.	.	.
Corrected Total	629.041	116		

Fig 6.8: Mean relative abundance of most common Crambidae species in three altitudinal zones in three seasons



6.3.3 Similarities in Species Composition among Different Season

To see the difference in species composition between three seasons, I performed Analysis of Similarity (ANOSIM). The Global R statistics from ANOSIM from 1% threshold level was 0.22 with p=.0001 demonstrating that the overall difference between seasons were large and statistically significant. Pair wise ANOSIM test (Table 6.5) showed most difference in species composition occurred between monsoon and post-monsoon season (R = 0.35, P = 0.0001), while significant difference was also there between monsoon and pre-monsoon (R = 0.2, P = 0.003). The least difference was between pre and post-monsoon which was also insignificant (R = 0.01, P = 0.39).

Table 6.5: Pairwise comparison of similarity of moth assemblages in different season from ANOSIM (Analysis of Similarity) [Highlighted cells represent significance level (bold : p<0.05); Non-highlighted cells are R values)

0	Pre monsoon	Post monsoon	Monsoon
Pre monsoon	0	0.01496	0.2024
Post monsoon	0.3931	0	0.359
Monsoon	**0.003**	**0.0001**	0

Mean rank Within	404.1
Mean Rank Between	546
R	0.224
p	0.0001

Further comparisons of dissimilarity in composition were made through SIMPER to identify the species contributing to the difference between seasons that differed most, i.e., between pre-monsoon and monsoon (Table 6.6) and between monsoon and post-monsoon (Fig. 6.7).

Nineteen species contributed around 30% to the difference between pre-monsoon and monsoon (Table 6.6). These species differed in mean abundance, which was reflected in the degree of group association. Most of these species had higher mean abundance in monsoon than pre-monsoon. Seven species of them, *Diphtherocome fasciata* (Noctuidae), *Spilosoma leopardina* (Erebidae:Arctiinae), *Eilema antica* (Erebidae: Arctiinae), *Spilosoma obliqua* (Erebidae: Arctiinae), *Hyaloplaga pulchralis* (Crambidae), *Alcis limbui* (Geometridae: Ennominae) and *Rheumaptera sp.*(Geometridae: Larentiinae) were only abundant in monsoon, but absent in pre-monsoon season. Contribution of the Arctiinae to the difference in species composition between pre-monsoon and monsoon assemblage was prominent. *Sirinopteryx sp.* (Geometridae: Ennominae), *Heterolocha phaenicotaeniata* (Geometridae: Ennominae), *Lyclene sp.*(Erebidae: Arctiinae), *Ecliptopera postpallida* (Gometridae:Larentiinae) comprised the species group which had significantly low abundance in pre-monsoon than monsoon. Five species, *Anonychia*

Table 6.6: SIMPER analysis of differences in the species of moth assemblage contributing to the dissimilarity (95.78%) between Pre-monsoon and Monsoon season

Taxon	Av. dissimilarity	Contrib. %	Cumulative %	Mean abundance	
				Pre-	Mon
Spilosoma erythrozonata	2.063	2.154	2.154	4.92	5.52
Diphtherocome fasciata	1.468	1.533	3.687	0	7.04
Agylla beema	1.418	1.481	5.167	1.92	3.89
Spilosoma leopardina	1.322	1.38	7.956	0	5.15
Colostygia albigirata	1.29	1.346	10.67	1.58	4.93
Triphosa sp.	1.277	1.334	12	2	4.04
Eilema antica	1.194	1.247	13.25	0	4.15
Lyclene sp.	1.107	1.156	14.4	0.417	3.56
Ecliptopera sp.	1.102	1.15	15.55	1.83	2.85
Medasina albidaria	1.049	1.095	16.65	2.25	2.07
Spilosoma obliqua	0.9942	1.038	18.74	0	3.67
Ecliptopera postpallida	0.9749	1.018	19.76	0.833	3.26
Heterolocha phaenicotaeniata	0.93	0.971	21.75	0.5	2.56
Perizoma albofasciata	0.8751	0.9137	22.66	2.67	0.444
Hyaloplaga pulchralis	0.8493	0.8868	23.55	0	3
Anonychia violaceae	0.7787	0.813	24.36	1	2.11
Alcis limbui	0.765	0.7988	25.16	0	2.78
Rheumaptera sp.	0.7562	0.7896	26.75	0	3.85
Sirinopteryx sp.	0.7357	0.7682	28.28	0.167	2.41

violaceae (Geometridae: Ennomine), *Agylla beema* (Erebidae: Arctiinae), *Colostygia albigirata* (Geometridae: Larentiinae), *Ecliptopera* sp. and *Spilosoma erythrozonata* (Erebiade: Arctiinae) had significant mean abundance in both the season, although lower in pre-monsoon. Only two species, *Medasina albidaria* (Geometridae: Ennominae) and *Perizoma albofasciata* (Geometridae: Larentiinae) had higher mean abundance in pre-monsoon than in monsoon. Total twenty species contributed around 30% to the difference between monsoon and post-monsoon (Table 6.7). Among these, six species, *Psilalcis inceptaria* (Geometridae: Ennominae), *Perizoma seriata* (Geometridae: Larentiinae), *Photoscosia miniasota* (Geometridae: Larentiinae), *Helicoverpa armigera* (Noctuidae), *Dasypolia atrox* (Noctuidae) and *Plusiopalpa dichora* (Noctuidae) had higher mean abundance in monsoon than in post-monsoon. Whereas, thirteen species, *Hyaloplaga pulchralis* (Crambidae), *Medasina albidaria*, *Heterolocha phaenicotaeniata* (Geometridae: Ennominae), *Ecliptopera postpallida*, *Triphosa* sp., *Ecliptopera* sp. (Geometridae: Larentiinae), *Spilosoma leopardina*, *Eilema antica*, *Lyclene* sp., *Spilosoma oblique*, *Agylla beema*, *Spilosoma erythrozonata* (Erebidae:Arctiinae) and *Diphtherocome fasciata* (Noctuidae) had significantly higher mean abundance in post-monsoon season than in monsoon. One species, *Colostygia albigirata* had significant mean abundance in both the season. Arctiinae and Larentiinae contributed most to the difference in species composition between these two seasons.

Table 6.7: SIMPER analysis of differences in the species of moth assemblage contributing to the dissimilarity (96.82%) between Monsoon and Post-monsoon

Taxon	Av. dissimilarity	Contrib. %	Cumulative %	Mean abundance	
				Mon	Post-
Psilalcis inceptaria	1.828	1.888	7.522	5.5	1.26
Perizoma seriata	1.76	1.818	9.34	6.88	0.667
Colostygia albigirata	1.75	1.808	11.15	4.13	4.93
Spilosoma erythrozonata	1.47	1.518	12.67	0	5.52
Diphtherocome fasciata	1.437	1.484	14.15	0	7.04
Photoscosia miniasota	1.388	1.434	15.58	5.13	0.593
Spilosoma leopardina	1.289	1.331	16.92	0	5.15
Ecliptopera postpallida	1.189	1.228	18.14	0	2.85
Eilema antica	1.161	1.199	19.34	0	4.15
Helicoverpa armigera	1.061	1.096	20.44	4.5	0.37
Lyclene sp.	1.03	1.063	21.5	0	3.56
Triphosa sp.	0.9889	1.021	22.52	0.75	4.04
Spilosoma obliqua	0.9675	0.9993	23.52	0	3.67
Agylla beema	0.9438	0.9747	24.5	0	3.89
Dasypolia atrox	0.9028	0.9325	25.43	2.88	0
Medasina albidaria	0.8604	0.8887	26.32	1.13	2.07
Plusiopalpa dichora	0.8523	0.8803	27.2	3.88	0.0741
Heterolocha phaenicotaeniata	0.8251	0.8522	28.05	0	2.56
Hyaloplaga pulchralis	0.8248	0.8518	28.9	0	3
Heterothera dentifasciata	0.8112	0.8378	29.74	2.75	0

6.4 Discussion

Seasonality of tropical insect populations and communities has universally been established wherever well-defined wet and dry seasons alternate regularly (e.g., Wolda 1978, 1980, 1992, DeVries *et al.* 1997, 1999, Novotny & Basset 1998; Kitching *et al.* 2000). In highly humid tropical ecosystem also, with weak climatic seasonality, a number of unique patterns in abundance fluctuation of light-trapped insect was observed (e.g., Kato *et al.* 1995). These previous studies in seasonal tropical areas recorded an increase in insect abundance in the wet season, suggesting that a seasonal correlation with rainfall is characteristic of a typical tropical insect community (Janzen 1973, DeVries & Walla 2001, Intachat *et al.* 2001, Pinheiro *et al.* 2002). The start of rainfall triggers bud break and flowering in many plants and thus makes available food resources for Lepidopteran larvae (fresh plant biomass) as well as adults (nectar). Exceptionally, there are also evidences that insect abundance decreases in wet season (e.g., Boinski & Scott 1988) which can be attributed to low flight performance due to strong rainfall.

Previous studies on effect of seasonality on Lepidopteran assemblage have documented various patterns according to regions and different groups of ensembles. In highly humid regions of South East Asia all moth ensembles studied thus far revealed little evidence for cyclic seasonal dynamics (e.g., Barlow & Woiwod 1990, Orr & H¨auser 1996, Intachat & Holloway 2000, Schulze & Fiedler 2003), even though leaf flushing, flowering, or fruiting of many plants that serve as larval host plants or adult food display seasonal fluctuations (Sakai *et al.* 1999, Wich & van Schaik 2000, Hamann 2004). Studies conducted in cool temperate regions of Japan on nocturnal Lepidoptera suggested a unimodal seasonal pattern with a peak in species richness and abundance in summer (July or August). Although the result varied according to forest types surveyed, like in deciduous broadleaved natural forest, there was a unimodal peak, whereas in deciduous broadleaved secondary forest, there were multimodal peaks in number of species and individuals in summer and autumn (Yoshida 1980). Seasonal changes in the number of species of adult moths in a mixed deciduous forest in southern Korea were bimodal with peaks in June and August (Choi 2008). In mixed hardwood forests in North America, no

clear peak was detected in the number of species, although the number of individuals was highest between March and June (Landau *et al.* 1999) or in July and early August (Butler *et al.* 2001). In Mediterranean mixed forests, abundance and diversity of adult Noctuidae moths were markedly bimodal with two distinct peaks, in early summer (mid-July) and in early autumn (late September to early October) (Yela & Herrera 1993). Although, there was no previous study conducted on nocturnal Lepidoptera in Himalayan system, a study on butterfly assemblage in Tons valley has reported marked seasonal variation in the abundance and species richness with peak in activity during summer and end of monsoon season, whereas, in colder season, the species richness and abundance remained very low (Bhardwaj 2013). So the differences in the validity of the link between insect dynamics and temporal patterns in climate should be attributable to variation between regions and with regard to the direct and indirect constraints imposed by climate onto different taxonomic groups.

In the current study, there is a clear indication that irrespective of habitat (different altitudinal zones) and taxonomic group (different families of moth) considered, there was a unimodal peak in moth activity with species richness and abundance at its highest during the monsoon season. The three seasons considered here represent the year-long climatic fluctuations in a typical western Himalayan altitudinal gradient. The strikingly similar trend in annual rainfall pattern and the activity-peak in moth assemblage suggest that a seasonal correlation with rainfall is typical of moth communities. Most of the moth species have short occurrence period; species are likely to have a univoltine life history and short life spans for adult moths. In cool-temperate regions, relatively shorter growing season may result in one generation per year. General life expectancy of adult moths is assumed to be from one to three weeks (Zborowski & Edwards 2007), although there are not much studies examining life span of adult moths. Similar life history traits seem to be common in moths because many moths have well-defined and characteristic periods of seasonal activity and, particularly in temperate regions, may fly for only short periods (New 2004). This was also evidenced from life cycle of an Arctiidae moth, *Chionaema coccinae* Moore studied in Dehradun, located in much lower altitude (600m) in Western Himalaya, which was completed within two weeks in peak monsoon, whereas the species was absent all through the year (Sanyal *et al.* 2013).

Effect of seasonality was more pronounced in middle and high altitude than in lower altitude. Post-monsoon was certainly not the time of moth activity in any altitude, night time temperature was certainly low for flight activity. Activity was highest in monsoon and reached at its peak even in high altitude sites. Different families of moth responded differently to seasonal cycle. The analysis performed on mean relative abundance of most dominant species gave a finer resolution of effect of seasonality. Being the most dominant family in the study area, Geometridae species regulated the assemblage structure in greater magnitude. Activity of Geometrids peaked in middle and high altitude during monsoon, whereas it was nil in high altitude during post-monsoon. Among the most prominent species in high altitude during monsoon, *Colostygia albigirata, Triphosa sp., Ecliptopera postpallida, Rheumaptera sp., Photoscotosia amplicata* and *Abraxas peregrina* were dominant, whereas in mid altitude *Alcis limbui* dominated the assemblage composition. Erebidae mean relative abundance was significantly higher in monsoon in all the altitude zones. The activity reached its peak in middle altitude which was dominated by species like *Agylla beema, Spilosoma obliqua, Spilosoma leopardina, Sidyma albifinis, Eilema antica* whereas in high altitude, species like *Spilosoma leopardina* and *Amascata lactinea* were more abundant. Noctuidae are mostly grass feeders and as during monsoon plenty of grass species mature in high altitude alpine meadows and pastures, different Noctuid species like *Diphtherocome pallida, Haderonia culta, Hermonassa sinuata, Heliophobus texturata, Xestia bdelygma* were superabundant. Crambidae mean relative abundance peaked in mid altitude during monsoon and species like *Hyaloplaga pulchralis, Glyphodes crithealis, Pleuroptya quadrimaculalis* were most common. Unlike other families, Crambidae abundance was low in high altitude during monsoon. Multivariate analyses on assemblage level (ANOSIM) revealed that all samples changed over time with regard to species composition. As with the abundance on more finer taxonomic scale, these temporal effects were far more pronounced in case of family Erebidae and subfamily Larentiinae (Geometridae).

My observations show that highly speciose Himalayan moth assemblages have a substantial β-diversity both with regard to sampling time (season) and habitat (altitude). In remnants of upland rain forest in Australia, Kitching *et al.* (2000) also found a segregation of moth assemblages according to season (wet vs. dry) and forest type. Such

finding may have impending consequences for topics in applied ecology, such as assessing and monitoring insect faunas for conservation purposes. This information is critical to determine efficient sampling periods in future study and provides a useful basis for comparative studies with other regions. If diversity or species composition change intensely with time (e.g., between seasons), then only sampling and monitoring programs performed during exactly the same time periods will yield meaningful data for comparisons between habitats or for assessing management effects.

In conclusion, like tropical communities, samples from species-rich moth communities in Himalayan altitudinal gradient can reliably be used for statements about the diversity and species composition. However, it should always be unambiguously assessed how variable community patterns are over time. Preferably, sampling should be spread as evenly as resources permit over the annual cycle. Moreover, as evidenced by diverse moth assemblages in Gangotri Landscape Area, the highest insect abundances and diversities are universally found in the more humid parts of the year, and the pattern is more pronounced in extreme habitats like high altitudes where resource availability is concentrated only during most suitable growing period of the year.

CHAPTER VII

CHANGES IN BODY SIZE OF GEOMETRIDAE ASSEMBLAGE ALONG ALTITUDINAL GRADIENT

7.1 Introduction

Carl Bergmann (1847) observed that within closely related warm blooded taxa, larger species inhabit northern and colder areas while smaller species are found in southern and warmer areas. He proposed that this pattern results from the difficulty of small animals to cope with heat loss in colder environments. As this phenomenon is also true in altitudinal gradient, some authors have argued that altitudinal gradients should also be regarded in this context (Brehm & Fiedler 2004). An extended version of Bergmann's rule is also established to the intraspecific level and due to the apparent differences in the mechanisms that may generate these gradients (Rensch 1938), Blackburn *et al.* (1999) named this pattern as "Jame's Rule". Bergmann's and Jame's rules are established in homeotherms with strong support from several studies (Roberts 1978, Meiri & Dayan 2003, Blackburn & Hawkins 2004). However, results in Ectotherms are contradictory. For example, individuals of the cricket *Melanoplus sanguinipes* and species of Geometrid moths are larger in lower altitudes (Mousseau 1997, Brehm & Fiedler 2004); specimens of the frog *Rana temporaria* and those of the dragonflies *Enallagma cyathigerum* show a non-linear but concave latitude-body size relationship (Johansson 2003, Laugen *et al.* 2005); in Neotropical butterflies larger specimens are found at intermediate altitudes (Hawkins & DeVries 1996); in some cases, the changes observed in body size are directly related with latitude while are negatively related with altitude (Arnett & Gottelli 1999). In other cases, lower atmospheric pressure in high altitude had influences on increased wing size in social wasps (Rodriguez-Jimenez & Sarmiento 2008).

Despite the interest generated by these patterns and their presence in several taxa, not a single explanatory mechanism can be postulated due to obvious intrinsic difference between the organisms, e.g. homeotherms vs. poikilotherms, and to the differences in the environmental challenges faced by them. In some cases, classic environment factors such as temperature or latitude are claimed as responsible while in other factors such as

daylight length, season length and development temperature are defined as influential (Patridge & Coyne 1997, Blackburn *et al.* 1999, Blanckenhorn & Demont 2004, Brehm & Fiedler 2004).

Another interesting aspect, size variation of body parts along a gradient does not have to follow a uniform trend because species habits and environmental conditions can determine stronger selective regimes that restrict the variation degree in some structures over others (Stern & Emlen 1999, Hodkinson 2005). Studies about Bergmann's or Jame's rules have been characterized by using just one structure as body size reference but these do not look at the proportional changes among individual parts (Hawkins & DeVries 1996, Mousseau 1997, Arnett & Gottelli 1999, Brehm & Fiedler 2004). It is possible that, in addition to a general body size change, there is reallocation of resources generating opposite body parts tendencies along the gradient or body part size adjustments according to environmental challenges (Hilton *et al.* 2000). For example, low atmospheric pressure has been identified as an explanation for larger wing size in flying insects (Hodkinson 2005, Dillon *et al.* 2006), additionally reduction in body size with altitude can be expected as larger proportion of resource allocation for structures associated with flight (Rodriguez-Jimenez & Sarmiento 2008).

Here I studied morphometric changes associated with flight in Geometrid moths to test whether Bergman's rule at the interspecific level applies to moths along an elevation gradient in a Western Himalayan altitudinal gradient. Among the four major families of moth sampled in the study area, Geometridae was most diverse and well represented all through the altitudinal gradient. The monophyly among Geometrid subfamilies are also well established. Similar kind of natural experiment with Geometridae was performed in Ecuadorian Andes (Brehm & Fiedler 2004) which gives the opportunity to compare the results and thus this family was a natural choice for the investigation. I explore both body size and proportional changes in body parts sizes such as thorax width, total body length. The diversity of this species-rich family has been investigated along an altitudinal gradient in Gangotri Landscape in Uttarakhand state in India. The analyses were carried out on a fine taxonomic scale. With a total of 641 specimens representing 124 species, the data set offered the unique chance to analyze body size patterns of a highly diverse

monophyletic group of herbivorous insects along an elevation gradient in their natural habitat. Within the framework of Bergman's rule, I tested how body size and other proportional body parts of Geometrid moths changes with increasing altitude. In order to detect phylogenetic effects on the results, analysis were carried out at the family and subfamily level with four subfamilies of Geometridae, viz. Ennominae, Larentiinae, Geometrinae and Sterrhinae being common in the study area.

In particular, I address following questions in this chapter:

i) What are the major morphometric characters defining body sizes in Geometridae and does body size distribution differ along altitude gradient?

ii) How different are major subfamilies within Geometridae in respect to body size changes along altitudinal gradient?

7.2 Materials & Methods

7.2.1 Study area and Sampling

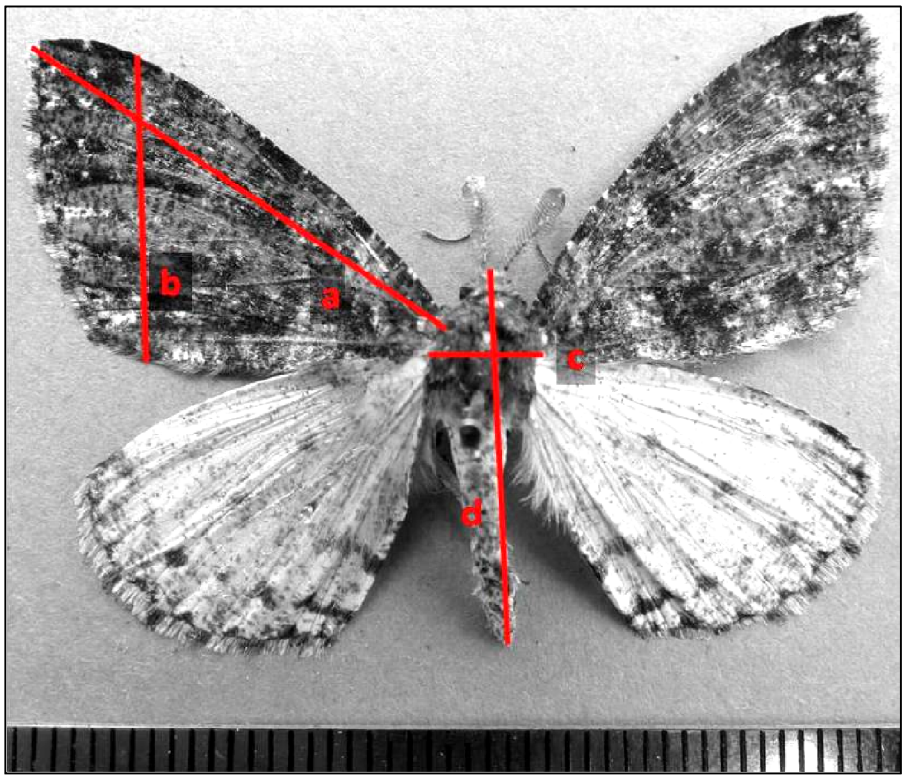
The study area in Gangotri Landscape in the Indian state of Uttarakhand is situated within Western Garhwal Area. The landscape represents typical Western Himalayan vegetation gradient and most parts are covered with dry and wet temperate forest, the vegetation is discussed in detail in chapter II. Forty-six sampling sites were selected at 12 elevation levels between 1400m and 3600m at every 200m. Mean monthly temperature ranges from 12°C to 32°C across the gradient. Moths were sampled manually by attraction to weak light sources. Sampling was restricted to the peak time of moth activity during the evening hours between 8pm and 4am, in two sessions. Specimens were first sorted to morphospecies level and later determined in the Zoological Survey of India, Jabalpur and Kolkata. Diversity and distribution was analyzed in detail in chapter IV & V. Total 3646 individuals of Geometridae were sampled representing 124 morphospecies. Fig.5.2 (Chapter V) shows the altitudinal distribution of the entire family while Fig. 3.8 (Chapter III) shows altitudinal distribution of four major subfamilies. Ennominae was the most dominant subfamily representing 71 morphospecies; Larentiinae comes second with 28 morphospecies. Geometrinae and Sterrhinae were represented by 18 and 7 species respectively.

7.2.2 Morphometric Measurements

There are various ways to quantify body size in arthropods. In the order Lepidoptera three measures are generally used, viz. body length, forewing length, and wing span (e.g. Siemann *et al.* 1999, Rydell & Lancaster 2000, Brehm 2002). Usually these measures are highly interrelated to each other (e.g. Bishop & Armbruster 1999).

I measured (a) the forewing length (distance from wing base to apex), (b) maximum forewing width, (c) maximum thorax width/ body width, and (d) body length (distance from frons to tip of the abdomen) (Fig 7.1).

Fig.7.1: Photograph of a Larentiinae specimen showing measured morphometric parameters: (a) forewing length, (b) maximum forewing width, (c) maximum thorax width, (d) total body length



Measurements were performed with a calliper rule (Mitutoyo 0.05m, No.505-633) at a degree of accuracy of 1mm from specimens set in standard manner (wings spread at a right angle to the body axis). Only male specimens were measured and analyzed because sexes are often dimorphic in body size (Hawkins & Lawton 1995), and males were much

more abundant in the samples than females. Body length and thorax width were used to calculate an index of body stoutness (ratio of body length to thorax width; e.g. Schulze *et al.* 2001). Slender-built species reach higher values, and low values characterize stoutly built species. To assess the flight and dispersal abilities of the moths, the following parameters were calculated (all approximate values): (1) wing surface area of the forewing (wing surface area = [forewing length **x** maximum forewing width]/2), (2) body volume as a proxy of body mass ($V = 4\pi lr^2$ with l = body length/2 and r = body width/2), the wing load (WL = body mass/wing area), and the aspect ratio (AR = forewing length/forewing width). A high wing load means that only a small wing area is available for swaying body mass, whereas low wing load means that the moth moves little mass per wing area. Moths with a high wing load are mostly robust with small wings and a high wing beat frequency, whereas the others have a slow flapping or rather a gliding flight (Rydell & Lancaster 2000). Moths with high values of the aspect ratio have long, small wings, whereas with low values have broad and rounded wings.

7.2.3 Quantitative Analysis

Two different approaches to analyze body size patterns along the elevational gradient were chosen. First, in a structure-oriented approach, the pattern of major body size parameters with increasing altitude was seen. To choose the measurement that better describes the general size of the Geometrid moth, I did a Principal Component Analysis via correlation matrix. To describe the relationship between altitude and measurements, I carried out Spearman rank correlation and quadratic regression analysis which was visually represented as scatter plot. Secondly, in a more taxa-specific approach, body size changes along elevation gradient were investigated among different subfamilies of Geometridae. Besides frequency distribution of forewing lengths in Geometridae and two major subfamilies Ennominae and Larentiinae, the trends in forewing length with increasing altitude were represented as scatter plot in four major subfamilies. Variability of the forewing length was measured as the relative coefficient of variation of wingspan across major taxa and checked against increasing altitude. Multi-dimensional scaling bi plots were produced to represent major subfamilies of Geometridae in three altitudinal zones, viz. low (<2000m), medium (2000-3000m) and high (>3000m) along two

principal axes: vertical axes representing characters associated with flight strength and horizontal one associated with flight energetic. Statistical analyses were performed using the software package SPSS (Version 22, 2013) and XLSTAT 2014.

7.3 Result

The Principal Component Analysis with nine morphometric variables indicated Aspect ratio (AR) and Body Stoutness Index (BSI) differs from all other variables. The first component of the PCA, as a linear combination of maximum sample variance, explained about 73% of the variation, except BSI, AR and WL (Wing Load) all the variables were influential (Table 7.1). The second component explained about 18% o the variation and only influential variable for this factor was BSI.

Table 7.1: Factor loadings of different morphometric variables from PCA

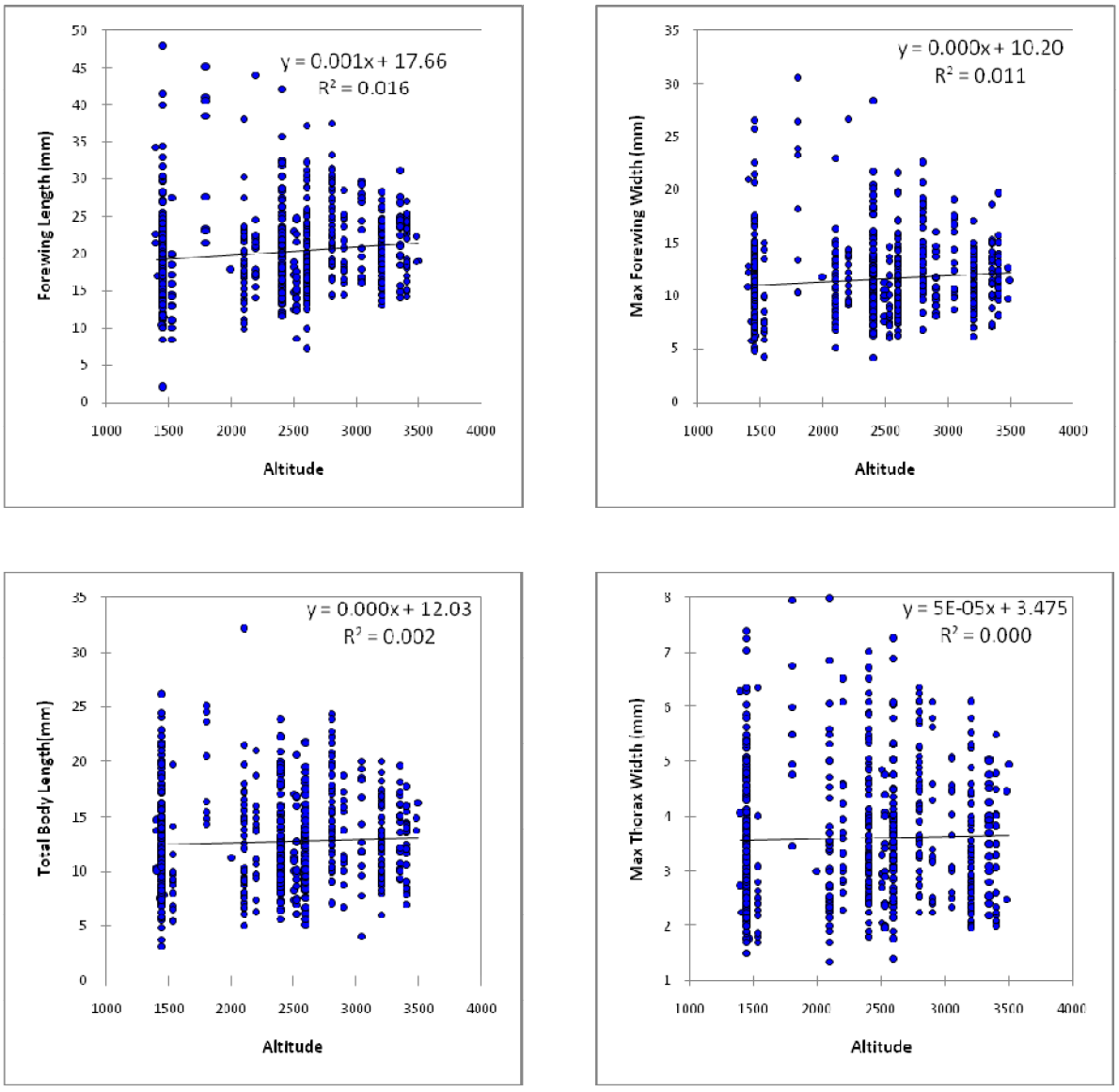
	F1	F2	F3
Forewing Length (mm) (FWL)	0.899	0.299	0.172
Max Forewing Width (mm) (MFW)	0.907	0.291	-0.212
Total Body Length(mm) (MBL)	0.907	0.206	0.112
Max Thorax Width (mm) (MTW)	0.911	-0.382	0.049
Body Stoutness Index (BSI)	-0.022	0.792	0.124
Wing Surface Area (WSA)	0.903	0.302	-0.046
Body Volume (BV)	0.916	-0.269	0.059
Wing Load (WL)	0.564	-0.682	0.061
Aspect Ratio (AR)	-0.155	-0.022	0.976

Among nine variables considered for the correlation test (Table 7.2), there was significant positive effect of altitude for only Fore Wing Length (FWL) (r=.127) and Maximum Forewing Width (MFW) (r=.108), other relationships being weaker. So there was an indication that these two variables increased significantly with increasing altitude. Fig. 7.2 shows the scatter plots for regression between altitude and four major variables. While MBL and MTW remained unchanged with increasing altitude, FWL and Maximum Forewing width (MFW) had clear indication of increasing trend with altitude.

Table 7.2: Pearson's Correlation matrix between altitude and different wing and body morphometrics (N=640)

		FWL	MFW	MBL	MTW	BSI	WSA	BV	WL	AR
Altitude	Pearson Correlation	**.127****	**.108****	0.044	0.027	0.037	0.074	-0.008	-0.052	0.018
	Sig. (2-tailed)	0.001	0.006	0.264	0.499	0.346	0.061	0.842	0.191	0.649

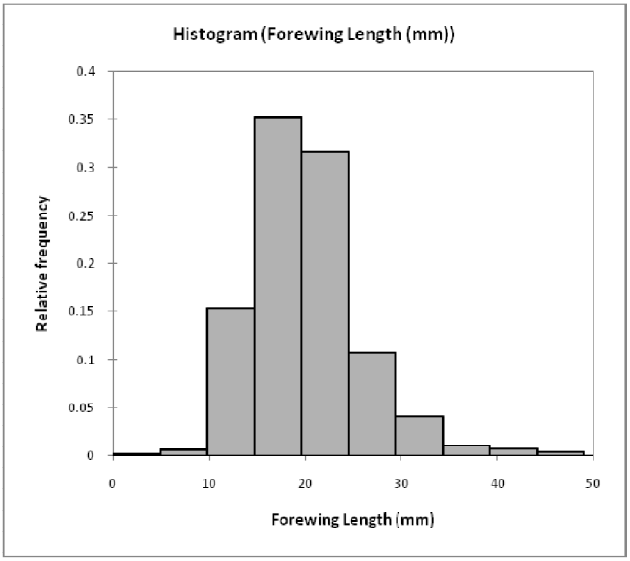
Fig. 7.2: Scatter plots showing trends in four major body size parameters (FWL, MFW, MBL & MTW) with increasing altitude



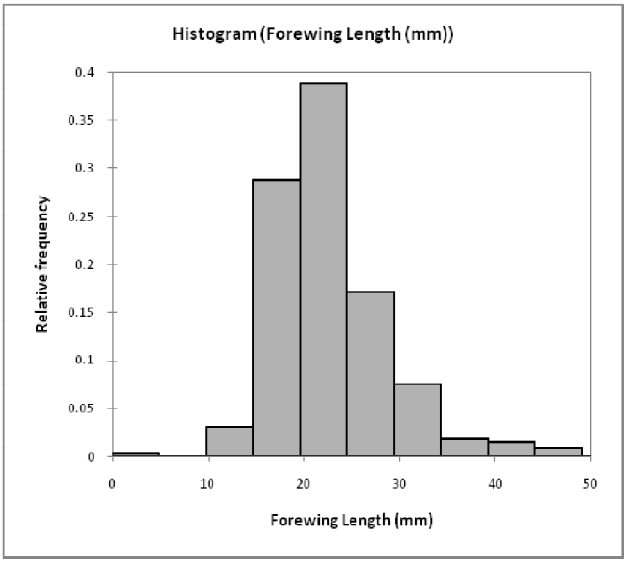
Frequency distribution of FWL for the entire Geometridae assemblage is little right skewed with species of category 10 to 30mm of wingspan dominating. Wingspan sizes of the Ennominae were mostly normally distributed with species having 15-30mm dominating. Within the Larentiinae, the size distribution is also normal and small species of the category between 12 and 25mm of wing-span dominate, with no species having wingspan larger than 30mm (Fig. 7.3a-c).

Fig. 7.3: Frequency distribution of forewing length in all the (a) Geometridae and two major subfamilies (b) Ennominae and (c) Larentiinae

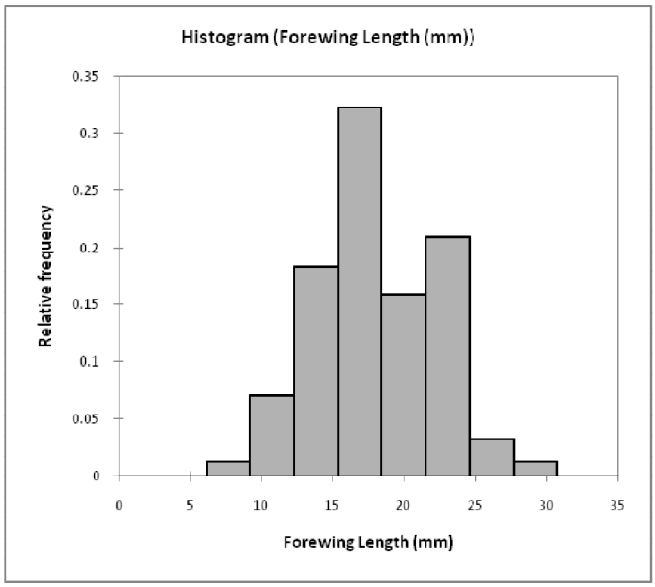
a)



b)



c)



Regression between altitude and FWL of four Geometridae subfamilies revealed very consistent pattern (Fig. 7.4 a-d). Correlations in Larentiinae and Geometriinae are significant where an increase of wingspan with increasing altitude is revealed. The relationships were not significant for Ennominae and Sterrhinae, although in both cases, wingspan sizes increased with increasing altitude.

The result clearly suggests that high altitude areas are dominated by large bodied Larentiinae species. Above 3000m, the assemblage was dominated by different species of *Photoscotocia* and *Rheumaptera* whose average wingspan size was 24mm and 21mm respectively. Although Geometriinae were rarely present above 3000m, except a single occurrence of *Thalassodes veraria* at 3200m with wingspan of 23.75mm, the trend in the subfamily is mainly due to presence of *Ornithospila avicularia* and *Tanaoctenia haliaria*, both of around 23mm wingspan, in high abundance between 2400m and 2800m.

Wingspan variability across sites tended to decrease in all the three taxa examined (Fig. 7.5 a-c). For entire Geometridae the pattern was most prominent with sharp decrease in variability with altitude, while in both Ennominae and Larentiinae the decrease was slight. Hence, while consistently increasing patterns of wingspan size can be found across the elevational gradient, in all the taxa there is a lower variability of wingspan at higher elevations compared to lower altitudes.

Fig. 7.4: Scatter plots showing trend in Forewing length along increasing altitude in four major subfamilies of Geometridae (a) Ennominae and (b) Larentiinae, (c) Geometrinae and (d) Sterrhinae

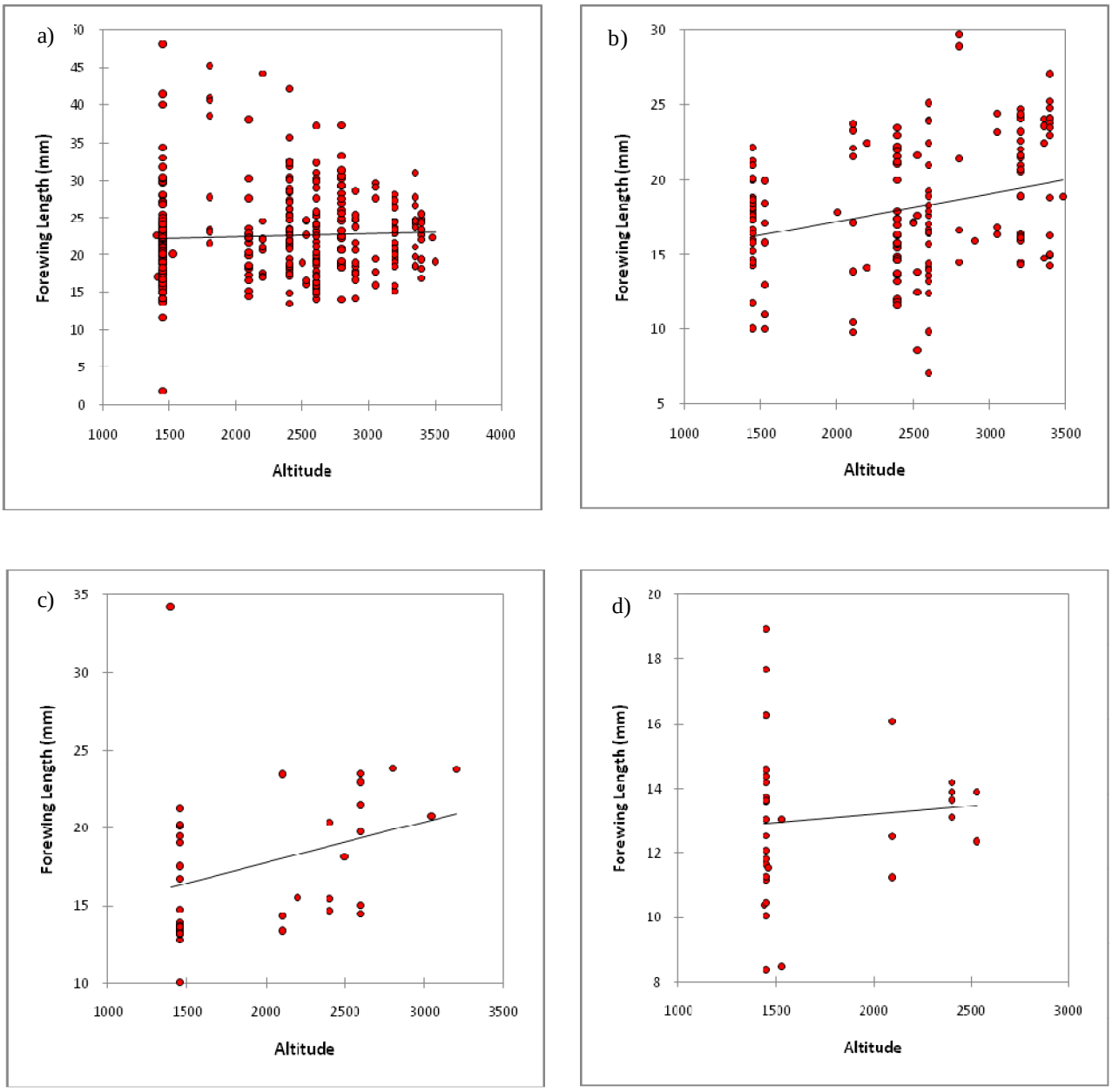
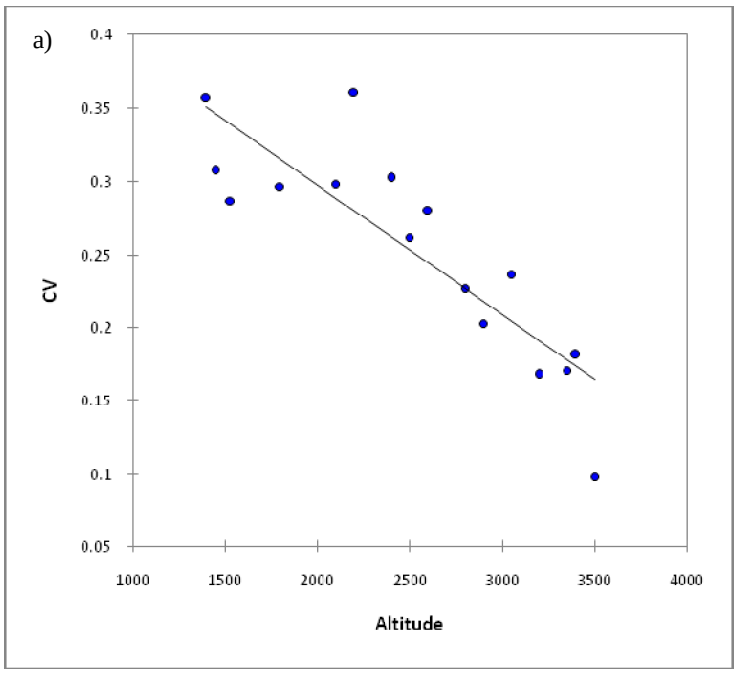
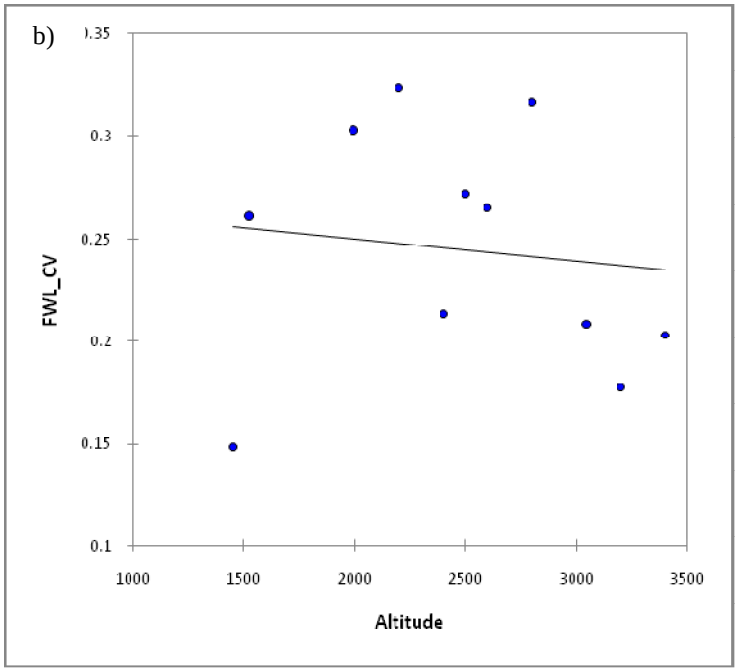
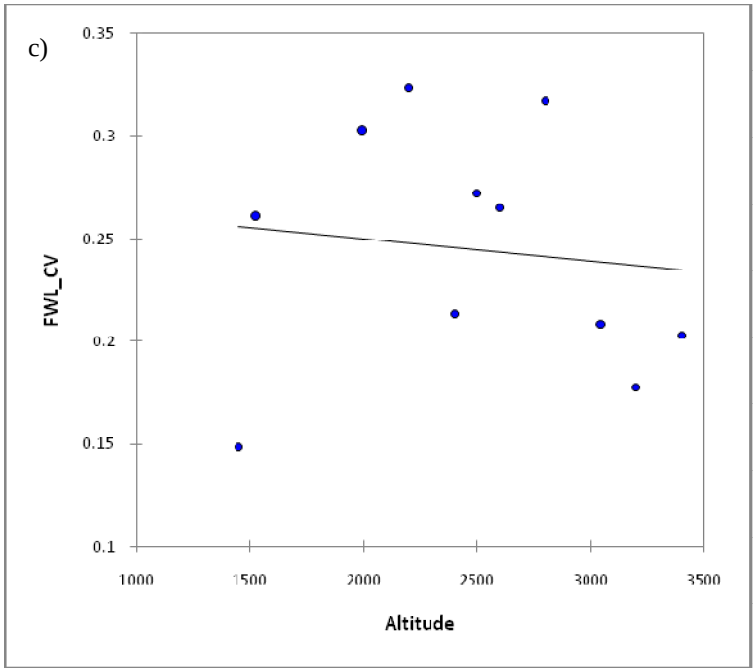


Fig. 7.5: Trends in variability in Forewing length (measured as co-efficient of variation) along increasing altitude for all the (a) Geometridae and two major subfamilies (b) Ennominae and (c) Larentiinae







In Multi Dimensional Scaling biplot, the horizontal axis was constituted by variables characterizing flight energetic like Wing Load, MTW and body volume. High wing load represents robust flyer. Whereas the vertical axis was constituted by variables associated with body size like FWL, FWW, WSA and TBL. Subfamily Ennominae were distributed around higher values for both the axes (Fig. 7.6) suggesting dominance of strong fliers as well as large-bodied species for this subfamily. Distribution of subfamily Larentiinae was much around negative values for both the axes, which suggests weak fliers and comparatively smaller sized species than Ennominae. While similar trend like Larentiinae is observed in Sterrhinae, Geometriinae were more evenly distributed along both the axes.

On the other hand, while most robust flier and largest bodied Ennominae were both recorded from lower altitude areas (<2000m) as revealed from Fig. 7.7, general altitudinal preference for species in these two extremes were not very clearly depicted.

Fig. 7.6: Multi Dimensional Scaling bi plot showing four major subfamilies of Geometridae along two principal axes: vertical axes representing characters associated with flight strength and horizontal one associated with flight energetics

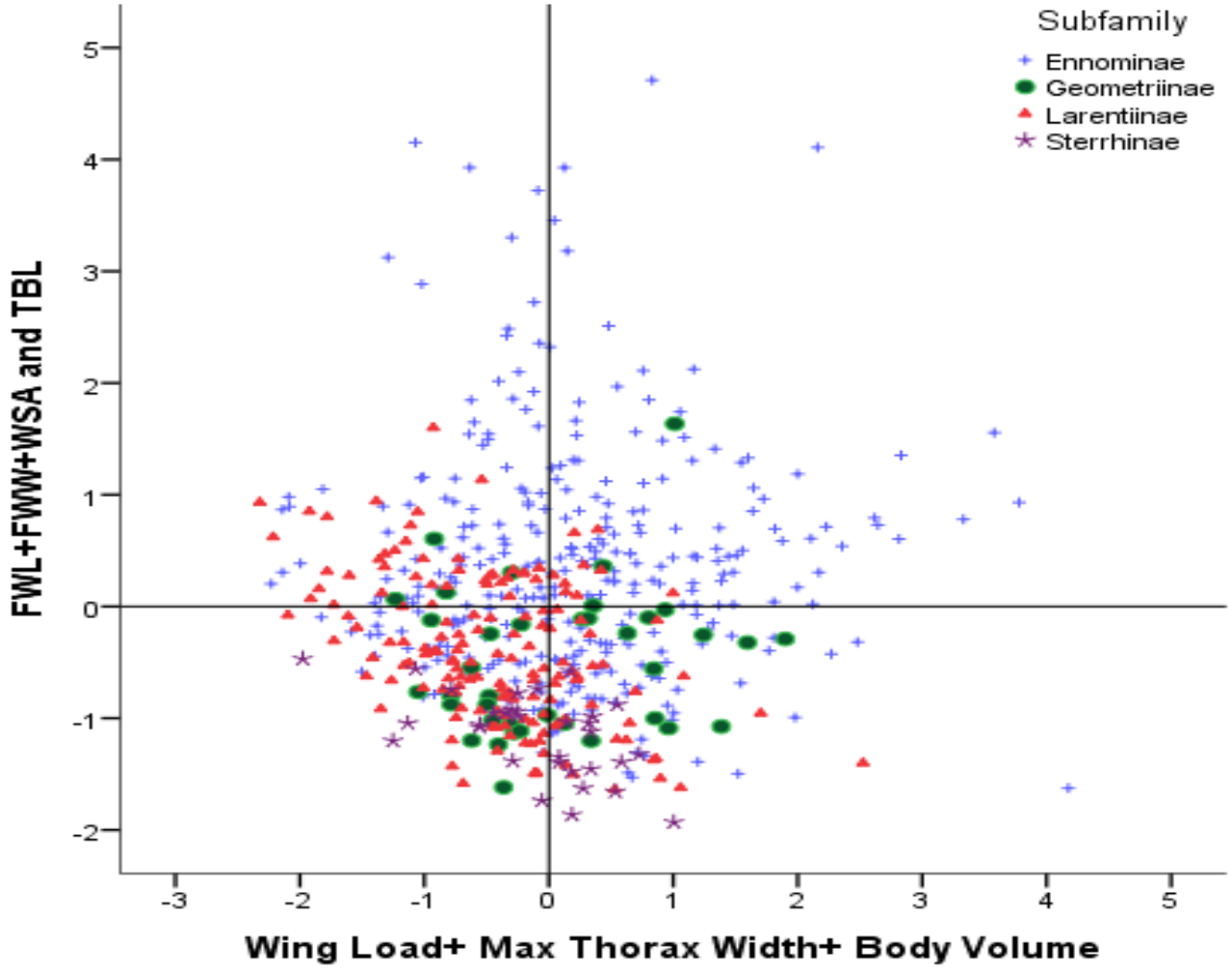
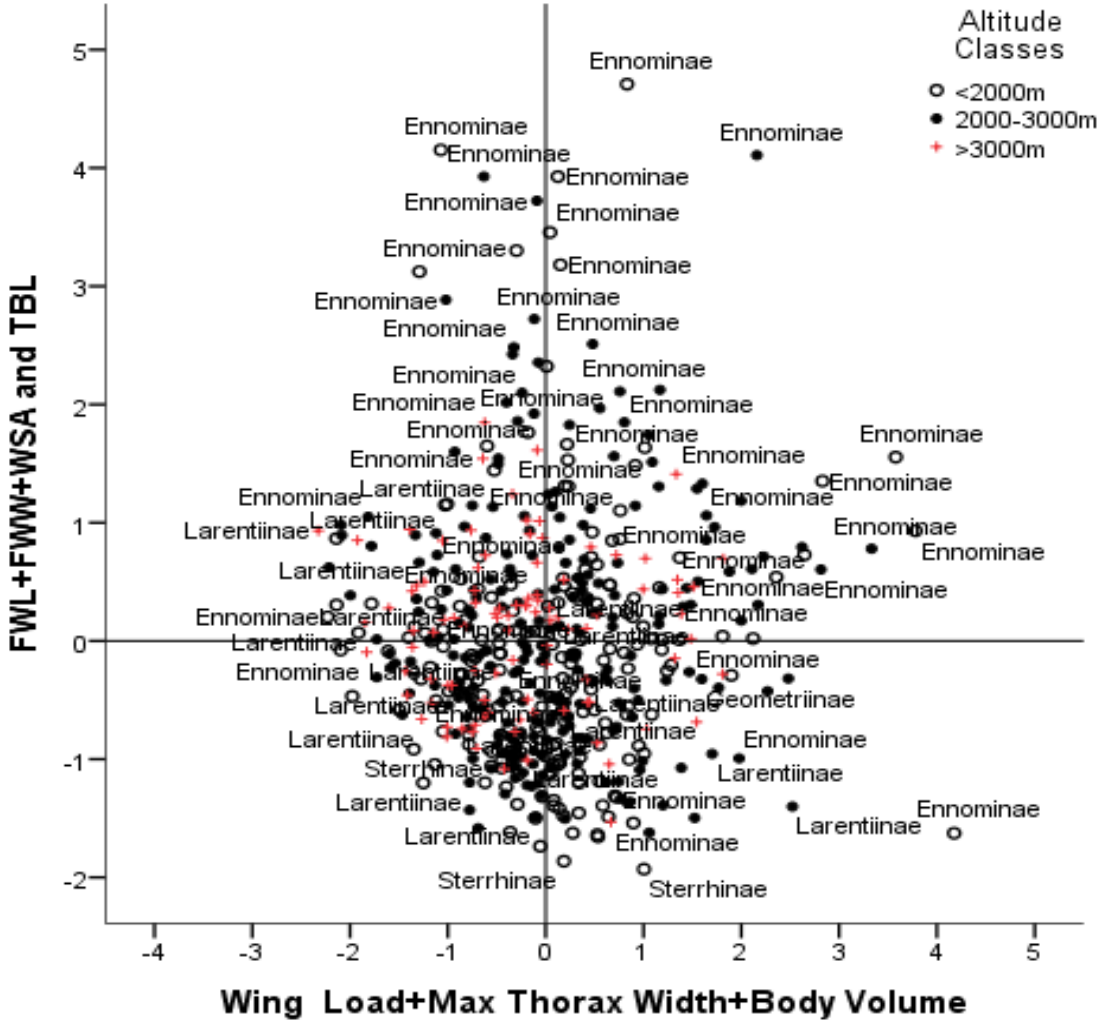


Fig. 7.7: Multi Dimensional Scaling bi plot showing representation of four major subfamilies of Geometridae in three altitudinal zones, viz. low (<2000m), medium (2000-3000m) and high (>3000m) along two principal axes: vertical axes representing characters associated with flight strength and horizontal one associated with flight energetics



7.4 Discussion

Variation in morphological traits of organisms is shaped by natural selection (i.e. adaptation to given environments) and historical legacy i.e. phylogenetic constraints that limit the scope of evolutionary change possible within ground plans. Body size distribution in a diverse night-flying insect assemblage along a changing environmental gradient allows a nice platform for assessing the relative strength of these two opposing forces on certain traits. Here I wanted to address if and how a set of morphological traits related to flight varies along an altitudinal gradient in a very speciose moth family Geometridae. Taxa moth, especially Geometridae was selected for this analysis as species of this group display a startling diversity of trait combinations (Kitching & Rawlins 1999).

My data indicated most of the structures associated with flight in Geometridae follow a similar trend with Forewing Length and Maximum Forewing Width being the most influential. Both of this structure had significant positive relationship with altitude. There was a consistent pattern of wing size increase in higher altitudes across two different subfamilies of Geometridae. Among all taxa analyzed, strong support for Bergmann's rule was found in subfamily Larentiinae and Geometriinae. They had not only larger forewing in high altitudes, data variability was reduced in higher altitudes, signifying strong selection pressure on larger wing sizes in high altitude. The harsher environmental conditions (i.e. lower ambient temperatures and higher precipitation) appeared to restrict the body sizes to a certain optimum range. In subfamily Ennominae, the pattern was similar but weakly depicted. Structural shifts in faunal composition along the gradient had a significant effect on the observed pattern. Ennominae being comparatively larger-bodied and strong flyer than Larentiinae inhabits entire altitudinal gradient in different size classes. On the contrary, Lareniitne moths were not only more abundant in higher altitudes, larger bodied species dominated the assemblage structure here.

My results clearly show that mechanisms that regulate generally larger body sizes at colder climates are applicable to geometrid moths along the elevational gradient investigated. For insects capable of flight, wing morphology and the relationship between wing size, wing shape and body mass essentially determine maneuverability, strength of

flight and thus dispersal capacity (Chai & Srygley 1990, Hall & Willmott 2000, Rydell & Lancaster 2000, Braun *et al.* 2004). Larger bodies have a more favorable ratio between surface and volume and can more effectively be insulated. Although this line of possible explanation is more applicable to Endotherms, larger bodied insects, more precisely larger-winged insects enjoy some advantages at flight in high altitudes. Reduced air density at high altitude reduces aerodynamic forces generated by insect wings (Vogel 1994, Dudley 2000). High altitude may therefore compromise flight because a greater downward flux of air is required to maintain the constant momentum flux necessary to offset body weight. The power required to produce this momentum flux therefore also increases at high altitude (Dudley 2000) which explains the advantages of larger wing with more muscle power. On a developmental or evolutionary timescale, flying insects may compensate for reduced air density by altering wing or body morphology. Insects with longer wings relative to body size reduce loss of momentum from the tip of the wing, decreasing induced power requirements of flight (Dudley 2000). Insects with greater wing area relative to body size decrease the induced velocity necessary to sustain flight, thereby reducing induced power expenditure (Dudley 2000). High-altitude insects may therefore minimize induced power by changing wing length and/or wing area relative to body size. Some previous studies in different taxa like Drosophila (Stalker & Carson 1948) and mountain honeybees (Hepburn *et al.* 1998) had supported this hypothesis. Another plausible explanation of larger body sizes in higher altitudes in Ectotherms can be the consequence of the effect of a decline in development temperature, which results in a larger final body size (Chown & Klok 2003).

In conclusion, given the multitude of selective forces, there remains serious doubts as whether a consistent variation of insect body sizes along environmental gradients exists at all (Blackburn *et al.* 1999). Previous studies, both at the intraspecific and interspecific level, revealed no consistent overall trends. Some studies showed an increase in body size with increasing altitude or latitude (e.g. Cushman *et al.* 1993), whereas other studies found a decrease in body size (e.g. Sota 1996), or inconsistent patterns (Hawkins & Lawton 1995, Hawkins & DeVries 1996, Krasnov *et al.* 1996). This non uniform trend of size variation of body parts along a gradient is due to the fact that species habits and environmental conditions can determine stronger selective regimes that restrict the

variation degree in some structures over others (Stern & Emlen 1999, Hodkinson 2005). But species rich Geometridae assemblage in Himalayan altitudinal gradient reveals that analysis of data of smaller and monophyletic units can be the first suitable step to show that body size relationships are shaped by ecological and physiological constrains under the concept of Bergman's rule.

CHAPTER VIII

SYNTHESIS & PERSPECTIVES

8.1 Synthesis

This study is an important step towards better understanding of a long-neglected but diverse and charismatic herbivorous insect assemblage in Himalayan montane temperate altitudinal gradient. Although many more topics need to be investigated further, the diversity of a very species-rich group of nocturnal Lepidoptera has been inventoried for the first time ever, in such an ecosystem in the Indian Himalaya. The detailed quantitative analysis of the diversity and structure of moth assemblages along an extensive altitudinal gradient from 1400m to 3600m, and their proximate determinant factors lays the groundwork for more experimental approaches in future. Beside concluding about main findings of the study and putting them in bigger perspective of insect conservation scenario, this chapter aims to comment on biogeograpical affinity of the assemblage sampled and on light trapping as a conservation monitoring tool for nocturnal Lepidoptera.

8.2 Diversity Pattern in different Altitude and Vegetation Types

The present study, conducted in Gangotri Landscape Area, has made a significant contribution towards increasing knowledge of moth species distributions in the Western Himalayan landscape. This area has extremely high moth diversity. A total of 670 morphospecies belonging to 356 genera and 22 families were sampled during the study period. No previous work on moths has been conducted in this area, thus the study represents new distribution records for all species recorded. The species compilation with their specific altitude and habitat information produces an initial baseline data which if accessible to wide range of users, will accelerate the rate of description, documentation and understanding of Himalayan moth diversity. Several species that are endemic to Himalaya and South East Asia occur in this area which further highlights the importance of maintaining the conservation status of this landscape.

Although local inventory at some plots were incomplete due to the presence of many singletons and doubletons, inventory protocol utilized in this study provided sufficiently thorough samples of local and regional moth species to permit an accurate comparison of species richness of different altitude and vegetation zones. The most remarkable finding is that the diversity of moths remains exceptionally high all through the complete elevational range investigated. Alpha diversity although decreased with increasing altitude, species richness, both observed and estimated remained stable, population abundance increased significantly with altitude. This is in contrast to any previous study on insect diversity along elevational gradients. Whether a low predation pressure, the availability of large resourceful habitat areas even at high altitudes, disturbance or historical factors are responsible for the patterns revealed remains to be investigated more thoroughly. In particular, some prominent taxa like Larentiinae and Noctuiinae showed exceptional distribution being highly diverse in high altitudes. A clear discrimination among moth assemblages based on forest types was also found. Among different forest types sampled, Western Mixed Coniferous forest was most diverse with maximum unique species. This habitat acting as a transition belt harbors species from both altitudinal extremes besides having its own unique assemblage. While the low elevation forests were characterized by a heterogeneous assemblage with many rare species, the high elevation forests were inhabited by specialized species in low diversity but high abundance.

Himalayan temperate forests in North-Western states of India face extreme challenges from ever increasing human population and remnant good quality forest patches are threatened by agriculture expansion, livestock grazing and timber harvesting. This study has not only shown that the diversity of moths is tremendous in these forests, but also that habitats at higher altitudes are richer in locally restricted species than habitats at lower elevations. This understandings of ecosystems based on scientific analysis can provide facts and arguments which can be used to decide upon the most effective conservation efforts in the area.

8.3 Assemblage Structure and Determining Factors

The patterns of abundance fluctuations were not identical among the moth families along the altitudinal gradient and differential responses of moth ensembles were determined by different habitat parameters. The data available on geometrid moths suggests that the family is more generalist as high diversity and abundance was recorded in all types of forest. Their polyphagous nature was more evident than previously thought and is further supported by the fact that their beta-diversity is less associated with vegetational and disturbance factors rather than with ambient microclimatic regimes. Family Erebidae and Noctuidae were more specialized to reflect ecological differences between habitats with a clearer picture for Erebidae moths. Patterns of beta diversity for these two families were best predicted by the degree of habitat openness, and to a lesser extent by understory vegetation. Noctuid moths responded more sensitively regarding to anthropogenic disturbance factors. Small families like Crambidae were more influenced by grass cover and grazing related activities. Faunal differences were probably not related to geographical distances between the sampling sites. Thus, even on the small spatial scale of my study the community differences observed can be related to local ecological effects and are not just a side effect of dispersal from neighboring areas.

Seasonal fluctuations in abundance and species richness have been documented in a number of tropical and temperate insect groups, however, much less was still known about dynamics of nocturnal Lepidoptera of the temperate Himalayan forests. In the current study, there is a clear indication that irrespective of habitat and taxonomic group considered, there was a unimodal peak in moth activity with species richness and abundance at its highest during the monsoon season. Effect of seasonality was more pronounced in middle and high altitude than in lower altitude. My data shows that, these insect assemblages are highly dynamic over time and comparisons between sites should be based on samples that have been taken in the closest possible temporal sequence.

The sampling of moths using light-traps is not free of problems, but overall provides a reliable, effective, rapid and well-established method. Analytical tools for the investigation of alpha- and beta-diversity of incomplete assemblages that consist of many rare species are available. Some methods such as non-metric multidimensional scaling or

CCA are established widely as appropriate analytical instruments. These methods help to reliably identify and analyze patterns in species-rich ensembles without the necessity of data transformations or the discarding of rare species.

Moths have already proven to be a suitable model group of herbivorous insects elsewhere in the world. This study has shown that this is also the case in the Himalayan ecosystems. My data allowed the identification of individual 'indicator' species among the more common and generalist species based upon degree of specificity and fidelity for the five different forest types and three different disturbance stages. Although there are lot of scopes to learn more about the indicator species' habitat requirements and host-plant relationships, this may constitute a necessary first step for using the nocturnal Lepidoptera as meaningful tools in better habitat management.

8.4 Biogeographic Pattern of Assemblage Composition

With reference to Lepidoptera, Himalaya represents a mixing ground of Palaearctic and Indo-Malayan communities which have caused a proliferation of species usually not found outside tropics. Biogeographically, the Himalayan Mountain Range straddles a transition zone between the Palaearctic and Indo-Malayan realms. Species from both realms are represented in the hotspot. At western end of Himalaya, Palaearctic elements dominate with many North-Asian and European species whereas at the eastern end Indo-Malayan groups dominate with strong presence of Sino-Himalayan elements (Smetacek 1994). The sampled moth assemblage in Gangotri Landscape Area, which was an essential Western Himalayan Landscape, was diverse enough to see representation of different biogeographic elements shaping local assemblage.

From previous distribution record, moth species were categorized into following zoogeographic elements. Majority of the fauna were from Indo-Malayan origin (49%), whereas significant proportions were of Palaearctic (19%) and Sino-Himalayan (17%) origin. Very small representation of Ethiopian (3%) elements was also there along with 12% species which were globally distributed (Fig.8.1)

Fig 8.1: Biogeographic representation of different faunal elements in sampled moth assemblage (n=371) in GLA

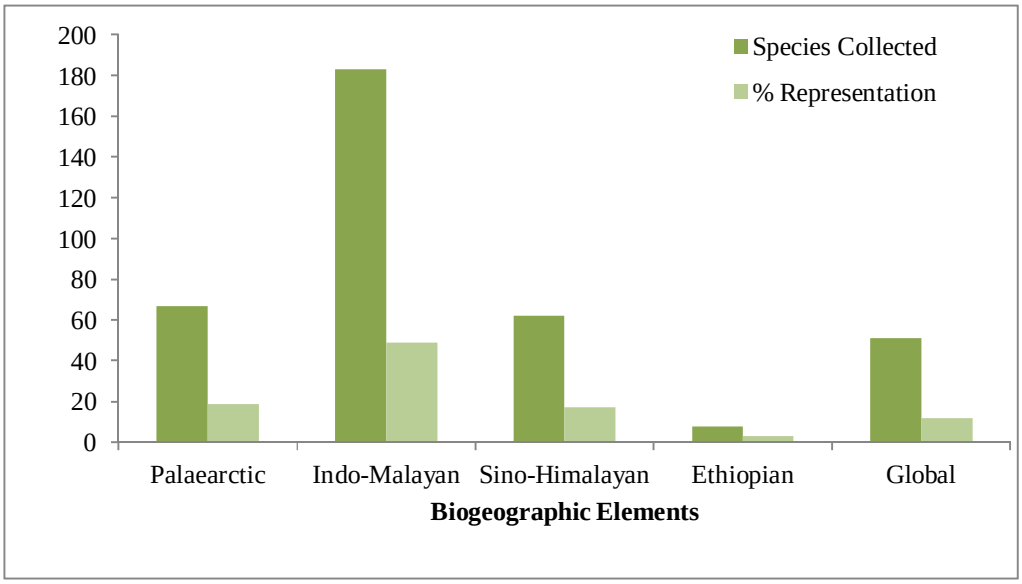
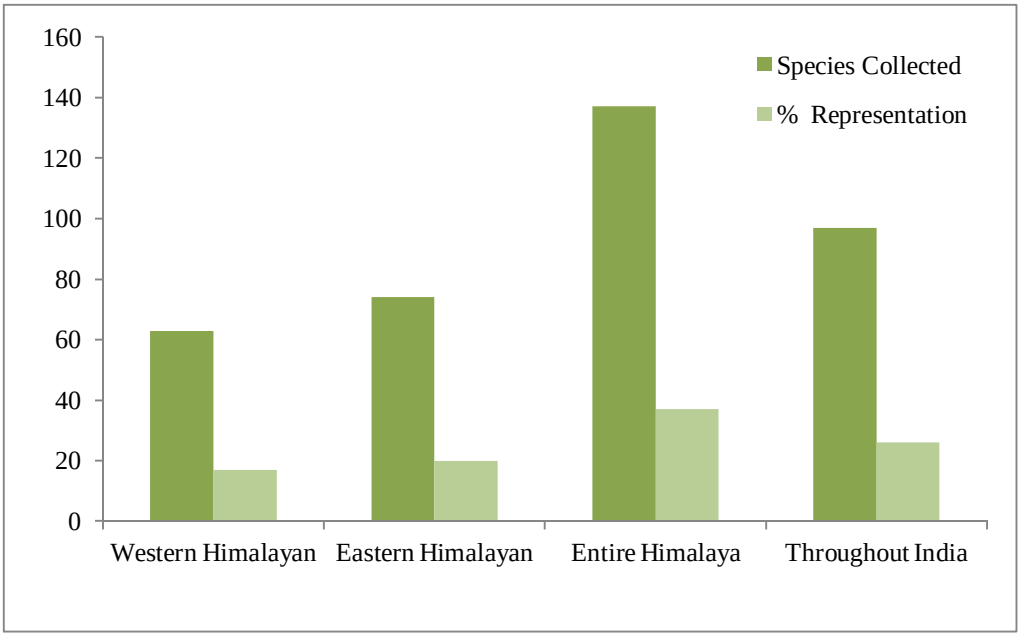


Fig 8.2: Biogeographic representation of different zonal elements within India for sampled moth assemblage (n=371) in GLA



Within Indian sub region, faunal elements correspond either to Himalayan elements or species which are distributed throughout the subcontinent. The sampled moth assemblage was composed mainly of Himalayan elements (74%), whereas only 26% species were distributed all through India. Among Himalayan elements, 17% were Western Himalayan

endemic whereas 20% were eastern Himalayan endemic (Fig. 8.2). High percentage of Himalayan endemics among moth species suggested that this assemblage is long adapted to Himalayan climatic gradient and human or climate induced perturbations may threaten their future survival.

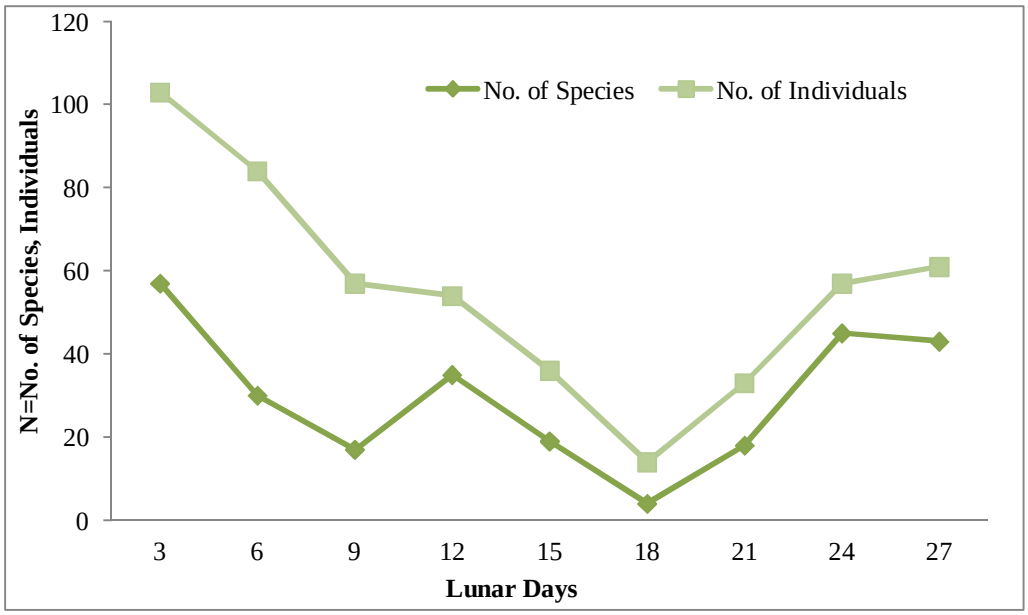
8.5 Light trapping as a Tool for Monitoring Nocturnal Lepidoptera

Many species of moths can easily be attracted to artificial light sources (Canaday 1987, Muirhead-Thomson 1991). This renders moths a very attractive group to study, particularly if large data sets are required for statistical analyses. Although the underlying physiological and behavioral mechanisms of the attraction to light are still not fully understood (e.g. Bowden 1982), light-traps have become an important tool for taking an inventory of insects in a wide range of studies. No other trapping method has proved so consistently successful in capturing large numbers or such a great variety of species (Muirhead-Thomson 1991). Moreover, light traps have been used for monitoring for more than 50 years (Leinonen *et al.* 1998). There is extensive literature detailing advantages and disadvantages of light-trapping and factors that might influence the results of this technique (Holloway *et al.* 2001). Three specific criticisms on the method were formulated by Schulze & Fiedler (2002): (1) Light traps sample selectively rather than randomly, (2) moths are attracted from a distance, i.e. from other habitats than those targeted, and (3) the effective attraction radius may depend on the visibility of the trap and hence be influenced by vegetation structure. Besides these issues, there are problems regarding the trap type, the site, and the influence of weather and the moonlight on the catches. The higher proportion of males in trap catches probably reflects their higher activity when they are searching for mates. Sex biases are common in Lepidoptera samples (Pollard & Yates 1993, Fischer & Fiedler 2000, Holloway *et al.* 2001) and their interpretation does not present any difficulties. Generally, light trap samples represent a certain unknown “distortion” of the real situation. Relative abundances of species in trap collections do not necessarily reflect relative abundances of species in a particular habitat but rather their activities (Wolda 1992, Simon & Linsenmair 2001). Furthermore, not all insect groups and species are attracted to light traps to the same extent (Bowden 1982, Butler *et al.* 1999). Therefore, samples cannot perfectly represent all flying insects in a

habitat. The density of the vegetation around a light trap might be assumed to have an impact on the number of individuals and species caught. Thus dense stands of vegetation should be avoided around trap station.

There is extensive literature concerning the influence of weather factors and the phase of the moon on light-trap catches (e.g. Muirhead-Thompson 1991, Yela & Holyoak 1997, Holloway *et al.* 2001, Intachat *et al.* 2001). Sample size is generally known to be influenced by weather conditions such as temperature, wind and humidity (Holloway *et al.* 2001). For example, Yela & Holyoak (1997) found that light-trap catches decreased with mean wind speed. An increased mean temperature can be associated with an increased catch in some Lepidoptera groups (McGeachie 1989). To observe whether the moon phase has any significant effect on catch success, an experimental light trap was run on daily basis for one month period in the month of April at an altitude of 1440m from 20:00–24:00 hr. The result of the observed species catch and individual catch per day in a complete lunar cycle is shown in Fig. 8.3. Most species as well as individuals were attracted in and around no moon nights and declined as the ambient moon light started to increase and came to a minimum around full moon nights when the ambient moon light was at its best.

Fig 8.3: Effect of lunar phase on catch success of light-trap performed in a monthly period in GLA



Moon phase or the monthly lunar cycle had a significant effect on the light trap catch success. Yela & Holyoak (1997) from their study recommended to restrict the light trapping to periods without strong moonlight because moths are not attracted to artificial light in the presence of high ambient moonlight, though their activity remains at its peak. My study documented the same phenomenon where maximum numbers of species as well as individuals were attracted to light traps in the beginning and end of lunar cycle, i.e. from 3rd to 6th day and 24th to 28th day when there was apparently no ambient moon light. Catch success eventually dropped as the ambient moon light started to increase and became almost zero in the full moon period from 14th to 18th day. One factor that masked this general pattern was the presence of cloud cover evident from the slightly increased catch success in 12th day when there was strong moon light but its effect was nullified by the clouds.

In conclusion, it can be said that collecting with light-traps is the only method that enables a wide array of taxonomic groups to be sampled quantitatively in large numbers (Holloway *et al.* 2001). Methodological constraints that result in a somehow "distorted" picture of moth assemblages must be considered during data analysis. The application of additional collecting techniques like baiting or netting should be included in the protocol if a complete inventory is to be achieved since some species are exclusively diurnal. The timing of light trapping should also be carefully planned, more so in Himalayan high altitudes, where some species might be on wings for a very narrow window of time.

8.6 Concluding Remarks

The current study on moth assemblage tried to achieve two basic insights; firstly, documentation of species richness of major macro moth families as site inventories in temperate Himalayan altitudinal gradient, gathered as basic information as well as to appraise changes over seasons, both in incidence and abundance; secondly, correlating those basic data with different environmental as well as disturbance effects to know what drives their distribution pattern. The variety of species sampled and the variety of habitats in which such notable species and assemblages exist demonstrate their values in practical conservation and also will help to publicize the plight of terrestrial invertebrates as well as development of sound conservation management based on detailed biological

information. The universal problem in analyzing assemblages of moths to indicate or monitor environmental change is to establish the characteristics of pre-disturbance baseline assemblages (New 2004). The problem is enhanced when the case is such that the fauna is distributed very patchily and the samples contain intermingling proportions of highly mobile tourists and less mobile residents, or simply many species in low abundance. But the samples used in this study were sufficient to accommodate both spatial and temporal heterogeneity. Indicator properties explored in the current study strongly supports that moth assemblages as well as changes to them can be useful tools for monitoring wider changes to natural assemblages in relation to changes in habitat quality. In short, the study will certainly help to promote moths as model terrestrial insect group for concurrent conservation management target.

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Appendix 3.1: Details of all the effective light-trapping nights performed during 2008-2012. Abbreviations: GNP: Gangotri National Park, GVS: Govind Wildlife Sanctuary, GVP: Govind National Park; S: Number of Species collected, N: Number of Individuals collected)

Date	Location (PA)	GPS Coordinates	Site Code	S	N
30.09.2008	Devghat (GNP)	30°59′44.4″ N, 78°58′57.8″ E	DV34	13	37
03.10.2008	Devghat (GNP)	30°59′44.4″ N, 78°58′57.8″ E	DV34	17	52
04.10.2008	Devghat (GNP)	30°59′44.4″ N, 78°58′57.8″ E	DV34	5	14
07.10.2008	Devghat (GNP)	30°59′44.4″ N, 78°58′57.8″ E	DV34	11	31
11.10.2008	Chirwasa (GNP)	30°58′52.5″ N, 79°01′17.0″ E	CW34	4	16
18.10.2008	Gujarati Ashram (GNP)	30°59′38.1″ N, 78°57′02.1″ E	GA30	14	37
13.10.2008	Chirwasa (GNP)	30°58′52.5″ N, 79°01′17.0″ E	CW34	7	13
14.10.2008	Chirwasa (GNP)	30°58′52.5″ N, 79°01′17.0″ E	CW34	11	25
17.10.2008	Bhojwasa (GNP)	30°57′09.0″ N, 79°03′01.7″ E	BW36	2	5
19.10.2008	Bhojwasa (GNP)	30°55′33.0″ N, 79°04′44.0″ E	BW36	1	3
21.10.2008	Bharonghati (GNP)	31°01′36.2″ N, 78°52′04.7″ E	BG28	21	32
23.10.2008	Harsil (GNP)	31°02′32.7″ N, 78°44′51.7″ E	HS26	14	61
24.10.2008	Harsil (GNP)	31°02′32.7″ N, 78°44′51.7″ E	HS26	13	36
30.10.2008	Bhatwari (GNP)	31°04′07.5″ N, 78°06′21.6″ E	BH16	16	67
04.11.2008	Bhatwari (GNP)	31°04′07.5″ N, 78°06′21.6″ E	BH16	21	109
29.05.2009	Netwar I (GVS)	31°04′07.5″ N, 78°06′21.4″E	NT14	46	145
30.05.2009	Netwar I (GVS)	31°04′07.5″ N, 78°06′21.4″ E	NT14	12	39
31.05.2009	Netwar I (GVS)	31°04′07.5″ N, 78°06′21.4″ E	NT14	24	87
01.06.2009	Netwar I GVS)	31°03′39.5″ N, 78°07′38.0″ E	NT14	34	120
03.06.2009	Netwar II (GVS)	31°04′26.3″ N, 78°06′46.2″ E	NT16	20	46
08.06.2009	Sankri (GVS)	31°04′00.3″ N, 78°07′06.0″ E	NT18	5	28
09.06.2009	Netwar II (GVS)	31°04′26.3″ N, 78°06′46.2″ E	NT16	18	51
12.06.2009	Netwar I (GVS)	31°04′15.4″ N, 78°06′22.6″ E	NT14	34	96
01.11.2009	Netwar II (GVS)	31°04′26.3″ N, 78°06′46.2″ E	NT16	10	36
02.11.2009	Netwar16 (GVS)	31°04′13.6″ N, 78°07′09.9″ E	NT14	2	4
03.11.2009	Sankri (GVS)	31°04′27.6″ N, 78°07′23.8″ E	NT18	5	11
07.11.2009	Sankri (GVS)	31°04′27.6″ N, 78°07′23.8″ E	NT18	13	46
08.11.2009	Sankri (GVS)	31°04′00.3″ N, 78°07′06.0″ E	NT18	9	40
09.11.2009	Sankri (GVS)	31°04′27.6″ N, 78°07′23.8″ E	NT18	6	9
10.11.2009	Netwar II (GVS)	31°04′26.3″ N, 78°06′46.2″ E	NT16	1	3
11.11.2009	Netwar II (GVS)	31°04′11.2″ N, 78°07′23.8″ E	NT16	15	59
12.11.2009	Netwar II (GVS)	31°04′26.3″ N, 78°06′46.2″ E	NT16	19	50

28.04.2010	Netwar I (GVS)	31°03′56.2″ N, 78°06′46.2″ E	NT14	5	6
03.05.2010	Netwar I (GVS)	31°04′11.2″ N, 78°07′23.8″ E	NT14	59	184
04.05.2010	Netwar I (GVS)	31°03′56.2″ N, 78°06′46.2″ E	NT14	27	79
06.05.2010	Netwar I (GVS)	31°04′11.2″ N, 78°07′23.8″ E	NT14	13	49
08.05.2010	Sankri (GVS)	31°04′27.6″ N, 78°07′23.8″ E	NT18	18	64
09.05.2010	Netwar II (GVS)	31°04′26.3″ N, 78°06′46.2″ E	NT16	19	51
10.05.2010	Kedarkanta22 (GVS)	31°04′13.0″ N, 78°08′19.2″ E	KK22	13	40
11.05.2010	Kedarkanta22 (GVS)	31°03′49.9″ N, 78°08′51.7″ E	KK22	12	38
13.05.2010	Jarmola24 (GVN)	31°03′51.3″ N, 78°07′12.1″ E	JM24	22	143
14.05.2010	Jarmola24 (GVN)	31°03′51.3″ N, 78°07′12.1″ E	JM24	27	86
15.05.2010	Jarmola24 (GVN)	31°03′50.2″ N, 78°07′38.7″ E	JM24	32	165
18.05.2010	Netwar14 (GVS)	31°04′14.9″ N, 78°06′43.9″ E	NT14	13	44
19.05.2010	Netwar14 (GVS)	31°04′07.5″ N, 78°06′21.4″ E	NT14	12	33
21.05.2010	Jakhol 24 (GVS)	31°06′07.7″ N, 78°13′39.1″ E	JK24	18	55
23.05.2010	Jakhol 24 (GVS)	31°06′07.7″ N, 78°13′39.1″ E	JK24	6	18
22.06.2010	Kedarkanta24 (GVS)	31°03′09.1″ N, 78°08′17.1″ E	KK24	16	57
25.10.2010	Taluka21 (GVN)	31°05′11.5″ N, 78°16′07.5″ E	TK22	27	143
01.11.2010	Netwar I (GVS)	31°03′39.5″ N, 78°07′38.0″ E	NT14	4	20
08.11.2010	Netwar I (GVS)	31°04′07.5″ N, 78°06′21.4″ E	NT14	2	4
09.11.2010	Netwar II (GVS)	31°04′11.2″ N, 78°07′23.8″ E	NT16	1	7
13.11.2010	Netwar II (GVS)	31°04′11.2″ N, 78°07′23.8″ E	NT16	5	14
14.11.2010	Sankri (GVS)	31°04′27.6″ N, 78°07′23.8″ E	NT18	6	13
15.11.2010	Sankri (GVS)	31°04′00.3″ N, 78°07′06.0″ E	NT18	1	1
30.11.2010	Sankri (GVS)	31°04′00.3″ N, 78°07′06.0″ E	NT18	3	5
02.05.2011	Changsil20 (GVS)	31°07′56.8″ N, 78°02′46.9″ E	CH20	21	158
08.05.2011	Changsil20 (GVS)	31°07′56.8″ N, 78°02′46.9″ E	CH20	14	73
12.05.2011	Changsil26 (GVS)	31°07′32.2″ N, 78°01′41.4″ E	CH26	15	80
13.05.2011	Changsil34 (GVS)	31°07′24.0″ N, 77°59′10.4″ E	CH34	12	149
09.06.2011	Kedarkanta20 (GVS)	31°03′39.5″ N, 78°07′38.0″ E	KK20	21	77
10.06.2011	Kedarkanta20 (GVS)	31°03′39.5″ N, 78°07′38.0″ E	KK20	20	69
22.06.2011	Netwar I (GVS)	31°03′56.2″ N, 78°06′46.2″ E	NT14	18	49
24.06.2011	Netwar I (GVS)	31°04′15.4″ N, 78°06′22.6″ E	NT14	61	235
26.06.2011	Netwar I (GVS)	31°03′56.2″ N, 78°06′46.2″ E	NT14	24	88
02.11.2011	Netwar II (GVS)	31°04′11.2″ N, 78°07′23.8″ E	NT16	3	15
11.11.2011	Netwar II (GVS)	31°04′13.6″ N, 78°07′09.9″ E	NT16	2	7
12.11.2011	Netwar II (GVS)	31°04′13.6″ N, 78°07′09.9″ E	NT16	3	12
29.11.2011	Sankri (GVS)	31°04′00.3″ N, 78°07′06.0″ E	NT18	4	9
30.11.2011	Sankri (GVS)	31°04′27.6″ N, 78°07′23.8″ E	NT18	4	4
25.05.2012	Kedarkanta26 (GVS)	31°03′09.1″ N, 78°08′17.1″ E	KK26	25	112
26.05.2012	Kedarkanta26 (GVS)	31°03′09.1″ N, 78°08′17.1″ E	KK26	24	90
27.05.2012	Kedarkanta29 (GVS)	31°02′37.8″ N, 78°09′05.5″ E	KK29	23	134

28.05.2012	Kedarkanta29 (GVS)	31°02′37.8″ N, 78°09′05.5″ E	KK29	17	69
29.05.2012	Kedarkanta32 (GVS)	31°01′43.1″ N, 78°09′42.6″ E	KK32	20	74
09.06.2012	Taluka24 (GVN)	31°04′15.7″ N, 79°16′13.4″ E	TK24	43	211
10.06.2012	Taluka24 (GVN)	31°04′15.7″ N, 79°16′13.4″ E	TK24	40	173
11.06.2012	Taluka26 (GVN)	31°04′03.1″ N, 78°15′06.7″ E	TK26	53	337
12.06.2012	Taluka26 (GVN)	31°04′03.1″ N, 78°15′06.7″ E	TK26	35	209
14.06.2012	Taluka28 (GVN)	31°03′45.5″ N, 78°15′48.6″ E	TK28	53	313
15.06.2012	Taluka28 (GVN)	31°03′45.5″ N, 78°15′48.6″ E	TK28	79	498
16.06.2012	Taluka30 (GVN)	31°03′08.7″ N, 78°17′24.9″ E	TK30	37	206
17.06.2012	Taluka33 (GVN)	31°02′36.5″ N, 78°15′45.3″ E	TK32	43	372
22.06.2012	Har-Ki-Dun34 (GVN)	31°08′09.3″ N, 78°23′57.8″ E	HD34	35	134
24.06.2012	Har-Ki-Dun30 (GVN)	31°08′28.1″ N, 78°24′36.9″ E	HD30	38	337
26.06.2012	Har-Ki-Dun30 (GVN)	31°08′28.1″ N,7 8°24′36.9″ E	HD30	42	216
28.06.2012	Har-Ki-Dun32 (GVN)	31°07′55.0″ N, 78°23′28.1″ E	HD32	35	232
10.07.2012	Changsil24 (GVS)	31°07′30.7″ N, 78°01′58.2″ E	CH24	66	613
13.07.2012	Changsil30 (GVS)	31°07′20.2″ N, 77°59′58.1″ E	CH30	57	398
15.07.2012	Changsil33 (GVS)	31°07′18.2″ N, 77°59′34.9″ E	CH32	48	478
16.07.2012	Changsil34 (GVS)	31°07′24.0″ N, 77°59′10.4″ E	CH34	53	617
17.07.2012	Changsil35 (GVS)	31°07′24.0″ N, 77°59′10.4″ E	CH36	54	407
19.07.2012	Changsil26 (GVS)	31°07′35.3″ N, 78°01′31.7″ E	CH26	49	370
20.07.2012	Changsil22 (GVS)	31°07′36.6″ N, 78°02′34.0″ E	CH22	28	133
23.07.2012	Changsil22 (GVS)	31°07′36.6″ N, 78°02′34.0″ E	CH22	39	189
24.07.2012	Changsil18 (GVS)	31°07′54.9″ N, 78°03′35.9″ E	CH18	48	313
25.07.2012	Changsil18 (GVS)	31°07′54.9″ N, 78°03′35.9″ E	CH18	51	202
21.10.2012	Gangotri32 (GNP)	31°01′36.2″ N, 78°52′04.7″ E	GT32	15	25
22.10.2012	Gangotri32 (GNP)	30°59′38.1″ N, 78°57′02.1″ E	GT32	13	32
24.10.2012	Gangotri30 (GNP)	30°59′48.9″ N, 78°55′39.4″ E	GT30	8	17
31.10.2012	Sankri (GVS)	31°04′27.6″ N, 78°07′23.8″ E	NT18	4	33
04.11.2012	Sankri (GVS)	31°04′27.6″ N, 78°07′23.8″ E	NT18	17	74

Appendix 4.1: Abundance matrix of all the moths (in alphabetical order) in five major forest types sampled (SPBM: Subtropical Pine Broadleaved Mix Forest, MTD: Moist Temperate Deciduous Forest, WMC: Western Mix Coniferous Forest, WHUOF: Western Himalayan Upper Oak Forest, SAF: Subalpine Forest) in GLA

Species	SPBM	MTD	WMC	WHUOF	SAF
Abraxas irrorata	0	0	0	0	3
Abraxas peregrina	6	0	0	0	0
Abraxas sp.	0	0	2	97	71
Agrotis ipsilon	18	19	0	0	0
Agylla beema	0	30	85	13	0
Agylla prasena	6	0	0	0	0
Alcis limbui	0	8	14	0	0
Aletia medialis	0	0	0	0	3
Aletia sp.	4	2	0	0	0
Allodonta sikkima	0	0	1	1	0
Altha subnotata	1	0	0	0	0
Amascata lactinea	0	2	0	19	0
Amnesicoma simplex	0	0	0	0	5
Amphipyra monolitha	0	0	5	0	3
Amphipyra sp.	0	1	0	0	0
Ancylolomia sp.	3	0	0	0	0
Anisozyga gavissima	2	0	0	0	0
Anomis mesogona	1	2	0	0	0
Anonychia sp.	0	0	0	0	1
Anonychia exilis	1	0	0	0	0
Anonychia violaceae	0	7	10	18	7
Apamea Aquila	0	0	8	5	3
Apona caschmirensis	0	3	0	0	5
Apostema sp.	0	0	0	0	4
Arcte coerula	2	0	0	0	0
Arctiinae sp 1	0	0	0	4	0
Arctornis comma	1	6	3	0	0
Areas galactina	6	0	0	0	0
Argina astrea	13	0	0	0	0
Arichana tenebraria	0	0	0	10	19
Artaxa sp.	1	0	0	0	0
Artaxa vilellina	3	7	11	23	0
Aspila peltigera	0	2	0	0	0

Asura calamaria	0	26	8	0	0
Auchmis indica	12	3	0	0	0
Auchmis indica	0	3	0	0	0
Autographa nigrisigna	11	0	0	0	0
Autographa purpureofusa	0	0	0	0	0
Axylia renalis	7	0	0	0	0
Bamra lepida	1	0	0	0	0
Bireta longivitta	0	11	3	0	0
Biston bengaliaria	0	2	0	0	0
Biston falcata	0	0	0	2	0
Biston sp.	0	0	6	0	0
Blepharita sp.	0	0	0	0	2
Bombyx huttoni	1	0	0	0	0
Brahmaea wallichii	0	0	1	0	0
Brahmaea wallichii	0	0	0	2	0
Brunia antica	0	0	10	102	0
Brunia sp.	0	0	7	0	0
Bryoxena centralasiae	0	0	0	0	9
Buckleria paludum	0	0	5	0	7
Calesia haemorrhoa	1	0	0	0	0
Caligula thibeta	3	0	0	0	0
Calliteara cerebosa	10	0	2	0	0
Callopistria albolineola	23	0	0	0	0
Callopistria placodoides	0	2	0	0	0
Callopistria placodoides	2	0	0	0	0
Callopistria rivularis	3	0	0	0	0
Catocala armandi	0	7	0	1	0
Chartographa sp.	0	0	1	0	0
Chersotis harutai	0	0	0	0	8
Chlorissa gelida	2	5	0	0	0
Chlorochaeta inductaria	3	0	0	0	0
Chlorochaeta pictipennis	0	0	2	0	0
Chlorochaeta quadrinotata	0	0	0	1	0
Chorodna interruptaria	0	0	46	3	0
Chrysorabdia bivittata	1	7	0	0	0
Chrysorabdia viridata	0	0	0	6	0
Chrysorabdia viridata	0	0	9	3	0
Cidaria aurata	3	0	4	0	3
Cidaria sp.	0	0	0	2	0

Cirrhochrista brizoalis	10	1	0	0	0
Clepsis sp.	0	0	1	3	0
Colostygia albigirata	17	9	37	42	107
Comostola subtiliaria	12	2	0	0	0
Conogethes punctiferalis	8	0	0	0	0
Cotachena histricalis	0	0	19	0	0
Crambidae Sp.	0	0	17	0	0
Creatonotos gangis	0	11	0	0	0
Creatonotos transiens	20	0	0	0	0
Cucullia pullata	0	0	0	1	0
Cyana horsfieldi	5	0	0	0	0
Cyana sp.	4	0	3	0	0
Cyana sp. 1	0	0	3	4	0
Cyana sp. 2	0	0	2	2	0
Cyana sp. 2	0	0	5	3	0
Cyana sp. 3	0	0	1	0	0
Cyana sp.4	0	0	2	0	0
Cyclidia substigmaria	7	0	0	0	0
Cydima albofinnis	0	0	0	0	0
Cymoriza ustalis	0	7	0	0	0
Cyphanta xanthochlora	0	0	0	1	0
Damata longipennis	0	0	0	5	0
Dasypolia atrox	0	0	16	0	7
Deinotrichia cervina	0	1	7	63	8
Diacrotricha fasciola	2	0	0	0	3
Diarsia albipennis	0	0	2	0	0
Dichocrocis definita	3	9	0	0	0
Diphtherocome fasciata	0	0	2	18	1
Diphtherocome pallida	0	0	5	78	97
Docirava pudicata	0	2	4	0	0
Docirava sp.	0	0	3	0	4
Drepana pallida	3	10	0	0	0
Dyloxia fimbriata	10	0	0	0	0
Dynatocephala omophaea	0	0	2	0	0
Dysgonia latifascia	1	0	0	0	0
Dysstroma sp	4	13	7	8	4
Ecliptopera postpallida	16	0	20	14	40
Ecliptopera sp.	5	0	50	32	35
Ecliptopera sp.2	0	0	0	13	0

Eilema antica	0	8	13	4	0
Eilema caniola	0	0	2	0	0
Electrophaes recta	0	7	3	19	0
Electrophaes sp.	0	8	10	13	20
Electrophaes sp.1	0	0	0	6	0
Electrophaes sp.2	0	0	0	9	0
Elphos pardicelata	0	3	2	0	0
Elphos pardicelata	0	0	0	0	0
Endotricha olivacealis	6	0	0	0	0
Eoophyla peribocalis	9	5	0	0	0
Epicrocis hilarella	14	0	0	0	0
Epiplema bicaudata	0	0	8	25	0
Erebomorpha fulguraria	0	0	1	1	0
Ericeia pertendens	15	0	0	0	0
Erythroplusia pyropia	0	0	1	1	0
Estigmene quadriramosa	6	4	2	0	0
Euchromius ocellea	2	0	0	0	0
Euphyia coangulata	5	5	3	2	15
Eupithecia rajata	11	0	3	0	0
Eupithecia sp.	0	11	0	0	3
Euplexia plumbeola	0	0	0	3	0
Euplexia semifascia	0	0	35	14	1
Euplexia tibetensis	0	0	0	5	2
*Euproctis sp.*1	32	0	0	0	0
*Euproctis sp.*2	5	0	0	0	0
*Eupterote sp.*3	0	4	0	0	0
Eustroma chalcoptera	0	0	0	2	26
Eutelia adulatrix	2	0	0	0	0
Euxoa hypochlora	4	0	0	0	10
Fascellina plagiata	1	0	0	0	0
Formofentonia orbifer	0	1	0	0	0
Gabala argentata	1	0	0	0	0
Gaurena dierli	0	0	3	5	3
Gaurena sp.	0	0	0	0	2
Gazalina apsara	3	4	52	8	0
Ginshachia gemmifera	0	0	0	1	0
Glyphodes crithealis	11	3	17	3	0
Gnophos albidior	6	0	0	0	0
Godonela avitusaria	1	0	0	0	0

Goniorhynchus signatalis	7	0	0	0	0
Habrosyne conscripta	0	0	4	0	0
Haderonia culta	0	0	6	53	65
Helicoverpa armigera	22	2	3	0	0
Heliophobus texturata	0	0	0	0	4
Heliophobus texturata	0	0	0	0	42
*Hemithea sp.*1	0	0	6	0	0
Hemithea sp. 2	17	0	0	0	0
Hermonassa consignata	0	0	0	11	36
Hermonassa incisa	0	0	0	10	17
Hermonassa sinuata	0	0	0	53	23
Herpetogramma luctuosale	9	11	0	0	0
Heterocallia temeraria	4	3	0	0	0
Heterolocha phaenicotaeniata	0	7	57	11	0
Heterothera dentifasiata	0	6	0	0	0
Hirasa muscosaria	2	4	6	3	0
Homana sp	0	0	6	2	0
Homocentridia concentrica	0	6	0	0	0
Hyaloplaga pulchralis	5	0	49	0	0
Hydrelia bicolorata	0	3	6	0	0
Hypena sp. 1	1	7	9	0	0
Hypena sp.2	6	0	1	0	2
Hypena sp.3	0	1	0	0	3
Hypena sp.4	0	1	0	0	0
Hypena sp.5	0	2	0	0	0
Hypochrosis abstractaria	1	0	0	0	0
Hypomecis infixaria	11	0	0	0	0
Hypomecis ratotaria	5	13	6	0	0
Hypopyra vespertilio	1	0	0	0	0
Krananda sp.	1	0	0	0	0
Lacera procellosa	4	0	0	0	0
Laciniodes plurilinearia	0	0	9	19	3
Laelia exclamationis	7	3	5	0	0
Lamprosema commixta	15	0	0	0	0
Larentiinae sp.	0	0	14	0	0
Larentiinae Sp.1	0	0	8	8	0
Larentiinae sp.2	0	0	0	7	0
Leucania compta	5	0	0	0	0
Leucophlebia lineata	0	1	0	0	0

Lithosia sp.	11	0	0	0	0
Lomographa sp.	4	0	3	12	4
Luxiaria sp.	2	0	0	0	0
Lyclene sp.	16	31	21	0	0
Lymantria concolor	8	2	0	0	0
Lymantria mathura	0	0	3	0	0
Lymantria serva	1	0	0	0	0
Lymantria sp.	0	2	0	0	0
Macrobrochis pallens	1	5	25	0	0
Macrocilix mysticata	0	0	0	5	0
Macroglossum bombylans	3	0	0	0	0
Malacosoma indicum	0	3	2	20	5
Medasina albidaria	18	8	50	16	0
Medasina sp.	5	0	6	0	0
Menophra sp.	1	0	0	0	0
Menophra subplagiata	17	0	1	0	0
Metrocampa haliaria	0	0	3	0	0
Miltochrista cuneonotatas	2	0	0	0	0
Miresa albipuncta	0	2	0	0	0
Mocis discios	4	0	0	0	0
Mustilia sphingiformis	0	0	0	8	0
Mythimna albicosta	4	0	0	0	0
Nacna malachitis	0	0	8	2	0
Neodrymonia sp.	2	0	0	0	0
Nomophila noctuella	18	2	0	0	0
Nordstromia duplicata	0	0	3	0	0
Ochropleura sp.	1	7	0	0	0
Ochropleura triangularis	0	0	3	5	20
Odontopera heydena	0	6	0	3	0
Odontopera kametaria	0	8	1	0	0
Odontopera lentiginosaria	0	0	5	19	4
Odontopera obliquaria	0	0	0	0	1
Odontopera sp.	5	3	5	3	5
Oligoclona chrysolopha	5	5	18	4	0
Omiodes noctesense	4	0	0	0	0
Ophthalmitis herbidaria	2	0	0	0	0
Opisthograptis sulphurea	0	0	3	7	23
Opisthograptis tridentifera	0	9	0	11	31
Oraesia emarginata	10	0	0	0	0

Oraesia indecisa	3	0	0	0	0
Oreta pavaca	0	0	10	1	0
Orthopygia igniflualis	9	0	0	0	0
Orybina flaviplaga	0	6	0	0	0
Ourapteryx convergens	0	0	1	1	0
Ourapteryx sciticaudaria	0	0	1	0	0
Ourapteryx sp. 1	0	0	0	1	0
Ourapteryx sp. 2	0	0	2	0	0
Panaxia principalis	0	2	0	3	0
Panaxia similis	5	1	24	2	0
Paralebeda plagifera	0	1	14	0	0
Parentephria stellata	0	0	0	0	18
Peratophyga hyalinata	6	4	0	0	0
Percnia belluaria	18	0	0	1	0
Percnia sp.	0	8	14	0	0
Perissandria sp.	0	3	0	15	24
Perizoma albofasciata	32	9	5	0	5
Perizoma seriata	34	0	13	18	9
Phalera grotei	4	0	0	0	0
Phalera sangana	0	9	0	0	0
Pheosia fasciata	0	2	0	0	0
Phlogophora sp.	0	0	0	1	0
Phlogophora subpurpurea	0	0	0	2	2
Photoscosia miniasota	0	30	14	14	17
Photoscotosia amplicata	0	0	6	17	83
Photoscotosia metachriseis	0	0	0	2	0
Photoscotosia multilinea	0	0	0	1	6
Photoscotosia sp.1	0	0	0	0	3
Photoscotosia sp.3	0	0	3	1	0
Photoscotosia sp.4	0	0	0	11	4
Photoscotosia sp.5	0	0	0	13	23
Photoscotosia sp.6	0	0	0	0	36
Phthonandria atrilineata	0	3	0	0	0
Pingasa subpurpurea	7	0	0	0	0
Plagodis inustaria	0	0	0	3	0
Plagodis reticulata	0	0	10	11	0
Pleuroptya balteata	3	0	3	0	0
Pleuroptya quadrimaculalis	5	2	26	3	0
Pleuroptya ruralis	8	0	11	0	0

Plusiopalpa dichora	9	0	0	2	0
Plusiopalpa sp.	1	0	0	0	0
Polia scotochlora	0	0	0	1	6
Polia sp.	3	0	0	0	0
Polia sp.2	2	0	0	0	0
Polygrammodes sabelialis	4	0	0	0	0
Prospalta leucospila	0	1	5	0	0
Pseudomiza cruentaria	4	0	0	0	0
Pseudopanthera himaleyica	0	2	42	0	0
Psilalcis inceptaria	25	27	13	9	0
Psilalcis sp.	4	0	0	0	0
Psyra angulifera	0	1	3	3	0
Psyra debilis	2	0	13	8	1
Psyra falcipennis	0	0	9	0	0
Psyra similaria	0	0	11	5	3
Pterophoridae sp.2	0	0	5	0	0
Ptilodon saturata	0	1	25	11	0
Pyral sp.1	0	0	0	0	1
Pyralidae sp.1	0	0	31	0	0
Pyralidae sp.2	0	0	1	7	0
Pyrrhia umbra	0	6	0	0	0
Rachia plumosa	0	0	22	38	11
Rheumaptera sp.	0	0	0	0	104
Rhodometra sacraria	0	0	0	4	0
Rhodostrophia pelloniaria	1	0	15	19	0
Rhopalopsyche nycteris	0	0	2	0	0
Risoba prominens	1	0	0	0	0
Sacada discinota	0	0	3	0	0
Saturniidae sp.1	0	0	0	0	3
Scopelodes venosa	3	4	0	0	0
Scopula pulchellata	9	0	0	0	0
Scopula sp.	6	0	12	3	0
Scopula sp.3	3	0	0	0	0
Scopula sp.4	6	0	0	0	0
Scopula sp.5	3	0	2	0	0
Scopula sp.6	8	0	0	0	0
Semidonta biloba	0	0	11	0	0
Semiothisa sufflata	10	0	0	0	0
Semiothisa triumbrata	0	0	3	0	0

Sidyma albifinis	0	0	29	21	1
*Sirinipteryx sp.*1	0	0	0	18	0
Sirinopteryx rufivinctata	0	17	0	0	0
*Sirinopteryx sp.*2	0	0	11	9	21
Somena scintillans	3	0	22	0	0
Spilosoma casigneta	16	0	4	0	0
Spilosoma erythrozonata	17	26	48	62	40
Spilosoma leopardina	0	6	24	98	0
Spilosoma melanostigma	0	0	9	13	0
Spilosoma obliqua	0	54	21	4	0
Spilosoma punctaria	18	0	32	0	0
Spilosoma sp.	0	0	13	31	1
Spilosoma strigatula	5	0	0	19	0
Spirama retorta	8	0	0	0	0
Spodoptera littoralis	27	0	0	0	0
Spoladea recurvalis	3	4	4	0	0
Stamnodes pamphilata	0	0	2	10	2
Syllepte verecunda	0	0	10	0	0
Syngamia alsidicalis	0	5	3	0	0
Tanaoctenia haliaria	0	0	11	14	0
Terastia egialialis	4	0	0	0	0
Tethea oberthueri	0	1	0	0	0
Thalassodes veraria	0	0	7	6	0
Thinopteryx crocoptera	1	0	0	0	0
Thyatira batis	0	0	2	0	0
Timandra ruptilinea	4	0	0	0	0
Totricia sp.1	5	0	0	0	0
Totricia sp.2	1	0	0	0	0
Trabala irrorata	7	0	0	0	0
Trichoridia hampsoni	0	0	0	5	3
Triphosa rubrodotata	3	0	6	2	31
Triphosa sp.	5	0	24	0	91
Utetheisa lotrix	0	3	0	0	0
Valeriodes heterocampa	0	0	0	8	32
Valeriodes sp.	0	0	0	12	12
Venusia classisign	0	0	0	11	30
Venusia roseicosta	0	0	0	7	10
Viidaleppia dentifasciata	4	0	11	0	6
Viidaleppia sp.	0	0	0	8	0

Xandrames latiferaria	2	11	0	0	0
Xanthorhoe hampsoni	0	0	0	2	0
Xestia bdelygma	0	0	0	35	66
Xestia sp	0	0	5	0	14
Zeheba sp.	2	0	0	0	0
Zeuzera multistrigata	0	2	0	0	0