Seasonal Occurrence and Altitudinal Distribution of Neuroptera (Insecta) in Uttarakhand, India

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Abstract

Temperature stratification at different altitude in different seasons has influence on hibernating and non-hibernating stages of Neuropterans depending on their developmental threshold temperature. This study is a comprehensive account of the seasonal occurrence and altitudinal distribution of Neuroptera associated with aphids of Uttarakhand, India. Their frequent association with aphids and carnivorous nature offers a better scope to the people for deploying some of these insects in biological control measures.A total of 26 species of Neuroptera were found to be associated with aphids. They are distributed under 4 families and 13 genera. The species diversity of the Chrysopidae family was highest. As Neuroptera are useful insects in the biological control of aphids, inferences from this type of investigation may prove to be beneficial in formulating integrated pest management (IPM) strategies.

Keywords: Neuroptera, seasonal occurrence altitudinal distribution, aphid predator, biological control

1. Introduction

The name Neuroptera is derived from the Greek word *"neuron"* meaning sinew and *"ptera"* meaning wings. The modern English translation "nerve-wings" is appropriate because it alludes to the extensive branching found in the wing veins of most Neuroptera. The order Neuroptera of Insecta comprises of the alder flies, ant lions, dobson flies, dusty wings, lacewings, owl flies and the snake flies. They are cosmopolitan in distribution and in general exhibit a carnivorous habit. The larvae of many species and the adults of a some species are predaceous on many insects like aphids, coccids and other soft-bodied insects.

Among the aphid predators the Neuropterans specially deserve attention as they are

predominantly predacious in habit and attack aphids. Their frequent association with aphids and carnivorous nature offers a better scope to the people for deploying some of these insects in biological control measures. They have the potential to be significant in reducing the number of aphids and establish themselves as a potential aphid predator in India.

Considering this beneficial aspect, study on aphidophagous Neuroptera is important. But for any predator to be considered as effective, preliminary study of its biosystematics, distribution and time of occurence is essential. Temperature stratification at different altitude in different seasons has influence on hibernating and non-hibernating stages of Neuropterans depending on their developmental threshold temperature. This investigation deals with the seasonal occurrence and altitudinal distribution Neuroptera species associated with aphids occurring in the Uttarakhand, India.

Aphids (Homoptera: Aphididae) are more or less cosmopolitan in distribution and are found abundance in temperate climate. They attack a wide variety of plants, both cultivated and wild and may feed on roots, stem, leaves, inflorescence, fruits and seeds. The larvae of many species of Neuroptera and adults of some species predate on aphids. Because of this, Neuroptera are often known as 'aphid lion'.

The Chrysopidae are one of the largest and economically most important families of the Neuroptera and are commonly known as lacewings. There are about 1,300 currently recognized species included in about 87 genera[1] in the world. Lacewings are delicate insects. They are characterized by a wide costal field in their wing venation, which includes the cross-veins. The bodies are usually bright green to greenish-brown, and the compound eyes are conspicuously golden in many species. The wings are usually translucent with a slight iridescence; some have green wing veins or a cloudy brownish wing pattern. The larvae are voracious predators of small, comparatively soft-bodied arthropods such as aphids, scale insects, whiteflies, thrips, insect eggs, and other prey[2]. For this reason they are used widely in biological control.

2. Area of Study

In the heart of South Asia is located the loftiest mountain chain on earth. The Himalaya, the youngest mountain in the world and yet the most awesome and the highest, literally means the 'Abode of Snow'. The Himalaya forms a distinct geographical divide that separates the Indian sub-continent from Central Asia, it extends from west to east in a massive arc of about 2500 kms. Covering an astounding area of 612,021 sq. kms. this vast mountain chain passes through the Indian States of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Uttar Pradesh, a small part of West Bengal, Sikkim and the Himalayan kingdoms of Nepal and Bhutan.

The Himalayas can be classified in a variety of ways. From south to north the mountains can be grouped into 3 major parallel, longitudinal mountain belts, each with its unique features and distinctive geological history. 1. Shivaliks (the Outer or the Sub- Himalayas) extending

from 300-1350 msl. 2. Himachal (the Lesser Himalayas or the Lower Himalayas) extending from 1350-4500 msl. 3. Himadri (the Greater or the Higher Himalayas) above 4500 msl.

Geographically, from east to west the Himalayas are divided into 1. The Eastern or the Assam Himalaya, 2. The Central or Nepal Himalaya, 3.The Kumaon-Garhwal or the Western Himalaya, 4.The North-West or the Punjab Himalaya (Mani, 1974, 1978).

Phytographically, India is divided into a number of divisions of which the Himalayan is one. The Himalayan division is further subdivided into Eastern, Central and Western Himalaya. Geographical Western (the Kumaon-Garhwal Himalaya) and North-West Himalaya (the Punjab Himalaya) fall under phytographical Western Himalaya.[3]

Based on international political boundaries, the Himalayas are divided into 1. Indian Himalaya 2. Nepalese Himalaya and 3. Tibetian Himalaya.

Here the Geographical Western Himalaya (the Kumaon-Garhwal) is selected as the area of study. The Western Himalaya extends between the river Kali in the east and the river Sutlej in the west. Politically the Western Himalaya include the Garhwal and Kumaon range of Uttarakhand, India. Geographically the Tons river separates the Garhwal from the state of Himachal Pradesh in the west. Starting from the foothills from the south, the region extends upto the snow clad peaks.

Garhwal is one of the two regions and administrative division of the Uttarakhand a mountainous state of northern India, the other being Kumaon. Lying in the Himalayas, it is bounded on the north by Tibet, on the east by Kumaon region, on the south by Uttar Pradesh state, and on the northwest by Himachal Pradesh state. It is the source of the two life giving rivers of the North *i.e.* Ganga and Yamuna. A variety of land forms like snow peaks, steep escarpments, deep gorges, valleys, glaciers, lakes, numerous gushing streams and swift cascading rivers and lush green meadows are found. The Garhwal range has some of the most challenging peaks eg. Banderpunch, Bhagirathi, Dunagiri, Nanda Devi, Neelkanth, Trishul and Shivling.

The Kumaon lies next to the Garhwal region. It is bordered on the east by the Mahakali river (or Kali or Kali Nanda) and the districts of Chamoli and Pauri Garhwal to the west. Tibet lies to the north and the Terai to the south. The Mahaka li river forms the Indo-Nepal border in the east. The Panchchuli Massif, the Gori, Pindari and the Sunderdunga valleys are found in the western part of the Kumaon.

3. Altitudinal Distribution of Insects

Altitude gradients exhibit strong abiotic variation over extremely short geo-graphical distances, and species at low or high altitudes experience drastically different abiotic environments. Insect species distributions are influenced by abiotic factors (e.g. rainfall, humidity and temperature), biotic (e.g. host plants, predators/parasitoids), and by their physiology.[4, 5] Hodkinson[6] in a review of terrestrial insects along elevational gradients, clearly shows that trends in species richness and abundance of individuals are variable, decreasing

with increasing altitude,[7, 8] increasing with increasing altitude,[9] peaking at middle elevation[10, 11, 12] or showing no altitudinal trend.[13] The literature on the response of insect species to the changing environments experienced along altitudinal gradients is diverse and widely dispersed. There is a growing awareness that such responses may serve as analogues for climate warming effects occurring at a particular fixed altitude or latitude over time.

4. Predator-prey Relationship

Extensive survey of the Eastern Himalaya have been made during the last decade to explore the aphid and the Neuropteran fauna.[14] In comparision the North-Western and Western Himalayan region have been less extensively investigated. Consequently the naturally enemy complex of aphids, particularly the Neuropterans have been less explored in the Western Himalaya than in the Eastern Himalaya. Publications pertaining to Western Himalayan region include Ghosh,[15] Debnath *et al*[16] Chakrabarti *et al*[17] and Dey and Bhattacharya.[18]

5. Material and Methods

Western Himalaya includes the Garhwal and Kumaon range of Uttarakhand, India. Collection of Neuroptera specimens were made at different locations of Western Himalaya, from different altitudes. The climatic condition of Western Himalaya is varied. It has a low annual rainfall (100-205 cm) with a considerable variation in outer and inner valleys; high temperature variation, both seasonal and diurnal; strong winds and heavy snowfall. Flucuation in humidity, altitudinal zonation, temperature stratification, wind and rainfall determine the flora and fauna of the area (Mani, 1978). This paper gives a comprehensive account of the altitudinal distribution and seasonal occurrence of lacewings associated with aphids in the Uttarakhand, India.

6. Result and Discussion

Members of the three families of the order Neuroptera viz. Chrysopidae (the green lacewings), Coniopterygidae (the dusty wings) and Hemerobiidae (the brown lacewings) are to remain closely associated with aphids and prey upon them. Members of another family, Dilaridae have also been found to feed on aphids in the study area. Three larval instars of all three families of Neuroptera (Chysopidae, Coniopterygidae, Hemerobiidae) are found to be active predators, as are some of the adults. Adults of Hemerobiidae are active predator of aphids. Adults of Chrysopidae feed on honeydew and pollen and sometimes on aphids (as seen in the gut con tent examination). They are generally collected to the vicinity of the aphids.

Table I gives a classified list of 26 species of Neuroptera belonging to the 4 aphidophagous families along with their aphid prey and aphid host plant in the Western Himalayan region. Of the 26 species majority belong to the family Chrysopidae (20 species under 10 genera) followed by Hemerobiidae (4 species under 2 genera). Coniopterygidae and Dilaridae each are represented by single species under single genus. These 26 Neuroptera species predate on 25 aphid pests which infest 24 plant species comprising of herbs, shrubs and trees. It is also found that most of these plants are of economic importance.

Altogether, these 26 species of Neuroptera fall under 13 genera. The species diversity of *Mallada* was the highest (7 species), followed by *Chrysoperla* (4 species) and *Micromus* (3

species). The genera *Nothochrysa, Retipenna, Italochrysa, Coniocompsa, Dilar and Hemerobius* contain single species each.

Table I also provides the list of aphid associated Neuroptera species with their altitudinal distribution and period of occurence in the Western Himalayan region. *Chrysoperla carnea* (Stephens) was found early in the year at Joshimath (1975 msl) during March and at Uttarkashi (1158 msl) during April. At higher altitudes viz. Lambagarh (2300 msl) and Chowrangikhal (2310 msl) the same species was found during the month of June and August respectively. *Micromus timidus* Hagen was found in the month of April from Chowrangikhal, situated at a height of 2310 msl. In places of comparatively lower altitude it was found as early as during the month of March from Bhatwari (1200 msl) and also as late as during October from Uttarkashi (1158 msl). *Retipenna jubingensis* (Hölzel) was found during the middle of the year from places of both lower and higher altitudes *viz.* from Joshimath (1975 msl) during June - September and from Lambagarh (2300 msl) during June-September. *Hemerobius indicus* Kimmins was found at Harsil (2620 msl) during the month of April whereas *Chrysopa septempunctata* Wesmael was found at Harsil in the month of August. In Uttarkashi (1158 msl) both *Micromus sp. A* and *Chrysoperla carnea* (Stephens) were found in the month of April. *Micromus sp. B* was found in Chowrangikhal (2310 msl) during April but *Chrysoperla carnea* (Stephens) was found in the same place during August. Exception to the above pattern of distribution were *Mallada murrensis* (Tjeder) found at Gongotri (3140 msl) in October, *Chrysoperla orestes* Banks found at Trijuginarayan (2215 msl) in April and *Mallada sp.* found at Gongotri (3140 msl) during October.

In the present study it was noted that in general the Hemerobiidae were prevalent during early summer at high altitude but Chrysopidae were scant. As summer progressed the number of chrysopids increased as the temperature was high enough for their development. Whereas in places of low altitude, where temperature was comparatively higher both the lacewings were found during early summer. So the distribution at different altitudes was dependent on the time of the year.

TABLE I. APHID ASSOCIATED NEUROPTERA SPECIES, THEIR PREY APHIDS, APHID HOST PLANTS WITH THEIR ALTITUDINAL DISTRIBUTION AND OCCURRENCE

Name of Neuroptera species	**Prey Aphid**	**Aphid Host Plant**	**Place of occurrence**	**Altitude**	**Time of occurence (month)**
Family : Chrysopidae					
Ankylopteryx octopunctata (Fabricius)	*Eriosoma ulmi* (Linnaeus)	*Ulmus sp*	Almora	1650 msl	May
C*hrysopa septempunctata* Wesmael	*Pemphigus mordvilkoi* (Cholodkovsky)	*Populus ciliata*	Chowrangikhal	2310 msl	June
	Chaitophorous kapuri Hille Ris Lambers	*Populus ciliata*	Harsil	2620 msl	August
Chrysoperla carnea (Stephens)	*Rhopalosiphum padi* (Linnaeus)	*Triticum aestivum*	Uttarkashi	1158 msl	April
	Betacallis sikkimensis Basu, Ghosh and RayChaudhuri	*Betula alnoides*	Chowrangikhal	2310 msl	August
	Capitophorus formosartemisiae (Takahashi)	*Artemisia vulgaris*	Joshimath	1975 msl	March July-August

Name of Neuroptera species	Prey Aphid	Aphid Host Plant	Place of occurrence	Altitude	Time of occurence (month)
Chrysoperla carnea (Stephens)	*Eriosoma lanigerum* (Hausmann)	*Pyrus malus*	Lambagarh	2300 msl	June
	Chaitophorus kapuri Hille Ris Lambers	*Populus ciliata*	Kalimath	1250 msl	July
	Macrosiphoniella kikungshana Takahashi	*Artemisia sp.*	Joshimath	1975 msl	March July-August
	Macrosiphoniella pseudoartemisiae Shinji	*Artemisia vulgaris*	Joshimath	1975 msl	March July-August
	Macrosiphum miscanthi Takahashi	*Triticum aestivum*	Uttarkashi	1158 msl	April
	Pemphigus siphunculatus Hille Ris Lambers	*Populus ciliata*	Kalimath	1250 msl	July
	Rhopalosiphum maidis (Fitch)	*Triticum aestivum*	Uttarkashi	1158 msl	April
Chrysoperla gujaratensis Ghosh	*Rhopalosiphum padi* (Linnaeus)	*Triticum vulgaris*	Rishikesh	356 msl	March

Name of Neuroptera species	**Prey Aphid**	**Aphid Host Plant**	**Place of occurrence**	**Altitude**	**Time of occurence (month)**
Chrysoperla gujaratensis Ghosh	*Myzus mumecola* (Matsumura)	*Prunus sp*	Lanka	2850 msl	May
Chrysopidia himalayana (Ghosh) *comb. nov.*	*Chromaphis hirsutustibis* Kumar and Lavigine	*Juglans regia*	Gobindghat	1829 msl	September
Cunctochrysa albolineata (Killington)	*Brevicoryne brassicae* (Linnaeus)	*Brassica campestris*	Bhatwari	1200 msl	April
	Rhopalosiphum padi (Linnaeus)	*Triticum vulgaris*	Joshimath	1975 msl	March July-August
Italochrysa sp **.**	*Greenidia (Paragreenidia) parthenocissi* Saha and Chakrabarti	*Perthenosisus semicondata*	Osla	2755 msl	June
Mallada alcestes (Banks)	*Betacallis sikkimensis* Basu, Ghosh and RayChaudhuri	*Betula alnoides*	Jangalchatti	3300 msl	August
Mallada boninensis (Okamoto)	*Greenidea (Trichosiphum) formosana* (Maki)	*Psidium guajava*	Kapkot	660 msl	August
Mallada sp. nov.	*Chaitophorous kapuri* Hille Ris Lambers	*Populus ciliata*	Dodital	3307 msl	March

Name of Neuroptera species *Mallada sp. nov.*	**Prey Aphid** *Macrosiphum miscanthi* Takahashi	**Aphid Host Plant** *Triticum aestivum*	**Place of occurrence** Ranikhet	**Altitude** 1830 msl	**Time of occurence (month)** August
Mallada garhwalensis (Ghosh) *comb. nov.*	*Lachnus sp.*	*Cedrus deodara*	Gongotri	3140 msl	October
Mallada kinnaurensis Ghosh	*Rhopalosiphum maidis* (Fitch)	*Triticum aestivum*	Barkot	1450 msl	March-April
Mallada murrensis (Tjeder)	*Lachnus sp*	*Cedrus deodara*	Gongotri	3140 msl	October
Mallada obvia Hölzel	*Rhopalosiphum maidis* (Fitch)	Wild grass	Joshimath	1975 msl	April
Nothochrysa indigena Needham	*Pemphigus mordvilkoi* (Cholodkovsky)	*Populus ciliata*	Sankri	1800 msl	September
Nothochrysa lefroyi Needham	*Pemphigus mordvilkoi* (Cholodkovsky)	*Populus ciliata*	Nainital	1940 msl	April
Retipenna dasyphlebia (McLachlan)	*Betacallis sikkimensis* Basu, Ghosh and RayChaudhuri	*Betula alnoides*	Khati	2210 msl	June
	Eumyzus pruni Chakrabarti and Bhattacharya	*Prunus cornuata*	Lanka	2850 msl	May

Name of Neuroptera species *Retipenna jubingensis* (Hölzel)	**Prey Aphid** *Aphis kuroswai* Takahashi	**Aphid Host Plant** *Artemisia vulgaris*	**Place of occurrence** Joshimath	**Altitude** 1975 msl	**Time of occurence (month)** June September
	Brevicoryne brassicae (Linnaeus)	*Brassica campestris*	Gobindghat	1829 msl	July
	Chaitophorus kapuri Hille Ris Lambers	*Populus ciliata*	Lambagarh	2300 msl	June-August
	Greenidia (Trichosiphum) formosana (Maki)	*Psidium guajava*	Kapkot	660 msl	August
	Mollitrichosiphum sp.	*Alnus nepalensis*	Almora	1650 msl	May
	Pmephigus mordvilkoi (Cholodkovsky)	*Populus ciliata*	Kalimath	1250 msl	July
Tumeochrysa indica Needham	*Chaitophorus kapuri* Hille Ris Lambers	*Populus ciliata*	Hanumanchatti	1870 ml	May

Name of Neuroptera	**Prey Aphid**	**Aphid Host**	**Place of occurrence**	**Altitude**	**Time of occurence**

species		**Plant**			**(month)**
Family : Coniopterygidae					
Coniocompsa indica Withycombe	*Chromaphis hirsutastibis* Kumar and Lavigine	*Berberis sp*	Harsil	2620 msl	September
Family: Dilaridae					
Dilar indicus Kimmins	*Prociphilus himalayensis* Chakrabarti	*Lonicera quinqulolocularis*	Harsil	2620 msl	April - May
	Eriosoma ulmi (Linnaeus)	*Ulmus sp.*	Harsil	2620 msl	April - May
Family: : Hemerobiidae					
Hemerobius indicus Kimmins	*Prociphilus himalayensis* Chakrabarti	*Lonicera sp*	Harsil	2620 msl	April
Micromus garhwalensis sp.nov .	*Rhopalosiphum padi* (Linnaeus)	*Triticum aestivum*	Gongotri	3140 msl	October
	Rhopalosiphum rufiabdominalis (Sasaki)	*Helianthus tuberosus*	Uttarkashi	1158 msl	April
Micromus himalayensis sp. nov	*Betacallis sikkimensis* Basu, Ghosh and RayChaudhuri	*Betula alnoides*	Chowrangikhal	2310 msl	April
Name of Neuroptera	**Prey Aphid**	**Aphid Host Plant**	**Place of occurrence**	**Altitude**	**Time of occurence (month)**

species *Micromus timidus* Hagen	*Lipaphis erysimi* (Kaltenbach)	*Raphanus sp.*	Bhatwari	1200 msl	March
	Aphis craccivora Koch	*Cajanus cajan* *Brassica campestris*	Kalimath	1250 msl	June
	Brevicoryne brassicae (Linnaeus)	*Brassica campestris*	Joshimath	1975 msl	June

7. Conclusion

Increasing altitude brings lower temperatures, increased precipitation (rain or snow), lower partial pressure of gases, higher wind speed and turbulence, and greater extremes in radiation input.[19] Combination of these factors may produce a general decrease in the structural complexity of insect habitats, as well as variation in the nutritional quality and availability of host plants. Phytophagous insects could well respond to these variations in host quality with changes in rates of growth, survival and fecundity (Hodkinson 2005). The manner in which these various factors individually and collectively influence the morphology, behaviour, eco-physiology, growth and development, survival, reproduction, and spatial distribution of insect species needs further in depth investigation. Adding data on the effect of temperature on larval consumption, adult fecundity, plant growth rate and data on migration patterns could help to build a predictive model of the dynamics of the biocontrol system in the altitudinal range. As Neuroptera are useful insects in the biological control of aphids, inferences from this type of investigation may prove to be beneficial in formulating integrated pest management (IPM) strategies.

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