International Journal of Zoology Studies
www.zoologyjournals.com
ISSN: 2455-7269
Received: 02-08-2021, Accepted: 15-08-2021, Published: 03-09-2021
Volume 6, Issue 5, 2021, Page No. 1-9

Behavioural analysis of silk moth: Similipal biodiversity a case study

Aratibala Sahu[1], Prasanta Kumar kar[2], Priya Ranjan Debta[3]
[1] Lecturer in Zoology Udala College Udala, Research Scholar, North Odisha University, Takatpur, Baripada, Mayurbhanj, Odisha, Inda
[2] Scientist, Basic Seed Multiplication and Training Centre, Central Silk Board, Ministry of Textile, Korba, Chhatisgarh, Inida
[3] Assistant Professor, Post Graduate Department of Zoology, North Orissa University, Baripada, Mayurbhanj, Odisha, India

Abstract
Tropical tassur silkmoth Antheraea mylitta Drury is exploited in country for commercial silk production and improved by means of optimial utilisation of the ecosystem. The Modal unique Eco race which is found in Similipal Biosphere Reserve (SBR) of Mayurbhanj district. It predominantly feeds on sal producing very high quality of cocoons rich in silk content. However this has a strong impact on the local economy of the immediate community. So there is a urgent need of studying the behavioural pattern of drury in the SBR. Here in this study an attempt has been made in this context. However there is a great variation in the genotypes of Modal in the varied ecological conditions of Similpal forest. However tussar silk has been fascinating the human society since time immemorial. Silk is the most elegant textiles in the world with unparalleled grandeur, natural shine, inherent affinity for dyes and high absorbance. The demand for it is growing constantly at the present time for its light weight, soft in touch and has high durability besides organic in nature. However Tussar silk is very much associated with Indian tradition and culture. It always enriches sacredness, religious faith and it promotes the progress of science, technology and economics. So, it is treasured like gold and offered as gift by each and every nation of all over the globe. The sector of sericulture has been emerged to explore more in this field to boost the contribution for mankind. It includes both agriculture and industrial activities. Sericulture involves the raising of food plants for silk moth rearing for production of cocoons, reeling and spinning of cocoon for products of yarn, weaving of silk yarn for production of fabric etc. The genus Antheraea is very important from economic point of view since this produce Tasar and Muga silks and has a direct bearing on sustainable resource management and ecosystem development. In this study an attempt has been made to study the behavior of mylitta Drury.

Keywords: sericulture, genus antheraea, cocoons, eco race

Introduction

In India, sericulture is as old as the Indian civilization. The knowledge of silkmoth and silk was known to Indians years ago. Nanavaty (1965) stated that India cultivated wild silk independent of China from very ancient times. The domestication of silkworm *Bombyx mori* is thought to have originated in the Himalayan foot-hill (Thangavelu and Joshi, 1983) and that the Aryans first discovered the silkworm in the Sub-Himalayan regions.

Now, Indian silk is known all over the world for its quality, quantity and design. Today, silk and silk making are no more a secret. The whole world knows about it. Presently, sericulture is being practiced in dozens of countries world over. Countries like India, Japan and China has international institutions and training centres to teach sericulture. However, with all these, China has not allowed any other country to surpass its first position in the world silk production.

The natural silk is broadly of two types namely (a) plant silk fibre and (b) animal silk fibre. The natural silk of plant origin is obtained from the members of the family *Bombacaceae*. The animal silk is further of two types such as (i) mulberry and (ii) non-mulberry. Mulberry silkmoth is a domesticated type whereas non-mulberry is universally known as “wild silk” or “vanya silk”. The non-mulberry variety is classified into two types, that is, insect and non-insect types. The insect type of silk is obtained from nine different types of insects. These are named as (i) eri (ii) muga (iii) anaphe (iv) cricula (v) fagara (vi) coan (vii) weaver ant silk (viii) green lacewing fly silk and (ix) tasar. The non-insect type of silk is of two types namely (i) mussel silk obtained from molluscs and (ii) spider silk obtained from spiders.

Insect type of silk is again classified as (i) commercial and (ii) non-commercial type. Eri, muga, tasar, anaphe, fagara and coan are commercial types of insect silk whereas the non-commercial type of silk is produced from the weaver ant and green lacewing fly. The non-insect silk obtained from mussel and spider is non-commercial type. Recently the wild silks, *viz*., tasar (both tropical and temperate or oak tasar), eri and muga have been given a new name “vanya silk” (Anonymous, 2006). Mulberry silk insect is monophagous whereas the non-mulberry silk insects are polyphagous.

Sericulture, the cultivation of silk is an agro-industry, the economic end product of which is silk. It is highly viable, employment creating and income generating industry providing quick returns in shorter duration. Undoubtedly, it plays a pivotal role in reducing unemployment and in assisting the poorest to make a decent living. Today, sericulture is the main source of livelihood either directly or indirectly for a large number of people, the majority of

whom are from the economically retarded section of the society – the Scheduled Castes (SCs) and Scheduled Tribes (STs). It is such a product that it is exclusively prepared by poorest of the poor but luxuriously used by the rich. Sericulture, thus, plays an important role in transferring wealth from rich, the consumers, to the poor, the rearers. China is now the biggest silk producing country in the world where about 20 million people are engaged in sericulture and India, ranking second, provides employment to about 5.5 million people. Silk, as an agro-based industry, is a natural fibre for the integration of a set of interdependent rural and semi-urban based activities such as cocoon production, cocoon reeling, yarn twisting, weaving and finally trading. While the cultivation of the food plants and raising of cocoons are agricultural in nature, the production of raw and spun silk are cottage industry based. All these activities result in employment at the rate of 13 work-year per hectare.

The Forest Conservation Act 1980 adjudicates the fact that "tasar cultivation in the forest area by the tribals as a means of their livelihood without taking monoculture, Asan and Arjuna plantation shall be treated as forest activities. Therefore, no prior approval of the Central Government under the act is necessary (Section 1.5 (1))".

Literature Review

The world of silk is mainly constituted by two distinct varieties like mulberry and non-mulberry. The non-mulberry silk constitutes Tasar, Muga, Eri, Anaphe, Cricula, Fagara, Mussel, Spider and Coan silk. Among non-mulberry silks, Eri, Muga and Tasar (both tropical and temperate or oak tasar) were called "wild silk" as these silkworms thrive on nature grown host plants. But, this group has now been given a new identity and is collectively called "vanya silk" (Anonymous 2006). Generally, it is thought that silk refers only to mulberry silk whose insects, *Bombyx mori*, are reared on mulberry leaves and is a high priced valuable and delicate textile fibre. The rearing practices of tasar silkworms have been studied by the following scientists. Benchamin and Jolly (1986) [1] and Ojha *et al*. (1994) [4] reported on principles of silkworm rearing. The integrated package of rearing and the transfer of the technology to the field has been suggested by Mathur *et al*. (1998) [6], Narain *et al*. (2014), Mohan Rao *et al*. (2014), Satapathy (2014) and Prasad *et al*. (2015). Sinha (2000) made a study on the rearing methods, seed and cocoon production. Some significant studies have been made on the indoor rearing and maintenance of some of the *Antheraea* species by Alam *et al*. 1991, Naveen and Savanurmath (2000) [10], Ch. Sudhakar Babu and Purushotham Rao (2000) and Siddiqui *et al*. (2006) [11]. Phenological studies in muga silkworm, *Antheraea assama* in relation to its rearing and grain age behaviour has been made by Sahu *et al*. (2000). The advantages of typical Tiwari grain age tray for better seed production have been discussed by Tiwari (1998). It is suggested that systematic and methodical rearing practice results in better production of tasar silk (Jolly 1972 [2], 1974, 1976, Jolly *et al*. 1973, 1975, and Prasad *et al*. 2012, 2015). Sengupta *et al*. (1981) studied the rearing performance of tasar silkmoth in crop III.

The different ecological aspects of tasar silkworms have drawn the attention of the following researchers. Mohanty (1991) and Nayak and Dash (1998) studied the biology, ecology and culture practices of the wild tasar silkmoth *Antheraea paphia* Linn. Danielvskii (1965) [13] proposed the aspect of photo periodism and seasonal development of silk insect. Saxena *et al*. (1997) and Srivastava *et al*. (2000) studied the impact of abiotic factors and microclimates on the qualitative and quantitative characters of *A. mylitta*. Patro *et al*. (2000) made a study on the influence of pruning frequency on different commercial characters of tasar cocoon in *A. mylitta*. Sahay and Kapila (1992) commented on the adverse effect of deforestation on tasar culture.

The following scientists have studied the nutritional behaviour of tasar silkworm. Nutritional ecology of the silkworm which helps in the proper selection of the host plants is of fundamental importance so far as consumption, digestion and assimilation of host plant leaves and production of cocoons are concerned (Evan 1939, Hamamura 1959 [12], Hamamura *et al*. 1962, Ramkishore *et al*. 2002). Findings on food plants and consumption of leaves in various larvae are recorded by some sericologists. Nayak *et al*. (1985), Mohanty and Nayak (1993), Prasad *et al*. (2004) [5] and Sinha *et al*. (2005) studied the leaf consumption by successive instars of *A. mylitta*. According to them, food consumtion is directly proportional to age and shows an extraordinary increase during the last stage (5^{th} instar) of larva. Sex-wise consumption and utilization of the leaves of different eco races of tropical tasar silkworm, *Antheraea mylitta* Drury during fifth instar of first crop is studied by Ojha *et al*. (2000) [3]. The diseases of tasar food plants and their control measures have been stated by Chakrovorty and Das (1979), Patro *et al*. (1998), Alam *et al*. (2004) [5] and Satapathy and Alam (2012). They have suggested the vegetable disinfectant for tasar eggs. Roy *et al*. (2006) reported on the improvement of tasar crop by using leaf surface micro flora to control harmful microbes. However ther is a need of a in depth study to investigate the factor which influence more to the tropical tasar silk moth of similipal biosphere reserve.

Objectives

- To study the behavioural traits of Tasar Silk worm in Simlipal Biodiversity.
- To trace the climatological and geographical factors for the modal eco race.
- To focus the life cycle of modal eco race in natural habitat.
- To ascertain habitat for its conservation.

Background of the Study

The study site for the observation and analyses was in Similipal Biosphere Reserve and the materials used for this investigation was Modal eco race of tropical tasar silkmoth, *Antheraea mylitta* Drury. During the course of investigation, the eggs, different stages of larvae from first to fifth instar, pupae and adults of Modal eco race of tropical wild tasar silkmoths *Antheraea mylitta* were observed. For metrical analysis, the instruments like monopan digital balance, slide callipers, screw gauge and measuring cylinder were used. The room thermometer, wet and dry bulb hygrometer, wall clock and rain gauge were used for recording the environmental parameters like temperature, relative humidity, photoperiod and rainfall respectively at the study site daily. Cocoons of Modal eco race constitute the important material for the detailed morphology, colour, quality and quantity of fibres. Physical characteristics such as length, breadth, weight, shell ratio, filament length,

nature and type of loop and peduncle of cocoons were also studied as the material.

Modal is a *Shorea* based eco race of tropical tasar silkworm *Antheraea mylitta* Drury, exclusively wild, multiplies sou moto in nature, univoltine, almost disease free, produces the heaviest cocoon with highest silk content among all the sericigenous lepidopterans of world and contributes 19% to raw silk production of India. Modal eco race is characterized by fecundity of eggs laying up to 390 in number; larvae of polyphagous nature but prefer to sal leaves before feeding on other leaves, highly variable in morphological features, clothed with numerous setae on whole body and of varied colour patterns, *viz*., brownish-yellow, green, leafy green and deep green; cocoons of large, oval upto 7.31 cm in length, 5.38 cm in diameter and 20 cc (male) to 50 cc (female) in volume and of varying colours; peduncle of cocoon strong and stout with one ring; pupae of robust and almost spherical with brunt sienna body colour; cocoon shells of thick and compact, thermo and hygro-proof; higher shell weight (males upto 16.7 gm and females upto 21.5 gm), silk content of 2.375 kg of reeled yarn from 1000 cocoons and silk ratio percentages of 25.68; filament of a single cocoon upto 1600 meters in length, coarse and heavier with average denier of 12; moths either brick red or brown in colour in males and polymorphic in colour, *viz*., yellow, pink, sepia etc. in females; moths emerge after nine months of diapause period with emergence and coupling percentages of 86 and 42 respectively. There is great variation in the genotypes of Modal in the varied ecological conditions of Similpal forest. there is an urgent need to investigate all the aspects.

Methodolodgy

During the study, the climatological parameters such as temperature, humidity, photoperiod and rainfall of the viable eco pockets were taken into account. The temperature was measured by centigrade thermometer. The maximum and minimum temperature was recorded at three different timings such as 6 am, 12 noon and 6 pm every day during the crop period. Then the mean or average value of maximum and minimum temperature was calculated each day. Similarly, the mean value of temperature was recorded for the entire crop period. In this way the maximum and minimum temperature along with its range during the study period were recorded for each crop of three successive years from 2017 June to 2019 June at the study site.

The second climatological factor is relative humidity, which was measured by the wet and dry bulb hygrometer. The dry and wet temperature were measured and recorded with the help of sling psychrometer for measuring wet and dry temperature. The relative humidity was recorded with the help of humidity standard table.

The third regulating climatological parameter for the crop cycle is photoperiod. The length of the day or photoperiod is the time of sunrise and sunset, which was recorded every day in various brood periods. The photoperiod is basically the length of day that is the difference of time from sunset to sunrise. The day length was determined with the help of the clock. On the basis of above method, the photoperiod was recorded daily during brood periods and the average photoperiod was calculated in each crop from 2017 to 2019.

The fourth parameter to study the life cycle was rainfall, which was measured by rain gauge at rain gauge station at Gudgudia. The precipitation is stated in units of inches or centimeters that falls per unit of time. The amount of rainfall was recorded by rain gauge at rain gauge station at Gudgudia during the crop period in each day. The average rainfall was calculated and recorded for each crop cycle in successive three years from 2017 to 2019.

For the study of larval growth and development, the tasar cocoons were collected from the study site. The brood period was started from the day of egg laying till the formation of cocoon which indicated the larval span. For analysis of cocoons, the tasar cocoons were collected randomly from the different study site of Similipal Biosphere Reserve.

The grain age performance of Modal eco race was studied in three consecutive years 2017, 2018 and 2019. The cocoons collected from the vicinity of study areas during the month of August were preserved (100 in each place) to evaluate the grain age behaviour and preservation effect. In all the study areas, the cocoons preserved with due care and grain age operations were conducted during September and October.

Rearing was conducted at three places, *viz*., Gudgudia, Sarat and Lulung during rainy seasons on sal and asan plants to study the effect of altitude, season and food plant.

The Similipal forest is divided into three divisions, *viz*., eastern, southern and north eastern. It is ranging from 50 m to 1000 m ASL and forest is full of sal and other tasar food plant. Due to abundance of available of sal tree the tasar silkworm which are eating sal leaf for food are called Modal Eco-races of *A. mylitta* D. when reared above 600 meter ASL exhibit univoltine character. Some eco race in ex-situ condition when bring down to level between 400-600 behave bivoltine and called Nalia and when reared within 400 meter ASL behave trivoltine and called Bogai. In all the cases silkworms feed upon sal leaf and called “Modal Gutti” and on the contrary the same species when feed upon asan or arjuna called Daba Gutti in some place.

Behaviour Study

Tasar silk moth *Antheraea mylitta* Drury belongs to the super family Bombycidea and the family Saturniidae. As a holometabolous insect, it exhibits four distinctive stages such as egg, larva, pupa (cocoon) and adult moth in its life cycle. The larva or caterpillar stage is reached when the future flying insect is ready to face the outside world and it bites its way out of the egg in which it was born. After about a week of incubation, tiny larvae come out from eggs. On hatching, these are dull brownish yellow with black head, but after 48 hours the body turns green and brown. After hatching, begins the most precarious journey of its life when the tiny creature must play a deadly game of hide-and-seek to survive. The larvae grow rapidly as they must race against time so as to pupate and fly away before the predators eat them. The total larval periods varies according to the season, altitude and the food plant.

Larval Feeding

The larval stage is the only feeding stage and the larvae are virtually eating machines. They eat not only for their own growth and metamorphosis, but also produce the several meters of silk they require in crafting a supporting platform while moulting. Their silk also serves as an escape device to drop down and away from attack. The most important of all is silk is used to weave the cocoon. Besides this, a female requires additional food reserves for the development of eggs. The larvae of tasar silkmoth are polyphagous feeding

mostly on sal (*Shorea robusta*), asan (*Terminalia tomentosa*), arjuna (*Terminalia arjuna*) and sometimes on ber (*Ziziphus jujuba*) and on some other food plants. But the larvae of Modal and Nalia eco races mostly feed on sal. The larvae feed from the margin to the center of leaves, but they never eat the midrib. The younger larvae rest on the leaf margin, and the older ones attach themselves to petioles or even small twigs with the help of their abdominal feet and claspers. The leaf lamina is pulled up between the mandibles by the thoracic legs. The young larvae are generally selective feeders and feed on the young and succulent leaves, which contain low content of crude fibre while the matured larvae ingest mature leaves in which crude fibre content is comparatively high. Every stretch of feeding is followed by a rest periods of about five minutes or of longer duration in winter and unfavourable weather. While resting, the larvae raise head, contract the body and assume a typical sitting posture. Feeding with rest periods continues round the clock, except when the mercury drops below 15^0C.

Moulting

The tasar larvae are tetra moulters. Their body grows to considerable extent both in size and weight. The skin does not keep pace with the growth of the larva's body. When a new layer of skin is formed beneath the old skin, the larvae stop eating and come to rest. The larvae secure a firm grip on either the underside of leaves (early stages) or the shaded part of twigs (late stages). During the moult, the anterior part of the body remains obliquely suspended, the prothoracic hood is fully stretched and the protruding dark head is bent ventrally inward. The larvae seldom lose their grip, but once detached they cannot reestablish and moult with difficulty. So the larvae are not disturbed during moulting. During ecdysis (moulting), the old skin splits behind the head, and the larvae slowly wriggle free out of the useless vestments. The larva's simple cigar-shaped structure makes this process of skin-shedding or moulting all the more simple. Moulting continues for 23-24 hours depending on the climatic conditions. The freshly moulted larvae have tender and pale skin. It takes a while for the new skin to harden and only after this the larvae resume eating, often by consuming their recently moulted skin.

The stage between two sheddings is known as an instar. *Antheraea mylitta* larva at rest, and the newly born larvae are the first instars. The rate of feeding is minimal before and after the moult, but it reaches its peak between these two periods.

Behaviour of Moth

The adult stage is reached when the moth emerges from the pupa around late evening and dawn. Thus, it has the advantage of low light or darkness during the most vulnerable stage of its life. The peak period of emergence varies according to season. The newly emerged moth's wings are crumpled, shrunken and limp. Instinctively, it climbs on to the nearest host plant to hang on the underside of a branch, while its wings slowly expand due to the blood being pumped into the hollow wing veins. The limp wings hang freely downward while they hardened. If they are obstructed, the wings get deformed and the moths die because they fail to fly. Once fully expanded, soft wings gradually become stronger. If by now, it is already day, the moths stay hidden. By evening the moths are ready to take off an exciting journey. If it is a male, the moth would set out in search of a newly emerged female whose presence is picked up by the male's supersensitive antennae. This receptor detects specific chemical attractants (pheromones) emitted by the females at amazing distances. Female moths are born loaded with eggs and they remain perched while discharging the chemical attractant to help males locating them to mate.

Copulation normally occurs in nature on the night of emergence. Oviposition starts 2 to 4 hours after depairing and continues both during the day and night till the death of the female moth intervenes. The maximum number of egg are laid in the first 12 hours of oviposition. The eggs are laid on the underside (dorsal side) of the leaves of preferred food plants. The incubation periods of eggs varies from 7 to 9 days depending on the season.

Moths have no proboscis for these do not feed at all during their short adult life span. All the energy needs are met from their fat reserves stored during the larval stage. Females barely use their wings. Instead they spend much of their brief life span laying eggs on precisely the same food plants on which they themselves grow up as caterpillars. The males die exactly after mating with the females.

Metrical Analysis of Modal

Modal is *Shorea* based eco race of tropical tasar silkworm *Antheraea mylitta* Drury, exclusively wild, multiplies *suo moto* in nature, univoltine, almost disease free, produces the heaviest cocoon with highest silk content among all the sericogenous lepidopterans of the world and contributes 19% to raw silk production of India. There is great variation in the genotypes of Modal in the varied ecological conditions of Similipal forest.

Modal eco race is characterized by fecundity of eggs laying up to 390 in number, larva of polyphagous nature but prefers to Sal leaves
before feeding on other leaves, highly variable in morphological features, clothed with numerous setae on whole body and of varied coloured patterns, *viz*., brownish yellow, green, leafy green and deep green. The cocoons are large, oval up to 7.31 cm in length, 5.38 cm in diameter and 20 cc (male) to 50 cc (female) in volume with varying colours. Peduncles of cocoon are strong and stout with one ring in each pupae are robust and almost spherical with brunt sienna body colour, cocoon shells are thick and compact, thermo and hygro-proof with higher shell weight (males up to 16.7 gm and females up to 21.5 gm), silk content of 2.375 kg of reeled yarn from 1000 cocoons and silk ratio percentage of 25.68; filament of a single cocoon is upto 1600 meter of length, coarse and heavier with average denier of 12, moths either brick red or brown in colour in males and polymorphic in colour, *viz*., yellow, pink and sepia etc. in females. Moths emerge after nine months of diapause periods with emergence and coupling percentages of 86 and 42 respectively.

Modal exhibits different voltinism and seasonal polymorphism in an altitude gradient of 50 to 1000 mASL characterized by varied environmental conditions. Its voltinism changes when reared out of its natural habitat and exhibits deterioration in its qualitative characters. It behaves univoltine in higher altitude (above 600 mASL) with lower temperature, higher humidity, fewer hours of sunshine and shorter day length. This univoltine eco race is the true Modal. However, it behaves bivoltine in medium altitude

(300 to 600 mASL) with medium temperature, higher humidity and medium hours of sunshine and day length. This bivoltine eco race is called "Nalia" which is also *Shorea* based and multiplies in rainy and autumn seasons suo moto. Qualitatively Nalia eco race cocoons are inferior to that of true Modal univoltine cocoons and characterized by a slender and long peduncle with more than one ring. Nalia is established as a distinct eco race as it has a distinct life cycle and gives rise to progeny. Further, at lower altitude (below 300 mASL) with occurrence of higher temperature and humidity and longer hours of sunshine and day length, the uni and bivoltine eco races like Modal and Nalia behave trivoltine. These trivoltine cocoons are not grown in nature. These are the F1 generation of Modal and Nalia reared for commercial purpose. The diapause cocoons of Modal and Nalia are collected from their natural habitat, reared in lower elevations and their F1 generation is known as "Bogei". Rearers prefer to rearing Bogei because it is totally disease resistant with lower larval mortality, higher cocoon and silk yield and guaranteed crop and reelers prefer Bogei cocoons for its better reelability, evenness, tenacity and lusture of yarn with denier of 9. However, when the diapause Bogei cocoons are preserved for grain age purpose, erratic emergence percentage during preservation is as high as 77.6% and preservation loss also high up to 46.5%. As such, Bogei cocoons are only used for commercial purpose and not for breeding. For taking up a Bogei crop, each time, the diapause cocoons of Modal and Nalia are collected from nature for seed purpose.

Bionomics of Modal

Bionomics (Gr. *bios* – life; *nomos* – law) is the study of the relation of an organism or population of organisms to its environment, animate and inanimate. Tasar silk moth is a unique insect, which exhibits voltanism in its life cycle. Some tasar wild silk moths show one crop, some show two crops and some also show three crops in a crop cycle or year. Basing upon the number of crops or cultivation, the voltine nature is called as univoltine, bivoltine, trivoltine. The life cycle of different insects at different heights (altitudes) seems to vary. The growth, development and life cycle are such phenomena that these are controlled and regulated by environmental factors like temperature, humidity, photoperiods, rainfall and altitude.

Temperature

The first environmental parameter was temperature. The temperature is defined as the degree of hotness or coldness of a body. It can also be defined as that thermal condition of a body, which determines the direction of heat flow when bodies are placed in contact. When two bodies at different temperatures are brought in thermal contact, the flow of heat energy will continue until the temperature of two bodies become equal. The state of equality in the temperature of two bodies is known as thermal equilibrium. In fact, the thermal equilibrium is said to be attained when the heat flowing away from the body is equal to the heat flowing towards the body. Since the Modal eco race is univoltine the maximum and minimum temperature were recorded in the first brood periods only. During the course of investigation, the temperature like maximum, minimum and its highest and lowest temperature were recorded with the help of room thermometer and the average temperature was calculated from 2007 to 2009 in first brood period. In the year 2007 in first brood period during rainy season, the average maximum temperature was found to be 34^0C and its range was observed to be 32^0 C to 36^0C. Similarly, the average minimum was noted to be 25^0C and that range of minimum temperature was from 25^0C to 30^0C. In 2008 during above periods, the average maximum temperature was observed to be 32^0C whereas the range of maximum temperature was from 30^0C to 37^0C. The average of minimum temperature was noted to be 27^0C whereas that range of minimum temperature was from 22^0C to 29^0C. In 2009 during above-mentioned periods, the average maximum temperature was found to be 30^0C whereas the temperature ranged from 28^0C to 32^0C. Similarly, the average minimum temperature was recorded to be 23^0C whereas the minimum temperature was from 22^0C to 25^0C. The mean of the average maximum and minimum temperature was calculated to be 32^0C and 25^0C respectively. The mean temperature during the year 2007 to 2009 in first brood period was observed. The mean of the average maximum temperature was calculated to be 32^0C, in first brood period. The mean of the average minimum temperature was calculated to be 25^0C in first brood periods from 2007 to 2009.

Relative Humidity

Humidity is the state of the atmosphere with respect to its content of water vapour. In fact, warm air is able to hold more water vapour than cold air. When the air holds its maximum amount of water vapour, it is said to be saturated. Absolute humidity is the amount of water vapour in a unit mass of air, usually measured by the grams of water vapour present in one cubic meter of the air (or in grains per cubic foot; 1 grain = 0.0648 gram). The amount of water vapour held by a body of air is governed by temperature and pressure. It becomes saturated at dew point. The lower the temperature, the lower is the absolute humidity.

Table 1: Average temperature of Gudgudia during first brood periods (July to August) from 2017 to 2019

Sl no.	Year	First Brood Periods (July to August)			
		Maximum temperature (^{0}C)		Minimum temperature (^{0}C)	
		Average	Range	Average	Range
1	2017	34	32-36	25	25-30
2	2018	32	30-37	27	22-29
3	2019	30	28-32	23	22-25
4	Mean	32	-	25	-
5	SD		-		-

Thus, over the landabsolute humidity is the highest near the equator and the lowest in Central Asia in winter.

Relative humidity (RH) is an index of the amount of water vapour present in the atmosphere. It is the actual vapour pressure expressed as a percentage of the saturation vapour pressure, which would be possible at the same air temperature. Relative humidity is an attempt to measure the readiness with which vapour will condense from the air and is concerned with two variables. The actual water vapour is a given mass of atmosphere and the temperature of that mass of air, which determines the capacity of the air to hold the water vapour. The value of relative humidity varies inversely with temperature and therefore, usually rises during the night, because temperature falls, even though the amount of water vapour may remain constant. It is measured by wet and dry bulb hygrometer. Broadly, relative humidity is the ratio between the actual amount of moisture in the air and that, which would be present if the air were saturated at

the same temperature, which is expressed as percentage. Air with an RH of 60 is usually considered as approximately separating dry from moist atmosphere.
It is defined as follows.

$$RH=\frac{\text{Actual quantity of water vapour present in a given volume of air}}{\text{Maximum amount of water vapour in the same volume of air}}x100$$

RH is given always in percentage and hence it has no unit. Relative humidity represents the amount of water vapour actually present in air compared with the maximum amount of air held at a given temperature. It tells simply relative content and indicates the degree of saturation of air at a given temperature with water vapour. Relative humidity of saturated air is 100 per cent. Relative humidity was considered as the second climatological factor, which was discussed as follows. The relative humidity was recorded daily by wet and dry bulb hygrometer with the help of relative humidity standard chart during first brood period in rainy season from 2017 to 2019. During rainy season in first brood period, the average relative humidity was observed to be 82 per cent, 80 per cent and 87 per cent in 2007, 2008 and 2009 respectively. But the range was recorded to be 79 to 85 per cent, 78 to 83 per cent and 75 to 80 per cent in 2017, 2018 and 2019 respectively. The mean of the average relative humidity was calculated to be 80 per cent and the range from 2017 to 2019 in first brood periods was from 75 to 85 per cent.

Photoperiod
The third climatological parameter was photoperiod. The photoperiod is the duration of daylight. When direct solar radiation reaches the earth surface, the relative length of dark and light periods affect the behaviour and growth of animals and plants (Strahler 1975). The length of day is the total hours of daylight perceived during the larval stages were recorded. This included the civil twilight time, that is, the time from sunrise to sun set determined with the help of clock at the study site. During the study periods, the day length was calculated daily as per recording of sunrise and sunset. Then total day length and average day length for a particular brood periods were calculated and recorded.

Table 2: Average relative humidity (RH) of Gudgudia during first brood periods (July to August) from 2017 to 2019

Sl no.	Year	First brood periods (July to August) Relative Humidity (%)	
		Average	Range
1	2017	82	79-85
2	2018	80	78-83
3	2019	78	75-80
4	Mean	80	75-85
5	SD		-

In first brood period during rainy season, the total and average day length were recorded to be 384.8hours and 10.04 hours respectively in 2017 but the stated day length were noted to be 372.59hours and 10.07 hours respectively in 2018 whereas these were observed to be 370.37 hours and 10.01 hours respectively in 2019 having the mean value of day length 375.92 hours and 10.04 hours respectively

Rainfall
The fourth climatological parameter was rainfall. The rainfall was recorded daily with the help of rain gauge at rain gauge station, Gudgudia in first brood period during various seasons from 2017 to 2019. During first brood period in rainy season of 2017, 2018 and 2019, the average rainfall was recorded to be 326mm, 302mm and 375mm respectively.
From the above mentioned data, it was observed that the average rainfall during first brood period in rainy season in 2017 was the highest (326.0 mm) in comparison to first brood period in 2018 and 2019. The mean average rainfall during first brood periods in Gudgudia was found to be 314.3 mm.

Metrical Analysis of Modal Cocoon
The cocoons collected from three ecopockets were predominantly blackish grey and yellow in colour with stout peduncle with a clear round ring. The length of the peduncle ranged from 4.57 cm to 9.55 cm, volume 23.62 cc to 40.00 cc, cocoon length 5.05 cm to 5.58 cm, cocoon breadth 3.33 cm to 3.65 cm, cocoon weight 11.20 gm to 17.25 gm, shell weight 2.76 gm to 3.41 gm and SR percentage from 19.59 to 24.64

Table 3: Photoperiod at Gudgudia during first brood periods (July to August) from 2017 to 2019

Sl No	Year	First brood periods (July to August	
		Total day length in hours	Average day length in hours
1	2017	384.8	10.04
2	2018	372.59	10.07
3	2019	370.37	10.01
4	Mean	375.92	10.09
5	SD		

Table 4: Average rainfall at Gudgudia during first brood periods (July to August) from 2017 to 2019

Sl no	Year	First brood periods (July to August)
		Rainfall in mm
1	2017	326.0
2	2018	302.0
3	2019	315.0
4	Mean	314.3
5	SD	12.01

Table 5: Morphometric parameters of nature grown Modal cocoons

Name of the ecopockets	Sex of cocoons	Volume in cc	Length of cocoons in cm	Breadth of cocoons in cm	Peduncle length in cm	Cocoon weight in gm	Shell weight in gm	SR %
Sarat	Female	32.25	5.58	3.59	5.83	16.40	3.41	20.79
	Male	23.62	5.16	3.33	6.17	11.20	2.76	24.64
	Average	27.93	5.37	3.45	6.00	13.80	3.08	22.35
Gudugudia	Female	39.80	5.49	3.57	4.57	17.25	3.38	19.59
	Male	33.50	5.16	3.33	6.01	13.42	2.85	21.24
	Average	36.65	5.32	3.45	5.29	15.33	3.11	20.31
Lulung	Female	40.00	5.55	3.65	5.61	17.00	3.35	19.70
	Male	37.00	5.05	3.51	9.55	12.67	3.10	24.45
	Average	38.50	5.30	3.58	7.58	14.83	3.22	21.74

Population Diversity of Eco Race Modal

Five thousand six hundred and fifty three (5643) nature grown Modal cocoons were collected from three eco pockets during the study periods. The colour polymorphism was observed in the cocoon population. Cocoons are predominantly blackish grey and yellow in colour occurring at a ratio of 82:18 and the male: female ratio was 63:37. Cocoons of different locations did not show any marked variation in cocoon characteristics indicating Modal population to be uniform in characters irrespective of its place of occurrence in the biosphere.

Plant Community Structure and Race-Food Plant Association

Studies on plant community structure were conducted in the identified pockets following quadrant method (10000 sq ft/ quadrant). Sal (*Shorea robusta*) dominated the area (72.70 to 83.95 %) followed by Asan (*Terminalia tomentosa*) (2.3 to 18.7 %). 1600 nature grown Modal cocoons collected with twigs of food plants from the forest area of the study sites were studied. Out of which 1552 (97 %) cocoons were Sal associated and 48 cocoons (3%) were Asan associated.

Grain age and Rearing Behaviour of Modal During Second Crop Season at Low Altitude Plain

Modal is mostly univoltine in nature and found in higher altitudes (above 150 m ASL) of Similipal Biosphere Reserve of Orissa. Breeding in nature takes place during March to May followed by a natural rearing. Cocoons in nature are available during July to August. When these cocoons are displaced from nature, these behave as bivoltine in low altitude plains, show moth emergence and breeding. A commercial rearing, thus was taken up in specific areas adjacent to peripheral biosphere zones during September to October resulting in production of cocoons during October to November. These cocoons locally known as "Bogai" are popular among the reelers but do not have any seed value due to continuous and erratic moth emergence during preservation periods. In order to exploit this elite eco-race commercially in other areas of low altitude plains, attempts were made to understand the grain age and rearing behaviour of Modal during second crop season (September to October).The nature grown Modal cocoons were collected from Similipal Biosphere reserve during the month of August of the study periods, i.e., 2017 to 2019 and subjected to indoor grain age at Regional Tasar Research Station (RTRS), Baripada (65 m ASL). Cocoons are sex separation (60:40) were woven into garlands and hung inside nylon net of 6' x 6' x 6' to increase mating. All recommended conditions for indoor grain age were followed during the entire grain age period. A total of three graina ges were conducted in August to September during 2017 to 2019.

The Dfls produced from the above grain ages were reared at Regional Tasar Research Station (RTRS) Farm, Rangamatia (65 m ASL) in the second crop season during 2017 to 2019. Asan plants at 8' x 8' spacing prunned during March and maintained under recommended package of practices were utilized for rearing worms after hatching were brushed on Asan plants in such numbers as to minimize handling. All precautionary measures were taken to restrict predator attack. Meteorological parameters were also recorded during the entire rearing period. A perusal of the data indicated moth emergence ranged from 59 to 74.85 %. Emergence of male moths varied from 30.9% to 36% and female moths from 30 to 44%. Coupling performance was found to be low in all the grain ages studied which ranged from 25. 75 to 35%. Though there were no traces of pebrine in any of the samples, few layings were found to be low in fecundity. As the coupling behaviour was not satisfactory, dfl recovery was found to be low, i.e., cocoons: Dfl ratio 9:1 to 25:1.

Corresponding to the grain ages, three rearings were also conducted during September to October season.

Average fecundity ranged from 178 to 232. Hatching of eggs was found to vary from 67.4 to 71.4%. Average larval weight ranged from 27.0 to 34.3 gm. The larval duration was from 36 to 40 days. Cocoon yield was very low ranging from 2 to 7 cocoons per DFL, with a very low effective rate of rearing of 1.5 to 5.7%. The shell ratio (SR%), was however, found to be 10.0 to 14.6%.

Indoor grain age of Modal was not found to be satisfactory at low altitude. The race being endemic to Similipal Biosphere Reserve and enjoying all the conducive climatological conditions, perhaps found it difficult in acclimatizing to low altitude plains where frequent fluctuations in temperature and humidity were experienced. Further, being completely wild in nature, the eco-race was not amenable to human interference and handling as is generally done in indoor grain ages. The above factors in combination might have influenced the grain age performance of the eco race resulting in lower coupling rate and poor dfl recovery. This is further corroborated by an in situ grain age conducted at a peripheral Similipal forest area during the same season in 2009 where 84% moth emergence was recorded with a coupling rate of 58% and cocoon: DFL of 4.7:1.

Table 6: Meteorological parameters during rearing seasons (September to October)

Sl. no	Year	Maximum temperature (^{0}C)		Minimum temperature (^{0}C)		Relative humidity (%)	
1		Average	Range	Average	Range	Average	Range
2	2017	36.0	32-37	25.0	23-28	75	68-93
3	2018	36.6	31-39	23.3	20-27	81	47-92
4	2019	32.0	28-38	21.6	21-29	89	59-100

Table 7: Grain age behaviour of Modal at low altitude plains (65 m ASL) Season: August-September

Sl. no	Year	Cocoons processed	Moth emergence		Total	Couplings obtained	DFLS produced	Cocoon: DFL ratio
			Male	Female				
1	2017	375	105 (32%)	116 (31%)	211 (59%)	30 (26%)	15	25:1
2	2018	350	126 (36%)	106 (30%)	232 (66%)	37 (35%)	35	10:1
3	2019	680	210 (30.9%)	299 (44%)	509 (74.85%)	77 (25.75%)	75	9:1

Table 8: Rearing behaviour of Modal at low altitude (65 m ASL) during September to October

Sl no.	Parameters	Periods		
		2017	2018	2019
1	No. of Dfls reared	6	35	75
2	Average fecundity	178	214	232
3	Percentage of hatching	67.4	68.5	71.4
4	Average larval weight (gm)	34.3	31.8	27.0
5	Larval duration (days)	38	36	40
6	Cocoons harvested	41	219	182
7	Effective rate of rearing (%)	5.7	5.3	1.5
8	Yield/Dfl	7	6	2
9	Cocoon weight (gm)	11.5	9.6	12.8
10	Shell weight (gm)	1.68	0.96	1.82
11	SR (%)	14.6	10.0	14.2

Similarly, poor rearing performance of the eco race may be attributed to the above factors. The race was found to be highly susceptible to diseases like virosis and bacteriosis due to frequent fluctuation in temperature and humidity resulting in crop failure at times. The deterioration in all the economic characters of the cocoons was observed when reared at low altitude. While nature grown Modal cocoons show an SR% of 22 to 28%, cocoons produced at low altitude during second crop season showed a maximum SR of 14.6%. The study, thus, indicated that the eco race Modal was very sensitive to changes in climatological conditions and human interference. Second crop season (September to October) which experienced wide and frequent fluctuations in climatological conditions was not found to be suitable for Modal raering in low altitude areas. More studies are required to understand the reasons for deterioration of the economic characters of Modal cocoons produced in this rearing season at low altitude.

Development of Race Conservation Technique

Tasar eco race Modal is unique in its behaviour. In nature it is predominately univoltine. The breeding takes place during March to May and a natural rearing is followed. Cocoons are available during July to August. These undergo diapause till next March and exceptionally a lesser percentage of cocoons show moth emergence during August to September. But no evidence is available of a following crop. On the other hand, cocoons displaced from nature showed moth emergence followed by breeding and a commercial crop on Asan and Arjun, locally known as Bogai. These Bogai cocoons, thus, produced do not reverse back and are not recycled.

Modal cocoons in nature are very tough and hard shelled with thick peduncle and a clear round ring. They are bigger in size and show colour polymorphism, blackish grey dominating the population. In nature, Modal is predominantly Sal based. Based on the experimental observations a conservation technique for Modal has been developed which is presented below.

Table 9

1. Seed	
Time of seed collection	February to March from Sal forest after leaf fall. Long distance transportation is avoided.
Area of seed collection	Transitional to buffer zones of Similipal Biosphere Reserve
Cocoon characters	-
Cocoon colour	Blackish grey
Cocoon stiffness	Hard and tough uniform cocoons
Cocoon size minimum	Length: 5.0 cm; Breadth: 3.0 cm
Peduncle length	4.3 to 6.5 cm
Peduncle ring	Clear, round and thick ring, diameter 1.08 to 1.14 cm
Cocoon weight minimum	Female – 13.00 gm, Male - 9.00 gm
SR% minimum	Female – 18%, Male – 21%
2. Cocoon preservation cum grain age	
Place of preservation and grain age	In transitional to buffer zones. It can also be done inside a grain age house if available
Method of preservation	In hanging garlands inside a nylon net
Time of grain age	March to May
Oviposition	In earthen cups
Fecundity	Above 230 eggs/dfl
Egg disinfection	No disinfection or surface sterilization is required. Eggs can be washed with light soap to remove meconium and to avoid fungal infection
3. Rearing	
Season of rearing	Preferably May to June. If climatic conditions are congenial, rearing can also be taken up in April. Rearing during August to September may be avoided due to pests, predators and diseases
Place of rearing	in situ rearing preferably in the transitional areas
Food plant	Sal (*Shorea robusta*)
Method of brushing	Worm brushing on Sal trees of medium height in compact patches.
Time of brushing	Early in the morning and late afternoon.
Method of rearing	Natural rearing with minimum interference.

Conclusion

India continues to be the second largest producer of silk in the World. The total raw silk production in the country in 2015-16 are28523 MT. Modal is a unique Eco race found in Similipal Biosphere Reserve of District Mayurbhanj Odisha. It predominantly feeds on sal producing very high quality of cocoons rich in silk content. Besides the fecundity of modal is comparatively more than the ruling Daba. The tribal tasar rearers in and around Similipal Biosphere Reserve, Mayurbhanj, Odisha mainly depend on the wild modal cocoons. Due to higher silk yield and higher cost of cocoon in the market, people collect it from the forest and sale it for profit. However due to certain reason this trend is declining in the natural population of Similipal Bioreserve. Thus there

is an urgent need to protect it and to develop a well-organized system to make it sustainable for the rural development at the time of alarming trend to decline. However it is required to trace the appropriate forward and backward linkages with necessary technical backup which must provide a gateway to the future prosperity of this culture.

Reference

1. Benchamin KV, Jolly MS. Principles of silkworm rearing, Proc. Seminar on "Problems of Sericulture", Ed. S. Mahalingama, Madras, 1986, 63-108.
2. Jolly MS. A new technique of tasar silkworm rearing. Indian Silk,1972:11(2):5-8.
3. Ojha NG, Sharan SK, Rai S, Pandey PN. Studies on the sex wise consumption and utilization of the leaves of different food plants in different eco races of the tropical tasar silkworm, *Antheraea mylitta* Drury during fifth instar of the first crop. Proc. 3rd Int. Conf. on wild silkmoth, Japan and Central Silk Board, India,2000:5:241-245.
4. Ojha NG, Sinha SS, Singh MK, Sharan SK. Rearing and cocooning of tropical tasar silkworm, *Antheraea mylitta* in indoor condition. Indian J. Wild Silkmoth and Silk,1994:1(2):257-260.
5. Narain R, Rath SS, Prasad BC, Alam MO, Rath PC, Mishra D *et al*. Integrated package for tasar seed cocoon production and preservation. Indian Silk,2004:42(11):17-18.
6. Mathur SK, Singh BM, Sinha AK, Sinha BRRP. Integrated package for rearing of *A. mylitta* D. Indian Silk,1998:37(2):15-18.
7. Mathur SK, Singhvi SR, Kushwaha RV. Effect of prolonged high temperature and low humidity on fertility and fecundity in tropical tasar silkworm. Indian Silk,2005:43(12):18-19.
8. Mohan Rao K, Satapathy B, Mohapatra SC, Kulshrestha V. Grain age and rearing behaviour of Modal in *ex situ* conditions. Indian Silk,2004:43(2):13-14.
9. Sinha RK, Kulashrestha V, Mishra PK, Thangavelu K. Constraints of tasar industry in India. Indian Silk,1992:3(1):31.
10. Naveen SP, Savanurmath CJ. Innovations in indoor maintenance of tasar silkmoth, *Antheraea mylitta* Drury. Proc. 3rd Int. Conf. on wild silkmoth, Japan and Central Silk Board, India,2000:5:61-65.
11. Siddiqui AA, Sharma AK, Chauhan TPS, Khatri RK. Breeding park for tasar silkworm in Uttaranchal: a feasibility. Indian Silk,2006:45(7):12-15.
12. Hamamura Y. Food selection by silkworm larvae. Nature,1959:183:1746-1747.
13. Danielvskii AS. Photoperiodism and seasonal development of insects. Oliver and Boyd, London, 1965, 1-283.
14. Dash AK, Nayak BK. Studies on some oviposition behaviour of Godamodal eco race of Indian wild tasar silkmoth *A. paphia* L. (Lepidopters: Saturniidae). Proc. 1st Int. Conf. on wild silkmoth, China, No,1990:118:5.
15. Mohanty PK. Tropical Tasar Culture in India. Daya Publishing House, New Delhi, 1998a, 1-153.
16. Chakravorty R, Das BC. Studies on diseases of tasar food plant and their control measure. Annu. Rept. Central Tasar Research, Ranchi, India, 1979, 139-141.