



**Morphological Variations, Life History and Natural Enemies of
Gazalina chrysolopha (Lepidoptera: Notodontidae) in Gandaki Province**

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Nepal

A dissertation submitted

**In partial fulfillment of the requirements for the award of the degree
of Master of Science in Zoology with special paper Entomology**

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Declaration

I hereby declare that the work presented in this dissertation "**Morphological Variations, Life History and Natural Enemies of *Gazalina chrysolopha* (Lepidoptera: Notodontidae) in Gandaki Province.**" has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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This is to recommend that the dissertation entitled “**Morphological Variations, life history, and natural enemies of *Gazalina chrysolopha* (Lepidoptera: Notodontidae) in Gandaki Province**” has been carried out by Bhawana Pandey for the partial fulfillment of Master’s Degree of Science in Zoology with special paper Entomology. This is her original work and has been carried out under my supervision. To the best of my knowledge, this dissertation work has not been submitted for any other degree in any institutions.

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Certificate of acceptance

This dissertation work submitted by Bhawana Pandey entitled “**Morphological Variations, Life History and Natural Enemies of *Gazalina chrysolopha* (Lepidoptera: Notodontidae) in Gandaki Province**” has been accepted as a partial fulfilment for the requirements of Master’s Degree of Science in Zoology with special paper Entomology

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Abstract

This study provides a comprehensive exploration of *Gazalina chrysolopha*, a distinctive processionary moth belonging to the family Notodontidae. Characterized by two pairs of scaley wings with three wave like black lines, complemented by furry bodies displaying a distinct white colour. The research encompassed peripheral area of Pokhara valley including Baglung, Myagdi, Parbat, Kaski, Lamjung, Syangja, and Gorkha districts, with the goal of studying morphological variation, life history, and identifying the natural control for this species. The light trap method was applied, additionally hand collection method was also applied wherever necessary. Based on their morphological characteristics, the morphological differences between males and females were measured. The egg, larva, pupa, and adults of this species illustrated in detail with photograph and measurement. Female has long wings, body with wider body comparison to male. The duration of the egg stage is almost two months, and the larval stage progressively lengthens from the first to the fifth instar which is about 174 days long period. The cocoon stage is about 1–2 month long period. *Carcelia spp.* (family Tachinidae) and *Pimpla spp.* (Family: Ichneumonidae subfamily: Pimplinae) are found as the parasitoids of larva and pupa respectively. Bats and wall lizard (*Hemidactylus flaviviridis*) are found as predator for adults in this study. These insights contribute to a deeper understanding of the life history *Gazalina chrysolopha*, offering valuable information for management efforts in the studied area.

शोध सार

यस अध्ययनले *Gazalina chrysolopha* को एक विस्तृत अन्वेषण प्रदान गर्दछ, एक प्रोसेसनरी कीरा, जो Notodontidae परिवारसँग सम्बन्धित छ। जसको दुई जोडी सेतो पखेटा पाल जस्तोआकारमा रहेको हुन्छ जसले पेट लाई धाकेको हुन्छ। अगाडीको पखेटामा तिन वटा तरंग जस्तो रेखा र अन्तिम तरंग बाट ठाडा नसाहरु निस्किएको हुन्छ। मोर्फोलोजिकल भिन्नता, जीवन कथा अध्ययन गर्ने र यस प्रजातिको प्राकृतिक नियन्त्रण पत्ता लगाउने उद्देश्यका साथ, लक्ष्यका साथ पोखरा उपत्यकाको वरपर बाग्लुङ, म्याग्दी, पर्वत, कास्की, लमजुङ, स्याङ्जा र गोरखा जिल्लामा यो अध्ययन गरेको हो। यस अध्ययन को लागि विशेष गरेर लाइट ट्र्याप विधि प्रयोग गरिएको थियो। यसका साथै हातको मदतले डाटा संकलन गरियो। तिनीहरूको रूपात्मक विशेषताहरूको आधारमा, भाले र पोथी बिचको रूपात्मक भिन्नताहरू मापन गरियो। यस प्रजातिका अन्डा, लार्भा, प्युपा र वयस्कहरूलाई फोटो र मापनको साथ विस्तृत रूपमा व्याख्या गरिएको छ। पोथीको लामा पखेटा हुन्छ, भालेको तुलनामा फराकिलो र लामो शरीर भएको हुन्छ। अन्डा अवस्थाको अवधि लगभग दुई महिना हुन्छ, र लार्भा अवस्था क्रमशः पहिलोदेखि पाँचौं इन्स्टारसम्म लामो हुन्छ जुन लगभग 174 दिन लामो अवधि हो। कोकुन चरण लगभग 1–2 महिना लामो अवधि हो। *Carcelia spp* (family; Tachinidae) र *Pimpla spp.* (family; Ichneumonidae subfamily: Pimplinae) क्रमशः लार्भा र प्युपाको परजीवीको रूपमा पाइएको उक्त अध्ययनमा चमेरा र भित्ता छेपारो (हेमिडाक्टाइलस फ्लाभिभिरिडिस) वयस्कका सिकारीको रूपमा पाइयो। यी अन्तर्दृष्टिहरूले उक्त मथको जीवन कथा अध्ययनमा योगदान पुऱ्याउँछ, अध्ययन गरिएको क्षेत्रमा उक्त मथको व्यवस्थापन प्रयासहरूको लागि बहुमूल्य जानकारी प्रदान गर्दछ।

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INTRODUCTION

1.1 Background

Lepidoptera includes butterflies and moths, about 180,000 species of Lepidoptera belongs to 126 families (Capinera, 2008) and 46 superfamilies (Mallet, 2007). In the context of Nepal, 3958 species of moths were reported (GoN/MoFSC, 2014). Many species of Moth are identified as potential pest for many crops while others are important pollinators for many agricultural as well as wild flowering plants. Some species of moths have medical and veterinary importance and plays significant role for causing many diseases in human and animals (Dar & Jamal, 2021; Hahn et al., 2015; Van Zandt et al., 2020; Wonderlin, 2023). The genus *Gazalina* (Walker 1865) of Notodontidae family has typically long and rather slender abdomen as their wings particularly the forewings. Usually, the body and legs are densely covered in long white hair, giving the entire insect a bushy look. The wing scale is frequently rough and the pattern is never very clearly defined (Holloway et al., 1983). Out of four, three species of *Gazalina* are reported from Nepal, they are *Gazalina transversa* (Moore, 1859), *Gazalina chrysolopha* (Kollar, 1844) and *Gazalina apsara* (Moore, 1875) (Haruta, 1992, 1993). Firstly, *G. chrysolopha* was reported from Kasmir (Kollar, 1844) and in Nepal, it was collected by Haruta (1993) in Godawari area of Kathmandu valley (1,600 m asl). *G. chrysolopha* is similar to other species of *Gazalina*, it has three black transverse lines on the white forewing. This species is also reported from other parts of Hindu kush Himalaya such as Bhutan (Raman, 1999), India (Kollar & Redtenbacher, 1840), Pakistan (Rahman & Chaudhry, 1992), and China (Blanford et al., 1896). *Gazalina* moths are processionary in nature and carry urticating setae, which cause severe health problems in humans and other many warm-blooded animals (Battisti et al., 2017). The setae of this moth seen damaging the eyes in some cases (Goulet et al., 2006). Nepal facing serious eyes problem by the setae of adult as well as larvae of this moth. The most prevalent cause of panuveitis in Nepal is believe to be a Seasonal Hyperacute Pan-uveitis (SHAPU). It is one of the most prevalent cause of panuvetis in Nepal has been identified as the mysterious eye condition (Manandhar, 2011). Which is firstly reported in 1975 from Nepal (Upadhyay and Shrestha, 2017). This disease mostly affects children, is nearly always unilateral, and causes fast visual loss (Gurung et al., 2021; Upadhyay et al., 2018; Upadhyay & Shrestha, 2017). This moth as

a risk factor for SHAPU has been established in a 2017 case control study on risk factors of SHAPU (Upadhyay et al., 2020).

Similar to the other moths, this species also has a life cycle consisting four stages: egg, larva (larvae), pupa (cocoon), and adults (Rahman & Chaudhry, 1994; Rahman & Chaudry, 1994; Srivastava, 2003). Its life cycle is long, that is one generation per year (Raman, 1999). The Larvae of *Gazalina chrysolopha* is the major defoliator of the *Anlus nepalensis*, *Quercus dilatata*, *Quercus lamellosa* (Raman, 1999; Srivastava, 2003). Fourth and fifth instar of its larvae are voracious (Srivastava, 2003). The monsoon season is regarded as the ideal time for their biological cycle to be completed (Gurung et al., 2021). Its outbreak usually seen in post monsoon time in Nepal (Gurung et al., 2021).

According to Schmitz and Suttle (2001), indirect interaction between species play a significant role in determining the composition and operation of communities (Werner & Peacor, 2003). The natural enemies of many phytophagous insects influence their populations immensely (Price et al., 1980; Wallner, 1987). The Eupelmidae family reported as the egg's parasitoids and the Tachinidae family is most common parasitoid family of larvae and pupae of processionary moths (Plamen & Tsankov, 2015). A detailed study of life history and Natural control of *Gazalina chrysolopha species* in Nepal is highly essential due to the rapidly increasing trend of SHAPU disease.

1.2 Statement of Problem

The *G. chrysolopha* has been thoroughly studied in India, but there is significant gap in research within Nepal. This lack of study results in insufficient knowledge about the morphological variations, life history, and natural enemies of *G. chrysolopha* in this region as well as globally. Without detailed morphological studies, it is difficult to accurately identify this species which hampers effort to understand actual etiology of SHAPU is this species or not. Moreover, the absence of research on their life history prevents a clear understanding of their developmental stages and population dynamics. Additionally, knowing the natural enemies of *G. chrysolopha* is crucial for developing management strategies, and this information is currently lacking.

1.3 Objectives

1.3.1 General objectives

The general objectives of this study is to describe the morphological variations, life history and natural enemies of *Gazalina chrysolopha*.

1.3.2 Specific objectives

The specific objectives of this study are as follows:

- To describe the morphological variations *G. chrysolopha*.
- To study the life history of *G. chrysolopha*.
- To invent the natural enemies of *G.chrysolopha* moth.

1.4 Research questions

Following research question solved at this study.

- a) What is the life history of *G. chrysolopha*?
- b) What are the bio-control agent of population of *G. chrysolopha*?

1.5 Significance of this study

This study is significant to fill crucial knowledge gaps about the *G. chrysolopha* in Nepal, which has been under-researched compared to neighboring country like India, Bhutan, and Pakistan. By examining the morphology, life history, and natural enemies of *Gazalina* species, this research is enhance taxonomic understanding, enabling accurate identification and providing essential ecological insights into their population dynamics and interactions within ecosystems. Additionally, the study is informed effective pest management strategies by identifying natural predators and parasitoids of *Gazalina*, crucial for sustainable agricultural practices. Furthermore, documenting the biodiversity and ecological roles of these species will support conservation efforts, emphasizing the importance of preserving their natural habitats. Overall, this research will contribute valuable data to the global scientific community, establishing a foundation for future studies and practical applications in ecological research, identification of this species and natural bio-control of this species in Nepal.

1.6 Limitation of this study

During the research period, the following limitations were encountered:

- Life cycle of this moth is so long, unable to do multiyear research because of the time frame of thesis dissertation.
- Limited references.
- Unavailability specific resources for sampling like pheromone trap.

2. Literature review

Moths are a diverse group of insects that belong to the order Lepidoptera, which also includes butterflies. They can be found in a wide range of habitats worldwide, except in extremely cold or high-altitude environments. Moths are highly adaptable and can thrive in various ecosystems, including forests, grasslands, deserts, and urban areas.

2.1 *Gazalina chrysolopha*

Genus *Gazalina* was first discovered in the Liparidae, which is now known as the Lymantridae. Grunbrerg 1912 moved it to the Notodontidae. Kiriakoff 1968 moved it to the Thaumetopoeidae in Wytzman, Genera insect (Fletcher et al., 1980). Four species of *Gazalina* were reported from all over the world. They are *G. chrysolopha*, *G. apsara*, *G. transversa*, *G. intermixata* (Swinhoe, 1922). *Gazalina chrysolopha* first described as *Liparis chrysolopha* in 1844 by Kollar from Kashmir by following character “Snowy wings; the outer edge of the former is veined with black; the thorax and abdomen of female with a golden beard; head and abdomen black ring this White. The head and the first pair of feet black; the antennae of the male are combed yellow. Abdomen black with white rings, particularly noticeable in females.” *Dasychira antica*, Walker (1855) is a senior subjective synonym. In which he listed following characters “Male. White; Head in front and palpi black; Antenna brown; Thorax with a pale luteous band in front. Abdomen above with a black band on the fore border of each segment, not extending beyond the hind wings. Fore legs mostly black. Forewings with three slender oblique slightly undulating brown bands; first very near the base; second at one-third of the length; third about the middle. Length of the body 6 lines; of the wings 16 lines (Butler et al., 1881).” and *Oligoclona chordigera*, Felder (1874) is a junior subjective synonym, he published pictorial article (Swinhoe, 1889). Henry (1899) was first reported of (3♀,5♂) *G.chrysolopha* in western and central china (Changyang, Wa-shan, Pu-tsu-fong, Kweichow) collected in July and August. In Nepal, Haruta (1992) firstly reported the *Gazalina chrysolopha* from the Godawari Lalitpur(4♀,8♂). He describe the genaitalia of *Gazalina chrysolopha* flying in April to October.

Type species

Liparis chrysolopha Kollar (1844), type locality: Kashmir

Dasychira antica, Walker (1855), type locality: North India

Oligoclona chordigera, Felder (1874), type locality: Sikkim

2.3 Life History

Packard (1893) study in entomology, specifically focusing on the life history of the Notodontidae family. This study, which highlighted that most Notodontidae species have five larval stage after egg deposition and before pupation. He describes about the developmental stage. Similarly, the combination of morphological and molecular analyses used in this study offers a robust framework for understanding the diversity and evolutionary history of these taxa (Miller et al., 1997). Choosing an appropriate sites for egg-laying is crucial for the successful development of offspring in phytophagous insects (Renwick, 1989). Positive correlation should be occur between the selection of oviposition sites and the performance of offspring (Holland et al., 2004) so in moths, they typically lay their eggs on or near suitable host plants for their larvae to feed on upon hatching (Renwick & Chew, 1994). Rahman & Chaudhry (1992) study on the life cycle of *Gazalina chrysolopha* on oak tree in Pakistan, they reported its caterpillars as serious defoliators which have nocturnal and processionary behavior and its life cycle is annual. Similarly Srivastava (2003) conducted an important study on the life history of processionary moths, specifically highlighting their impact on *Alnus nepalensis*. The study reported that the larvae of these moths are significant pests for *A. nepalensis*, with a life cycle that averages around 265 days including egg, larva, and pupae stages have typical duration of 60.5, 165.5, and 35.5 days. This extended life cycle includes several larval instars, during which the larvae feed voraciously on the foliage of their host plants specially *Alnus nepalensis*.

Alnus nepalensis, common name Himalayan alder, also called Nepalese alder. *Alnus nepalensis* belongs to the Betulaceae family, which is in the Fagales order. It grows at elevations ranging from 700 to 3600 meters (Xia et al., 2023). It regenerates spontaneously on landslide-affected sites that have been freshly exposed and degraded. It is a fast-growing plant that is commonly employed in the restoration of damaged habitats in the eastern and central Himalaya (Sharma et al., 1998). It plays an important role to regulate the Himalaya ecosystem as predominant producer but Pest of it i.e. larva of *G. chrysolopha* destroy it's leaf and disturbance in ecosystem. Being the defoliator, it feed on all the leaf of this plant and reduce the carbon fixation by 9.56% (Ranabhat et al., 2008).

2.4 Natural enemy of *Gazalina chrysolopha*:

Prince et al. (1980) discuss how the abundance and diversity of natural enemies can be affected by the host plants, which in turn impacts herbivore populations. Brown & Cameron (1982) worked on the natural enemies of egg of moth and they mention egg parasite and hyperparasites span across six different hymenopterous families, indicating a diverse range of biological controls targeting this pest. Additionally, egg predators belong to thirteen families within five arthropod orders, showcasing a broad spectrum of predatory species that naturally regulate moth populations. Vertebrate predators, including both birds and mammals, further contribute to this natural control, encompassing six birds and three mammal families. In Europe and North Africa, over seventy arthropod species have been observed as natural enemies whereas 20% are predators (specifically family Miridae) and 80% are parasitoids (specifically family Eulophidae and Braconidae) in moth (Zappala et al., 2013). Eulophidae, Braconidae and additionally Ichneumonidae family of Hymenoptera reported as natural enemy of moth (Furlong et al., 2004). Plamen and Tsankov (2015) compiled an extensive list of parasitoids and predators that target Processionary moth specifically *Thaumetopoea* spp., contributing significantly to the biological control of these pests. The checklist includes various species of parasitoid wasps and flies, as well as predatory insects and birds. These natural enemies play a critical role in regulating Processionary moth population by parasitizing eggs, larvae, and pupae or preying on larvae and adults. In his finding, seven families (dominantly Tachinidae) of two order reported as the parasitoids of larvae and pupae of processionary moth and family Asilidae of Diptera recorded as adults predators. De Boer & Harvey (2020) reported birds and bats are the predator of processionary moth as well as genus *Carcelia* (Diptera) and *Pimpla* (Hymenoptera) mention as the biocontrol agent of processionary moth. In the context of *Gazalina chrysolopha*, For the Natural control of defoliator, there is some parasitoids of larval and pupal (Raman, 1998). Srivastav (2003) discovered that tachinid flies (Diptera) are the larval parasitoids and lacewings and ants (*crematogaster* spp.) are the natural enemies of egg of *Gazalina chrysolopha*.

This moth is exclusively distributed in South Asian countries, therefore limited research was done. There is a study gap in terms of morphological variations, life history, and natural enemies. Furthermore SHAPU has only been documented from Nepal whereas *G.*

chrysolopha is the suspected causative agent. There is the need of detailed study about this species.

3. Materials and Methods

3.1 Study area

The study were carried out in seven districts of the Gandaki province that is Kaski, Lamjung, Gorkha, Parbat, Myagdi, Baglung, Syangja in western region of Nepal. Which falls between 27.7955° N to 28.75157° N latitudes and 82.87511° E to 85.19783° E longitudes. The altitudinal variance range from 525 m to 8163 m asl. There are four distinct climatic types in study area, ranging from subtropical to alpine.

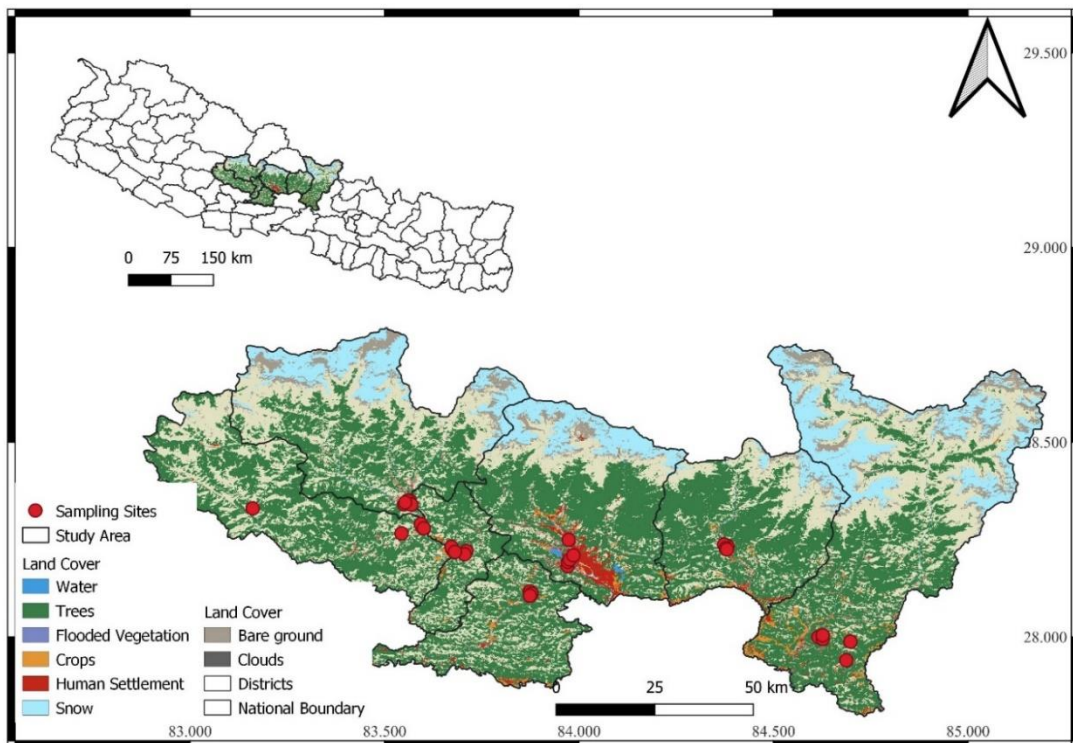


Figure 1: Map of study area

3.2 Materials

The materials employed during data collecting were,

Light Traps

Sweeping Net

GPS Machine (Garmin eTrex R 10)

Ethyl Acetate

Killing Jar

Moth Collection Envelops

Forceps

Field Stationary

Plastic

Entomological box

Safety kit (Mask, Apron, Gloves, Glasses)

Verniercalliper

3.3 Field design

Based on the local information, literature review and previous medical records about SHAPU outbreak in Gandaki Province and its adjacent districts, sampling sites (Villages and Municipalities) for the moth collection was ascertained. Altogether, 35 points were identified within seven districts, where moths were collected. Moths were collected in different methods in selected sites of these seven districts. Precaution were used during the sample collection.

3.4 Sample collection

The sample collection was done in August to December of 2023. During this time, adults and larvae were collected. Light trap were used for collection of moths. 15Watt LED light and white cloths were used during sample collection. Light trap were run from 7-10pm at night. Around the light trap, we employed a sweeping net for collection of moths. For inside-house collection, the direct handpicking approach was applied. For the larval collection, extensively search around the sampling site where light trap was established. The fresh, recently hatched first-instar larvae were collected using forceps from the bark of *Alnus nepalensis* and placed it in a vial with host plant leaves to ensure its immediate environment mimicked its natural habitat. These larvae were then brought to the laboratory, where they were reared at room temperature to provide natural conditions. During the sample collection ecological data such as GPS coordinates of each sampling site were obtained by GPS device (etrex 10 GARMIN), Location, host plant also recorded.



Figure 2: Light trap

3.5 Preservation and Identification

Moths were collected using the a fore mentioned techniques, placed in an ethyl acetate killing jar, and covered with paper envelop for dry preservation. The date and location of collection were then marked on the specimen's envelop that had been gathered. A plastic container held the specimen envelope. Similarly some larvae is collected in alcohol vial for morphological study of these larvae.

Collected specimens were brought to Entomology Laboratory of Central Department of Zoology, Tribhuvan University, Kirtipur. Single species were collected and sorted districts wise. Some specimens were speared with the help of spreader. The collected specimen were examined under BS-3020B (10*4.5) binocular stereoscope. Specimens were identified by using key (Haruta, 1992; Dombroskie, 2011) and online database such as Moth of India (Sondhi at el., 2024). For the identification of natural enemies, dichotomous taxonomic key were used. Order, family by Borror and Delong (1970), subfamily and genus by (Broad, 2011; Crosskey, 1984; Shaw, 2006) . Reference specimens of moths pinned with entomological pins in entomological box. The Moths were deposited in the Central Department of Zoology Museum of Tribhuvan University (CDZMTU), Kirtipur, Nepal.

3.6 Rearing of Larvae

Freshly collected first-instar larvae were reared in the laboratory at room temperature from the month of November to February. Larvae were kept inside the glass jar. The opening of jar is covered by paper with small holes to pass the adequate oxygen inside the

jar. For feeding, their primary host plant that is *Alnus* leaves provided them as natural food source, to ensure proper growth and development. 3-4 fresh leaves were kept inside the jar in alternative day and removed frass and remaining leaves. During the development of larvae, larvae go through multiple stages of development called instars, and molting is a crucial part of this process, it is marked by the shedding of their body cover, symbolizing the transition to the next instar, each instar representing a distinct developmental stage. Allowing them to grow and adapt to their changing size. During rearing period the average room temperature and humidity were 14.1⁰C and 46 %. Then, different life stages were studied.



Figure 3: Rearing of larvae of *G. chrysolopha* in laboratory.

3.7 Data Analysis

Taxonomic comparison was done on the basis of before published article. The body measurement is done by the help of digital verniercalliper. Data were manage in MS-Excel and analyzed wisely. Similarly Qgis were used for mapping.

4. Results

Altogether 238 (♀= 165 ♂=79) adult specimens were collected from the 35 different sites of the seven districts. The collected adult samples are dominantly a single species. Which are Medium-sized stout, hairy moths, forewing sometimes with prominent scale tuft in middle of inner margin, often boldly patterned with black and white. At rest, wings are held tent-like over the body so they belongs to Notodontidae family. Thorax and head covered with erect hairs. Palpi covered with usually soft hair, elongated, and inclining slightly downward. The antennae are usually thread-like in females and bipectinate in males. Abdomen somewhat tumid and covered with down or fine soft hair at the tip, extending a little beyond the hind wings. Legs rather short and slender; femora and tibia very broadly fringed; spurs very short. Wings elongate, moderately broad. Fore wings rounded at the tips; outer border slightly convex, very oblique. So these specimens belongs to Genus *Gazalina*. Four species belongs to this Genus.

Table 1: Species of genus *Gazalina* with their character

Species	Color	Abdomen	Main differentiation
<i>G. intermixa</i>	White wings	narrow blackish segmental bands.	Forewings with two medial, oblique, thick, black transverse lines, the outer one outwardly elbowed beyond the cell.
<i>G. apsara</i>	White wings	Abdomen with narrow blackish segmental bands.	Forewing with the veins yellowish basally, and brownish apically.
<i>G. transversa</i>	White wings	Abdomen with narrow blackish segmental bands.	Forewing with two transverse medial narrow black bands, the first short and inwardly oblique.
<i>G. chrysolopha</i>	White wings	Abdomen with narrow blackish segmental bands.	Three transverse medial line on the forewing. Horizontal lines arise from the last transverse line.

On the basis of above table, the collected specimens are morphologically similar to the *G.chrysolopha*.

4.1 Morphological variations

Among the 238 (♀= 165 ♂=79) adult specimens, morphological variations were recorded in male and female.

4.1.1 Male

Male moths are white colour, with a white head with yellow tuft and thorax, black legs, a brown antenna shaft, extremely small palpi, bi-pectinate antennae with long setae (Figure 5 (a)), and a black abdomen with white fringed segments. White wing with black veins. The forewing has three black transverse medial lines bolder.

4.1.2 Female

Females are identical to males, but with a less fringed abdominal segment, a larger fulvous anal tuft, and barbed setae in the tuft (Figure 5.d). Females' segmental white fringes on the abdomen are narrower. The female released setae of anal tuft over the eggs for the protection of eggs. Which were easily spread by the wind.

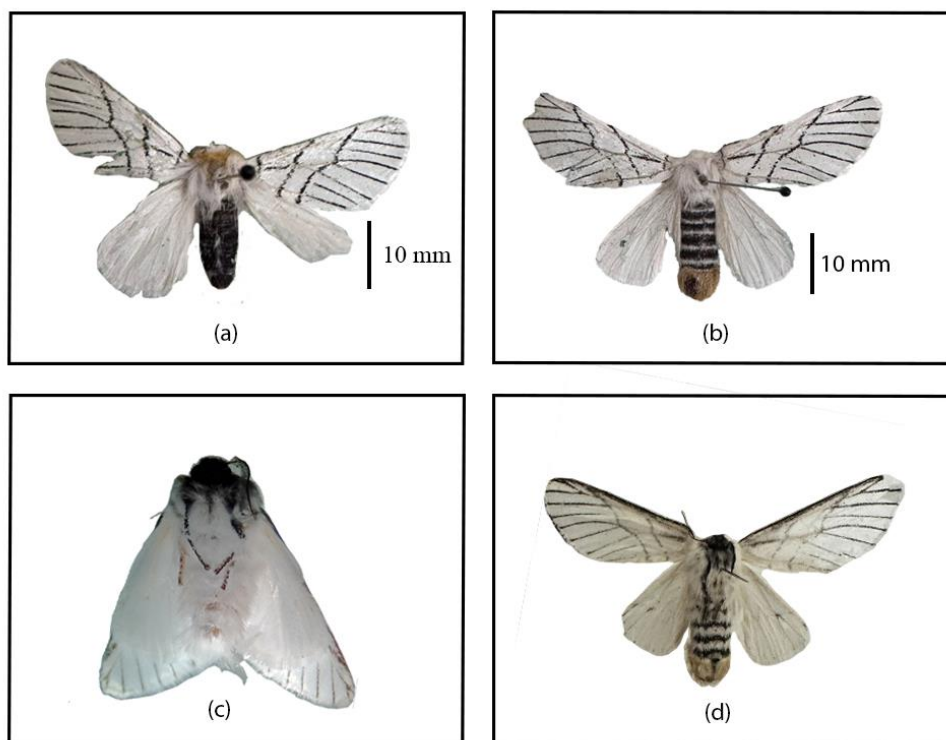


Figure 4: *Gazalina chrysolopha*; (a) Male; Dorsal view, (c) Ventral view (b) and (d) Dorsal and Ventral view of Female

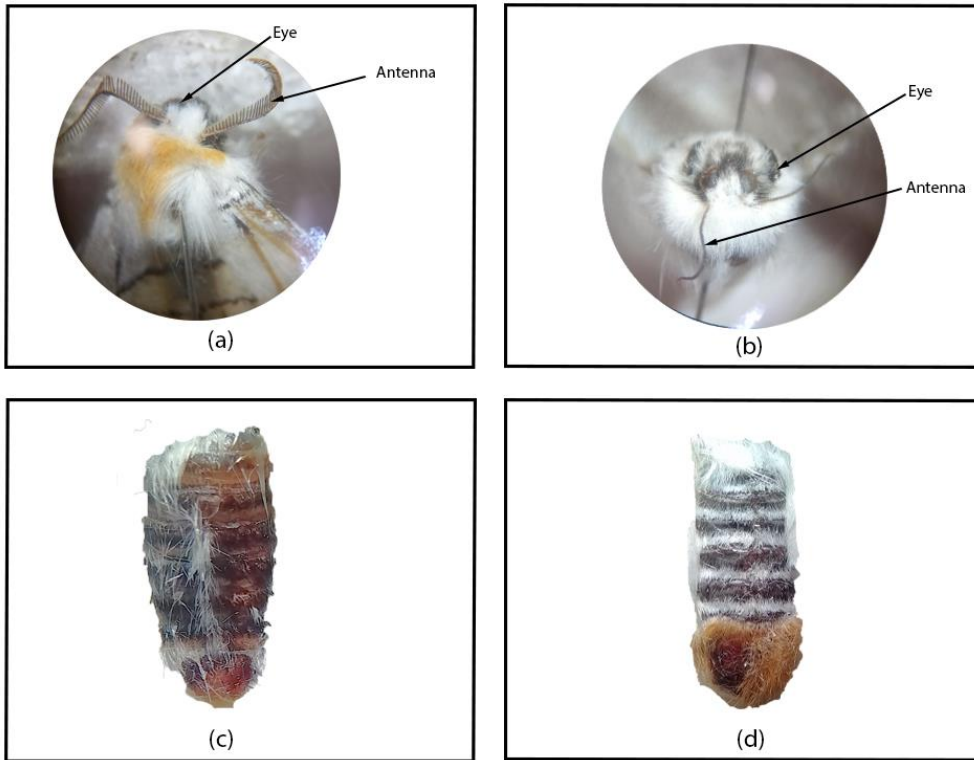


Figure 5: *Gazalina chrysolopha*; Male (a) Head (c) Abdomen; Female (b) Head and (d) Abdomen

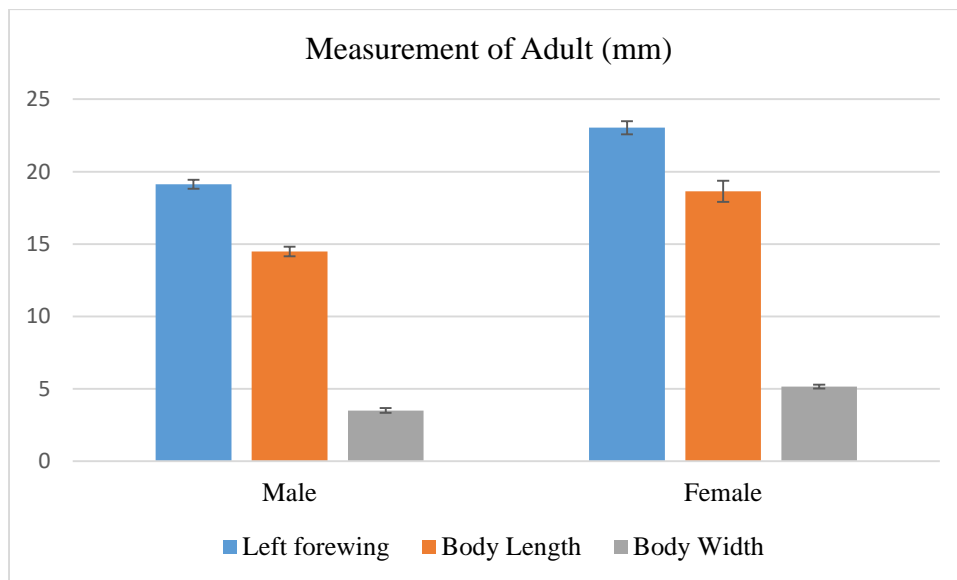


Figure 6: Measurement of adults (mean of 10 random sample)

The Maximum length of forewing of female is 23mm and body length is 18mm and abdominal width is 5.6mm whereas the size of female is greater than male which is shown in above graph.

4.1.3 Location of Specimens

Baglung (Kathekhola 28.26539° N 83.5436°E 1♀1♂, Upallachaur 28.2787°N 83.6009°E 121♀, Dhorpatan-1 28.3298°N 83.161°E 13♀18♂), collected by Pandey, B. Myagdi (Beni-8 28.3507°N 83.564°E 7♀, Kaulegauda 28.345°N 83.553°E 6♀9♂, Khapra 28.3395°N 83.569°E 5♀2♂, Arthung 28.345°N 83.553°E 9♀4♂, Beni-4 28.34°N 83.55°E 5♀) collected by Pandey, B., Parbat (Kusma 28.212°N 83.706°E 4♀, 28.224°N 83.674°E 16♀2♂, 28.2205°N 83.7105°E 3♀, 28.218°N 83.681°E 8♀1♂) collected by Pandey, B. and Pathak, P., Kaski (Pokhara 28.18164°N 83.97073°E 2♀6♂, 28.19831°N 83.97073°E 8♀42♂, 28.248894°N 83.97337°E 2♀) collected by Pathak, P., Syangja (Putalibazar 28.10558°N 83.87364°E 5♀2♂, 28.8742°N 88.8742°E 4♀) collected by Pathak, P., Lamjung (Beshisahar 28.2243°N 84.38015°E 3♀16♂, 28.23306°N 84.3823°E 3♀7♂) collected by Pathak, P. and Bhusal, D., Gorkha (Haramtar 27.993914°N 84.627054°E 5♀3♂, Kholkhole 27.9876°N 84.6872°E 7♀5♂, Sahid lakhan 27.9395°N 84.6872°E 1♀6♂, Durbar 28.0038°N 84.6265°E 1♀2♂, 27.999°N 84.6152°E 3♀) collected by Pandey, B. and Pathak, P..

4.2 Life History of *Gazalina chrysolopha*

Initially, adult specimens and their eggs were collected. After allowing sufficient time for the larvae to develop, we revisited the field to collect them. The larvae were then transported to the lab, where they were kept at a room temperature to ensure proper rearing conditions. Moths are holometabolous so they completed their life cycle in four stages that is egg, larval, pupae, and adults.

4.2.1 Egg

Female *Gazalina chrysolopha* laid eggs on cluster (Figure 7). After 3-5 days of emergence (after copulation). Brown with a little center dip on the top. Egg has almost 0.7mm in diameter. The number of eggs in one cluster are 160-250. The egg mass is coated in brown hair that resembles the scales and setae from the female body. The *G. chrysolopha* does not have a distinct oviposition location. They placed eggs primarily on the dorsal side of the host plant's leaf, *Alnus nepalensis*, but they can lay eggs anywhere near a light source, as indicated in the (Figure 8).

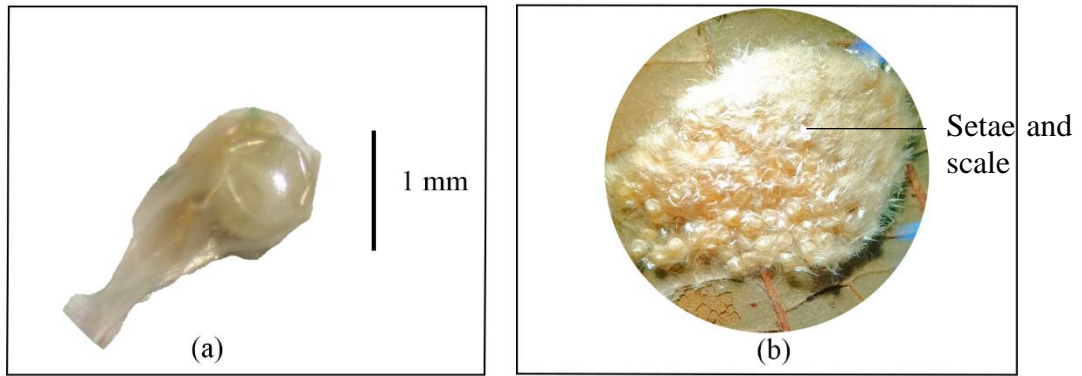


Figure 7: a) single egg and, b) cluster of the egg

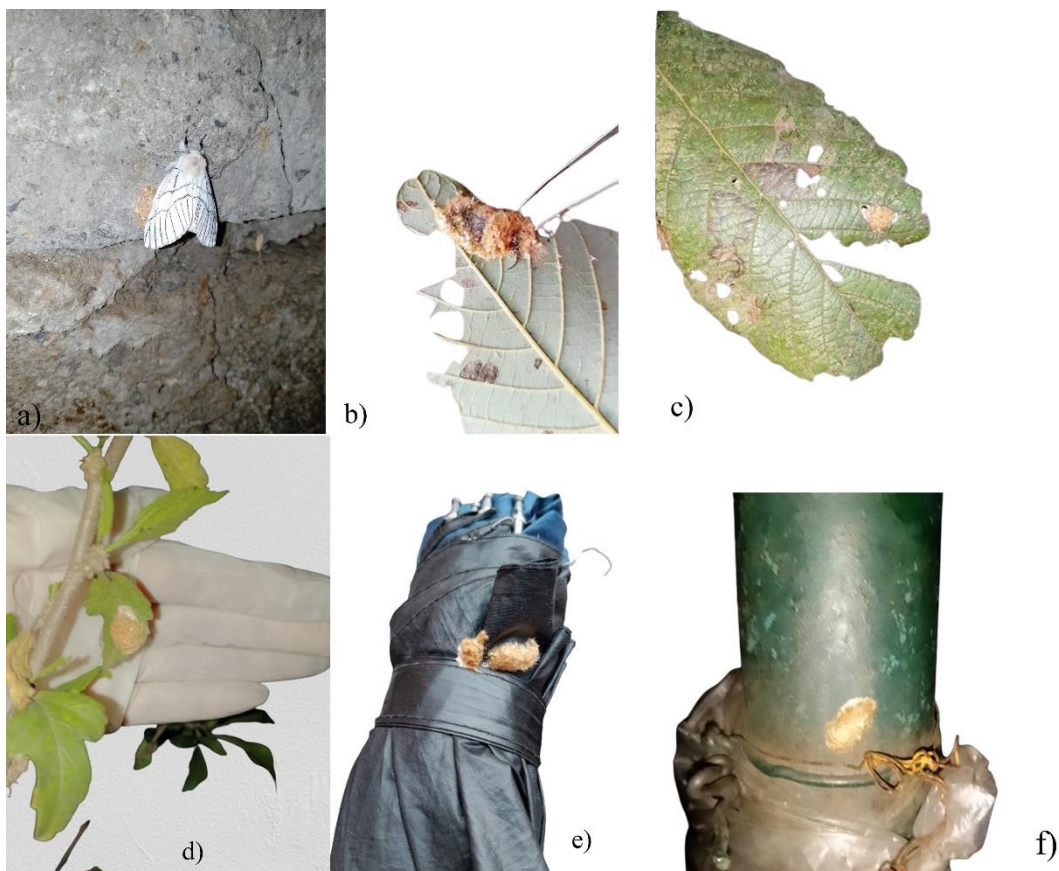


Figure 8: Egg deposition on different objects

4.2.2 Larvae

Gazalina chrysolopha larvae have been found on their primary host plant *Alnus nepalensis*. Egg deposition were observed on dorsal surface of *Alnus* leaves. After two months, the larvae of this moth found on the same plant where egg deposition had been noted. Almost all the egg hatched found in host plant and turning into larvae. The newly hatched larvae were taken into the laboratory, where they were fed *Alnus* leaves and

reared them. As well as observed larvae in natural habitat. *G. chrysolopha* larvae have five instars. Like adults, they exhibit nocturnal habits, feeding at night and resting throughout the day. They are spending daytime resting at the ground level of the host plant. One by one, they proceeded in a trail and made their mark on the host plant's bark by secreting white silk as they went. The first and second instar feed solely on *Alnus nepalensis*, whereas the third, fourth, and fifth instar feed on secondary host plants as well.

First Instar

First instar larvae whitish color during emerge, turning into dark brown color; small in size; less developed setae, number of setae is also very thin; legs and prolegs are white in color. From the first instar they shows processionary behavior. Less mortality occur in first instar.

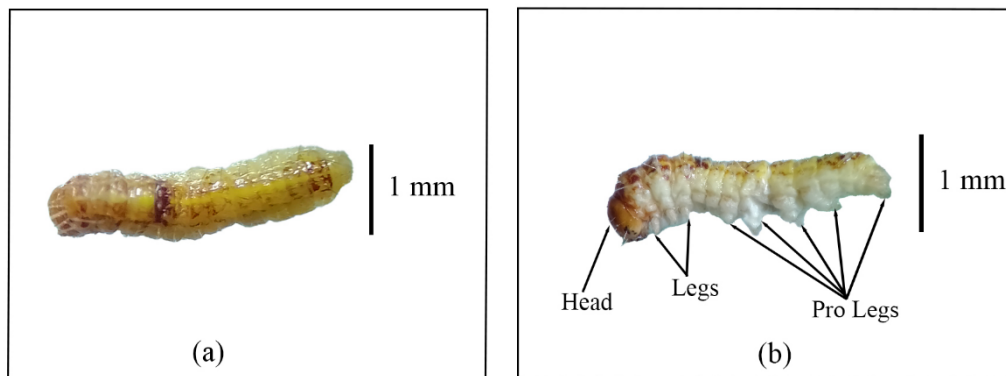


Figure 9: First instar larva of *G. chrysolopha*; (a) Dorsal view and (b) Side view

Second instar

They are dark brown colour; head brown-red with a little dip and a crescent mark; increase in number of setae, red setae present on dorsal line; length increase; legs and prolegs become brown. A humps-like structure is observed in the third segment.

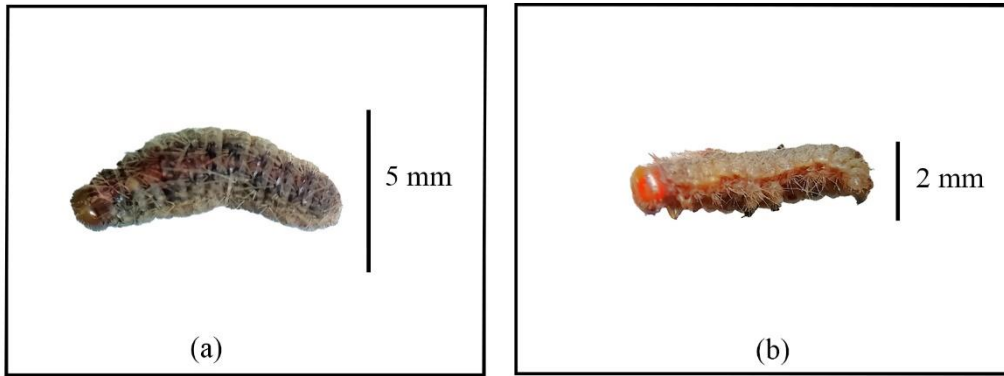


Figure 10: Second instar larva of *G. chrysolopha*; (a) Dorsal view and (b) Side view

Third instar

Increase in length and width; number of setae increases with length. On the back, there are tufts of long pale brown hair and a dorsal series of short fulvous tufts they are called urticating setae. Hair causes itching and discomfort; head turn into reddish color; tip of the prolegs develop brown color adhesive hair (Figure 11).



Figure 11: Third instar larva of *G. chrysolopha*; (a) Dorsal view and (b) Side view

Fourth instars

Same as third instar, increase in length and width; well distinct segment; dense and long setae, dorsal series of short fulvous tufts are clearly seen (Figure 12). They are voracious. Area of head increases gradually.

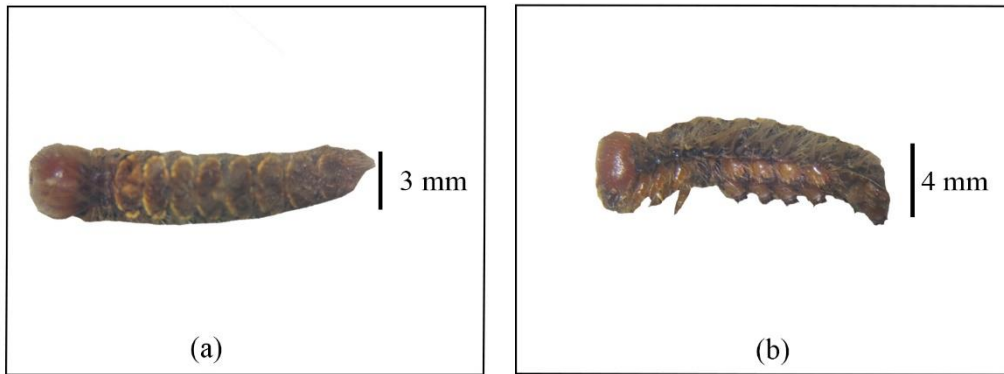


Figure 12: Fourth instar larva of *Gazalina chrysolopha*; (a) Dorsal view and (b) Side view

Fifth instar

Same as fourth instar, increase in length and width; well distinct segment; more dense and long setae, dorsal series of short fulvous tufts more distinct, urticating setae are longer, color of head is dark brown (Figure 13) They cover themselves before entering the pupal stage.

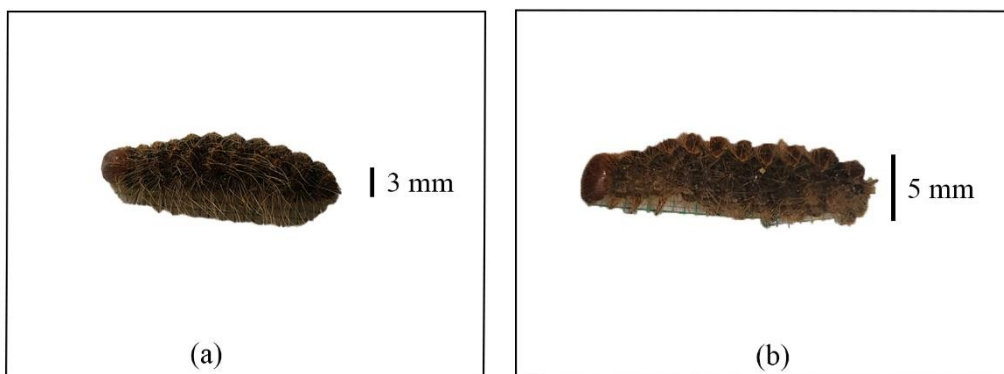


Figure 13: Fifth instar of *G. chrysolopha*; (a) Dorsal view and (b) Side view

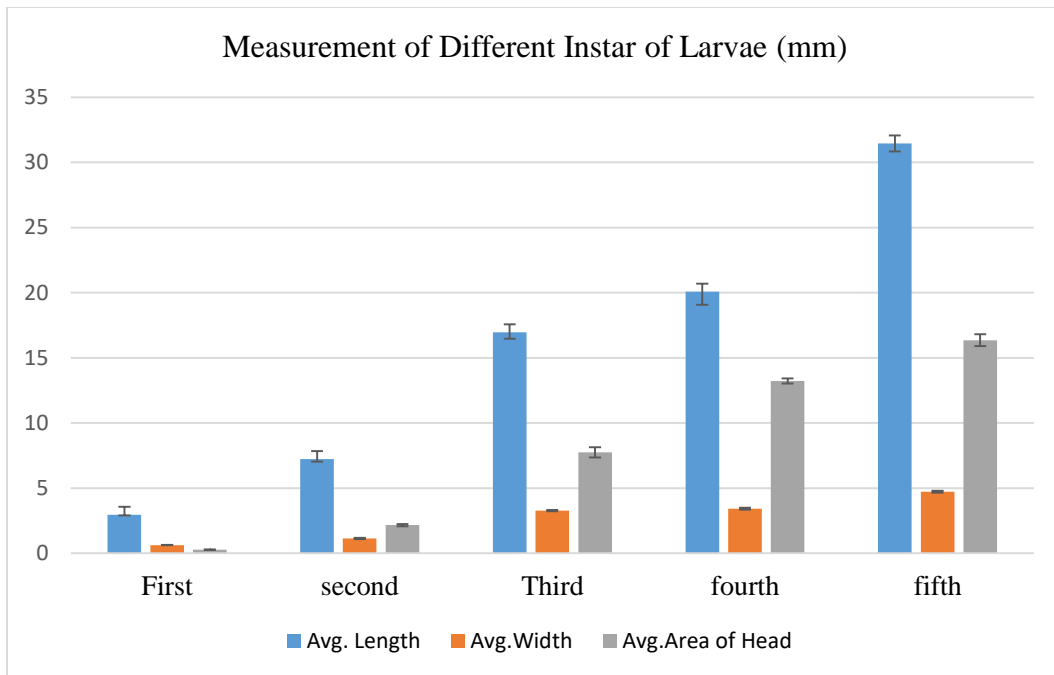


Figure 14: Measurement of first- fifth instar Larva

The length and width of larva is gradually increases from first instar larva to fifth instar larva as well as area of head also gradually increases in each instar shown in (Figure 14). The larval period is the longest period of their life cycle which start from November to April. The development of larvae depends on the availability of suitable food and appropriate environment. During the rearing process, we were unable to proceed beyond the fourth instar due to lack of food and suitable artificial environment facilities. However we regularly visited the larvae in their natural environment. They have high in number during hatched and first and second instar larva. They have high mortality rate in third, fourth, and fifth instar larva.

4.2.3 Pupae

Pupal stage were found at the base of *A. nepalensis* tree with silk covering near to soil. Fifth instar larva cover themselves with silk and formed cocoon and turn into the pupa. Initially cocoon were white in color and later on it change into reddish brown color but the actual pupal color is dark brown color (Figure 15). The average length and width of pupa

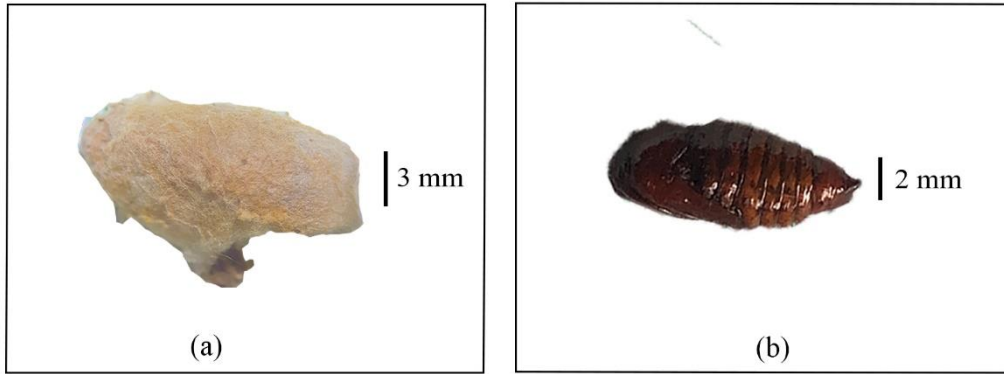


Figure 15: Pupa of *Gazalina chrysolopha*; (a) Pupa with cocoon (b) Pupa inside cocoon

Table 2: Life stage and their time interval of *Gazalina chrysolopha*

Life Stage		Emerge time	Time period
Egg		Mid August- mid October	1-2 months
Larvae	First instar	November	26 days
	Second instar	November-december	32 days
	Third instar	January- February	42 days
	Fourth instar	February- March	39 days
	Fifth instar	March- April	35 days
Pupae		May-August	1-2 month
Adult		Outbreak mid-August-October	5-7 days

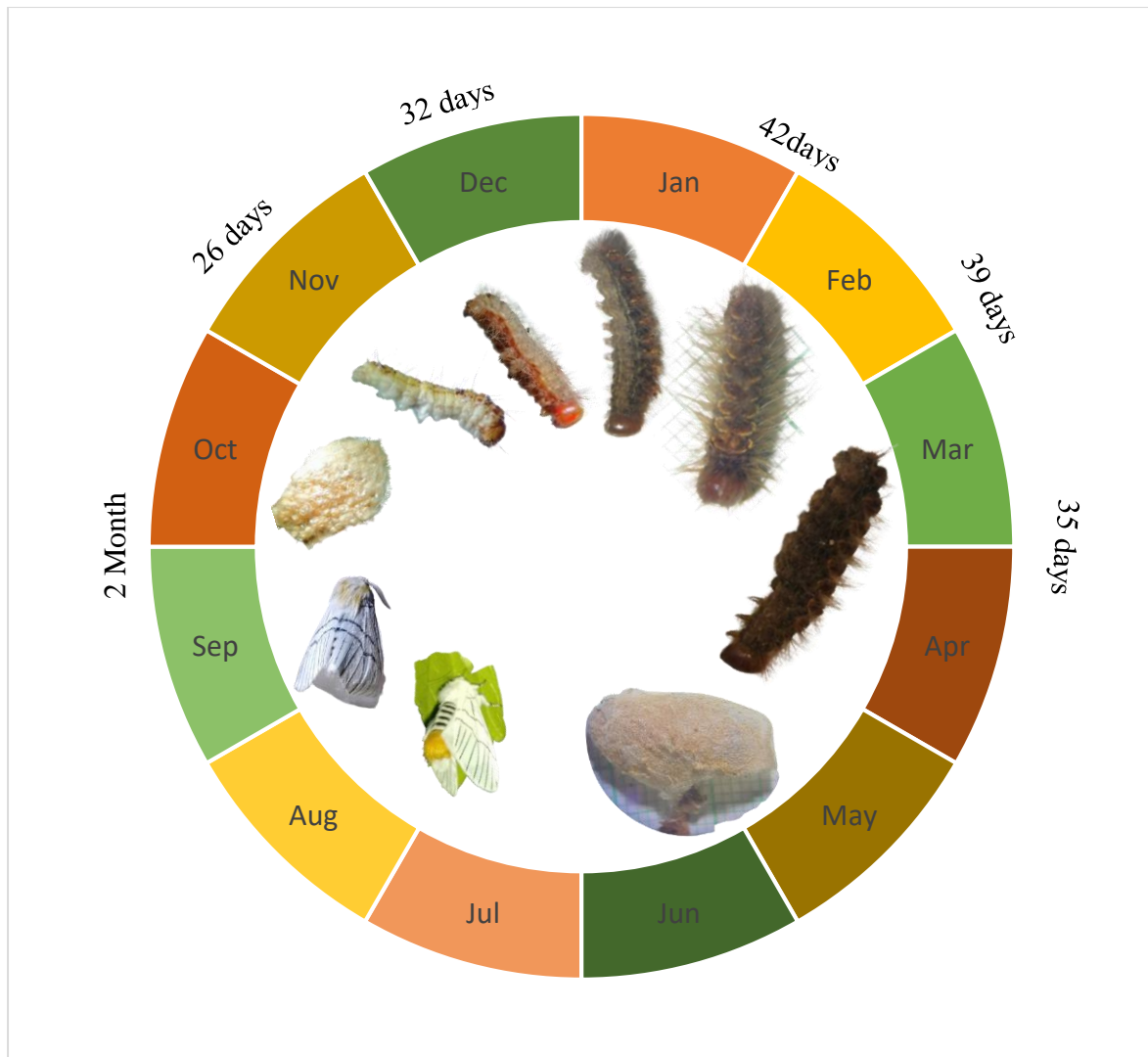


Figure 16: Diagrammatic representation of life cycle of *G. chrysolopha*

4.3 Natural Enemies of *Gazalina chrysolopha*

Adult moths were active at evening and the nocturnal insectivores like bats, house lizards were seen predated on the moth. In the outdoor habitat bat preying on flying moths and in indoor habitat wall lizard (*Hemidactylus flaviviridis*) predated on adult *Gazalina* (female) around the source of light (Figure 19). In the larval stage, *Carcelia spp* (family: Tachinidae, order: Diptera) act as parasitoids while during the pupal stage *Pimpla spp.* from (subfamily; Pimplinae, family: Ichneumonidae, order; Hymenoptera) serves as a parasitoid. The larva of diptera was found inside the fifth instar larva of this moth (Figure 18). By creating a hole, the mature larva of parasitoid emerges from the moth's larva. The adult of ichneumonidae was encountered (Figure 17 a and b) when it penetrates the cocoon and damages this.

By the following characteristics, they are identified;

Table 3: Description of identified species

Name of Species	Description Character
<i>Carcelia spp.</i>	Compound eye large and usually densely microtrichose. Gena very narrow, Parafacial narrow and bare. Facial ridge with only a few decumbent, short setae above vibrissa. Two or three reclinate orbital setae. Scutellum with one or two lateral setae, total of four or five pairs of marginal scutellar setae. Presutural intra-alar seta present. Four postsutural dorsocentral setae. Two or three katepisternal setae. Hind coxa with one OR more setae on posterodorsal margin.
<i>Pimpla spp.</i>	Inner margin of eye weakly concave above antennal socket; clypeus not divided into basal and apical parts by a transverse suture; face of male black; mandible broad at the tip and with the lower tooth not decidedly smaller than the upper tooth; occipital carina present; epicnemial carina present; tarsal claws of female without a basal tooth.

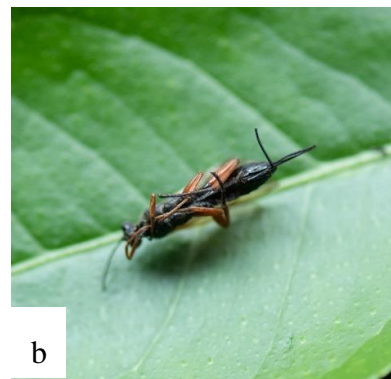
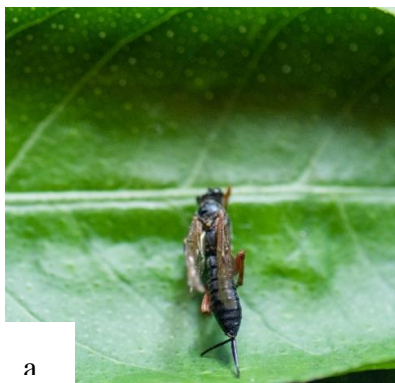


Figure 17: Parasitoides of *Gazlina chrysolopha*; a) dorsal view, b) ventral view of *Pimpla spp.*, c) dorsal view and d) ventral view of *Carcelia spp.* in May

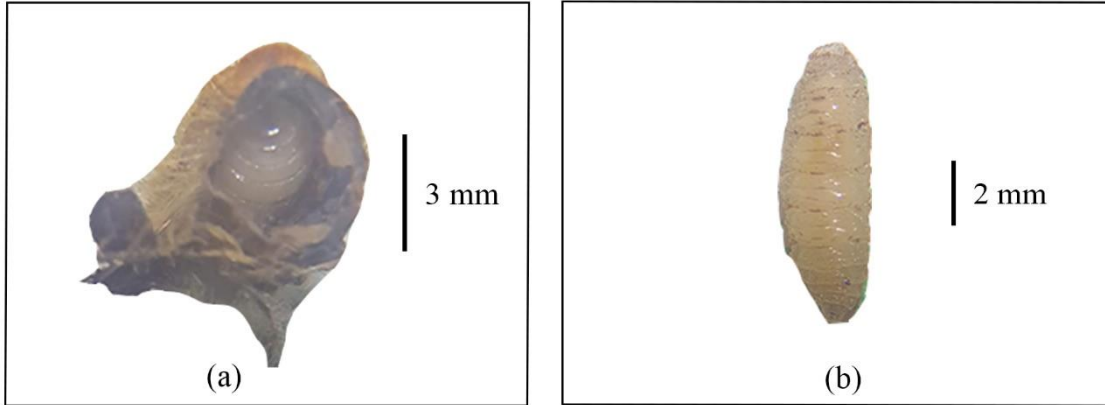


Figure 18: Larva of parasitoid (diptera) a) inside the Larva of *G. chrysolopha* b) outside in May



Figure 19: *Hemidactylus flaviviridis* preying on adult *G. chrysolopha* in September

5. Discussion

Moths being functionally important and huge, diverse groups, can be used as potential bio-indicator groups in the present scenario of environmental degradation. Moths as ecological indicators are associated with current environmental issues like habitat alternation, climatic changes (Dar & Jamal, 2021) .The major defoliator of *Alnus nepalensis* and the main suspect of SHAPU, *G. chrysolopha* is the aesthetic white moth.. This Moth was first described by Kollar in 1844 from Kashmir as *Liparis chrysolopha*. The body length of male *G. chrysolopha* is 14mm , however Walker found 6 line (12.702 mm) (Edward et al., 1856). Body length of male (14mm) is smaller than female (18mm) in this study (Figure 14) but Srivastava (2003) mention that male and female have almost same body length (0.50 mm length difference female and male).The venation of the wings of forewing has three transverse bold lines, however Walker mentions just two transverse lines (Walker, 1856)

5.1 Life history of *G. chrysolopha*

Holometabolous, *G. chrysolopha* have completed life cycle in four stage that is Egg, Larva, Pupa, and Adults. One generation per year of this moths have almost 265 ± 8.5 days long life cycle (Srivastava, 2003). In Nepal, it appears between mid-August and mid-October, however in Bhutan, it appears between mid-July and mid-August (Rahman & Chaudhry, 1992). Accidental emergence also observed in April to May 2023 and 2024, Khanal & Shrestha (2022) also mention about this unusual emergence. The defoliation of *A. nepalensis* observed in Nepal from November to May similar to the Sikkim, India (Srivastava, 2003). Rahman and Chaudhry (1992) noted a comparable occurrence of this species defoliating oak trees in Jammu and Kashmir. On the other hand, their occurrence on *A. nepalensis* was documented in November to April in eastern and central Bhutan (Raman, 1998). The topography and climate both may contributed to this. Egg laid during the emergence time In case of larva, length and width of different instar of larva increases gradually (Figure 10) (Srivastava, 2003). During the rearing, unable to go only fourth stage. When moulting from the third to fourth instar, a high death rate was noted. Similar observation were obtained during the fifth instar's moulting and during pupation.

5.2 Natural control of *G. chrysolopha*

Natural enemies control the population naturally and regulate ecosystem. In this study, tachinid flies (Genus *Carcelia*) were discovered as the larval parasitoid. Similarly, in Sikkim same parasitoid found on *G. chrysolopha* (Srivastava, 2003). Seventeen species of Parasitoid were recorded including tachinid flies (Genus *Carcelia*) as the larval parasitoid of processionary moth (Plamen & Tsankov, 2015). *Pimpla Spp.* also recorded as the pupal parasitoids in *G. chrysolopha* in study area. According to De Boer & Harvey (2020), *Pimpla spp.* from the processionary moth were identified. While there is no egg parasitoids or predators found. However in other researches the families Encyrtidae, Eulophidae, Eupelmidae, Trichogrammatidae, were reported as egg parasitoids (Plamen & Tsankov, 2015). Tachinidae (Diptera) and Ichneumonidae (Hymenoptera) are the most common parasitoids of Lepidoptera (Magar et al., 2017; Plamen & Tsankov, 2015; Rahim et al., 2021; Romeis & Shanower, 1996). In case of Adult, Wall lizard found as predator beyond this some coleopteran and bats are found as predators (Barbaro & Battisti, 2011). These bio-control agent help to control the population which ultimately reduce the defoliation and risk of SHAPU.

6. Conclusion and Recommendations

6.1 Conclusions

This study has provided crucial insights into the morphological variations, life history, and natural enemies of this moth. It was first described as *Liparis chrysolopha*. Understanding its four-stage life cycle allows for the identification of vulnerable stage where control measure can be most effective. The female has greater size than male. The five-instar larval stage is gradually increases in size. One generation emerge in a year, where adult emerges in August to mid-September. Tachinid flies (genus: *Carcelia*) and parasitic wasp (family: Ichneumonidae, genus: *Pimpla*) are identified the natural bio-control agent of pre- mature stage and the wall lizard (*Hemidactylus flaviviridis*) is the adult's natural enemy of this moth which help to balance the population naturally and reduce reliance on chemical pesticides, promoting more sustainable and environment friendly pest control practices.

6.2 Recommendations

According to the current study, the following recommendations have been made:

- More research should be conduct to know about the secondary host plant.
- Molecular study should be done for taxonomy.
- Support the introduction and conservation of parasitoid species, including parasitic wasps (Ichneumonidae) and tachinid flies.
- Further study should be done for finding effectiveness and interaction with natural enemies.

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Appendix

Appendix –I



प्राप्त पत्र सख्या र मिति:-
पत्र सख्या:- 068/170
च. नं:- 9001

नेपाल सरकार
वन तथा वातावरण मन्त्रालय

वन तथा भू-संरक्षण विभाग



फाँन नं { ४-२२७५७४
४-२२०३०३
क्याम्पस: ४-२२७३७४



(कृपया पत्रोत्तरमा प्राप्त पत्र सख्या
र मिति उल्लेख गर्नुहोला।
बबरमहल, काठमाडौं, नेपाल

मिति : २०७९/१२/०५

विषय: अनुसन्धान अनुमति सम्बन्धमा ।

श्री भावना पाण्डे,
पाल्पा, नेपाल ।

प्रस्तुत विषयमा Central Department of Zoology, Tribhuvan University, Kirtipur Kathmandu मा M.sc. 3rd Semester मा अध्ययनरत तपाईंले " Habitat Preference by *Gazalina chrysolopha* Moth in Kaski, Lamjung, Gorkha Districts of Gandaki Province" को विषयमा अध्ययन अनुसन्धानका लागि अध्ययन अनुमति उपलब्ध गराइदिनु हुन भनि मिति २०७९/१०/२५ गते यस विभागमा दिनु भएको निवेदन साथ प्रपोजल प्राप्त भयो । सो सम्बन्धमा कारवाही हुँदा उक्त प्रपोजलमा उल्लेखित Methodology (Light Trap) अनुसार तपसिलको शर्तहरूको अधिनमा रही डिभिजन वन कार्यालयसँग समन्वय गरि सन् २०२३, नोभेम्बर सम्मका लागि अनुसन्धान गर्नु हुन निर्देशानुसार अनुरोध छ ।

शर्तहरू

१. अनुसन्धानकर्ताले वन ऐन २०७६ तथा वन नियमावली २०७९, राष्ट्रिय निकुञ्ज तथा वन्यजन्तु संरक्षण ऐन, २०२९ र नियमावली २०३० तथा यस मातहतका नियमावलीहरूको पूर्ण पालना गर्नुपर्नेछ ।
२. अनुसन्धान कार्य डिभिजन वन कार्यालयसँगको समन्वयमा गर्नुपर्नेछ ।
३. संकलित नमूनाहरू (*Gazalina chrysolopha* Moth) को परिक्षण कार्य प्राणी शास्त्र केन्द्रीय विभाग, कीर्तिपुरको प्रयोगशालामा गर्नुपर्नेछ ।
४. अनुसन्धानको क्रममा प्राप्त भएको जैविक विविधता संरक्षणसँग सम्बन्धित संवेदनशील सूचनाहरू गोप्य राख्नु पर्नेछ अनाधिकृत रूपमा त्यस्ता सूचनाहरू कसैलाई पनि उपलब्ध गराउन पाइने छैन ।
५. अनुसन्धान कार्य समाप्त भए पश्चात एक प्रति रिपोर्ट/प्रतिवेदन (कागजी तथा विद्युतिय) यस विभागमा अनिवार्य रूपमा बुझाउनु पर्नेछ ।
६. तोकिएका शर्तहरूको पालना नगरिएमा विभागले कुनै पनि समयमा अनुसन्धान अनुमति रद्द गर्न सक्नेछ ।

(सवनम पाठक)

सहायक वन अधिकृत

बोधार्थ

श्री डिभिजन वन कार्यालय, गोरखा, कास्की र लम्जुङ्ग । : जानकारी तथा आवश्यक सहयोगका लागि अनुरोध छ ।

Annex 1

The detail of the specimens deposited in the museum of Central Department of Zoology

CDZ Reg. No.	Location
CDZMTU-LEP-01010	Gorkha-8
CDZMTU-LEP-01011	Gorkha-6
CDZMTU-LEP-01012	Gorkha durbar
CDZMTU-LEP-01013	kushma-10
CDZMTU-LEP-01014	kushma-10
CDZMTU-LEP-01015	Kushma- 6
CDZMTU-LEP-01016	Dhorpatan-1
CDZMTU-LEP-01017	Dhorpatan-1
CDZMTU-LEP-01018	Burtiwang
CDZMTU-LEP-01019	Beni-8
CDZMTU-LEP-01020	Beni-2
CDZMTU-LEP-01021	Beni-2

Annex 2

Measurement of different stages of *G. chrysolopha*

Pupae	width	8.91	7.71	8.9	10.94	9.27
	length	17.69	13.66	19.19	21.35	18.7
Eggs	diameter	0.56	0.68	0.61	0.71	0.76
Male	Width	2.73	3.51	3.76	4.83	3.74
	L.B	14.41	15.42	14.41	15.69	15.81
	L.FW	19.13	17.99	18.81	19.68	19.25
Adult(Female)	Width	5.18	4.73	5.3	5.37	5.02
	L.B	20.21	16.83	18.51	19.99	20.1
	L.F.W	22.49	20.05	22.8	23.46	24.18
5th	Area of Head	14.5706	15.045	19.6445	15.6284	16.7698
	H.Length	4.07	4.25	5.05	4.39	4.39
	H. width	3.58	3.54	3.89	3.56	3.82
	width	5.88	4.37	4.82	4.37	4.96
	Length	31.66	34.19	32.88	31.86	28.74
	Area of head	14.003	12.882	14.0685	13.4136	13.284
4th	H.Length	4.18	3.8	4.15	4.14	4.05
	H. width	3.35	3.39	3.39	3.24	3.28
	width	3.31	3.44	3.15	3.41	3.11
	Length	20.84	18.01	17.6	16.43	18.57
	Area of head	8.35	6.7575	6.7017	10.1656	8.0454
	H.Length	3.34	2.65	2.67	3.88	3.18
3rd	H. width	2.5	2.55	2.51	2.62	2.53
	width	2.92	3.36	3.39	3.61	3.33
	Length	13.48	19.1	17.59	17.28	15.37
	Area of head	1.9304	2.054	2.603	2.0828	1.905
	H.Length	1.52	1.58	1.9	1.64	1.5
	H. width	1.27	1.3	1.37	1.27	1.27
2nd	width	1.12	1.08	1.13	1.05	1.24
	Length	6.96	7.6	8.03	7.02	6.45
	Area of head	0.258	0.2842	0.3078	0.2773	0.312
	H.Length	0.43	0.49	0.57	0.47	0.52
	Head width	0.6	0.58	0.54	0.59	0.6
	width	0.66	0.59	0.6	0.61	0.63
1st instar	Length	2.69	3.13	2.93	2.99	3.09

8.56	10.45	10.43	10.78	10.09	9.604	1.178514	0.372679
19.33	21.32	21.45	22.62	20.67	19.598	2.741246	0.866858
					#DIV/0!	#DIV/0!	#DIV/0!
0.8	0.76	0.62	0.71	0.86	0.69	0.072997	0.023084
					#DIV/0!	#DIV/0!	#DIV/0!
3.56	3.69	3.18	2.86	3.26	3.512	0.514578	0.162724
13.04	14.4	13.88	14.36	13.47	14.489	1.026626	0.324648
18.06	19.21	20.77	19.36	19.09	19.135	0.962376	0.30433
					#DIV/0!	#DIV/0!	#DIV/0!
5.44	5.17	4.3	5.7	5.34	5.155	0.407665	0.128915
20.59	18.3	13.99	18.35	19.56	18.643	2.313547	0.731608
23.41	24.3	23.42	23.56	22.67	23.034	1.4333	0.453249
16.506	16.5912	16.821	16.8	15.1712	16.35477	1.450564	0.458709
4.2	4.46	4.45	4.48	4.31	4.405	0.279753	0.088466
3.93	3.72	3.78	3.75	3.52	3.709	0.152143	0.048112
4.6	4.58	4.45	4.7	4.43	4.716	0.225958	0.071454
29.27	32.06	31.47	32.09	30.38	31.46	1.922454	0.607933
12.0901	12.493	13.1127	13.5136	13.4045	13.2265	0.64396	0.203638
3.79	4.03	4.01	4.12	4.15	4.042	0.146953	0.046471
3.19	3.1	3.27	3.28	3.23	3.272	0.10406	0.032907
3.75	3.53	3.42	3.55	3.6	3.427	0.219122	0.069292
26.3	19.52	19.67	20.62	23.32	20.088	3.224033	1.019529
6.7344	8.2296	7.9104	7.2644	7.3606	7.75196	1.243728	0.393301
2.76	3.24	3.09	2.86	2.98	3.065	0.433963	0.137231
2.44	2.54	2.56	2.54	2.47	2.526	0.054423	0.01721
3.18	3.22	3.48	3.2	3.13	3.282	0.14739	0.046609
15.69	19.09	19.05	17.54	15.46	16.965	1.596662	0.504909
2.3607	2.506	2.0375	2.24	1.9635	2.16829	0.266827	0.084378
1.83	1.79	1.63	1.75	1.65	1.679	0.145929	0.046147
1.29	1.4	1.25	1.28	1.19	1.289	0.056188	0.017768
1.51	1	1.09	1.06	1.11	1.139	0.172599	0.054581
8.33	7.23	6.84	7.13	6.78	7.237	0.668125	0.211128
0.2898	0.2736	0.2352	0.2695	0.2632	0.27706	0.025525	0.008072
0.46	0.48	0.42	0.49	0.47	0.48	0.047509	0.015024
0.63	0.57	0.56	0.55	0.56	0.578	0.029114	0.009207
0.62	0.69	0.64	0.69	0.58	0.631	0.033094	0.010465
2.67	2.89	2.94	3.04	3.18	2.955	0.150602	0.047625
					Avg	STDV	Error

Appendix –II

Photoplates



Figure: Light trap during sample collection

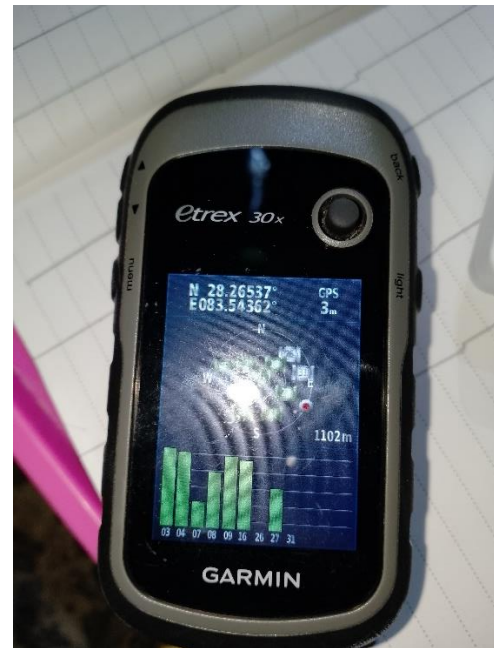


Figure: GPS device using in field



Figure: Hygrometer used in field



Figure: Sweeping net



Figure: Collection of Moth



Figure: Temporary Preservation of Moth



Figure: Female while egg laying



Figure: Preservation of moth



Scanned with CamScanner

Figure: Leaf of *Alnus nepalensis* defoliated by second instar larva of *G. chrysolopha* in nature



Scanned with CamScanner

Figure: Second instar larva of *G. chrysolopha* showing processional behaviour on bark of *A. nepalensis*



Figure: Larva while moulting

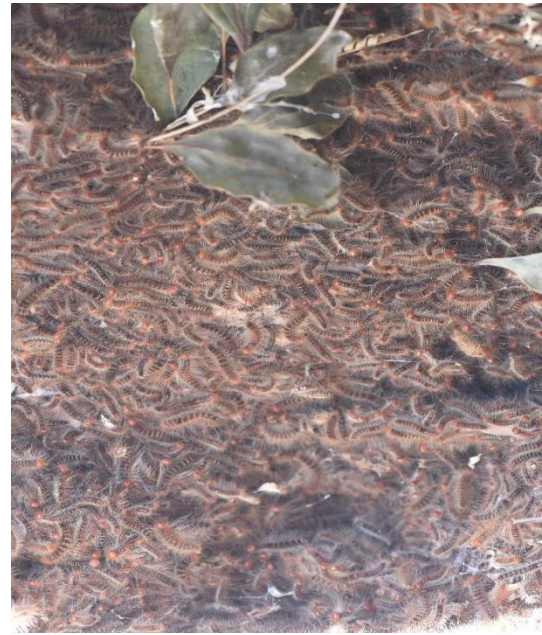


Figure: Larva resting at the base of tree



Figure: Pupae of *G. chrysolopha* at nature



Figure: Natural enemy of pupae of *G. chrysolopha* (*Pimpla* spp.)