FURTHER OBSERVATIONS ON THE BIONOMICS OF THE EARLY STAGES OF TORRENTIAL LEPIDOPTERA FROM INDIA.

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(PLATE VI.)

Though the existence of aquatic Lepidoptera has been known for a long time, our knowledge of the torrential forms is comparatively recent. In 1909, Poulton [1] published an account of the life-history of a torrential species—*Aulacodes simplicialis* Snell—based on observations made in China by Kershaw and Muir. Five years later, Llyod[2] discovered in America a species of *Elophila* with similar habitat and, in 1927, I[3] directed attention to the occurrence of Lepidopterous larvae and pupae in the hill-streams of India. It was pointed out that similar larvae had previously been collected from India by Drs. F. H. Gravely and B. N. Chopra, and were present in the collection of the Zoological Survey of India. In 1928, Pruthi [4] published certain observations on the biology and morphology of the immature stages of *Aulacodes peribocalis* Wlkr. Some of the views expressed by Pruthi are at variance with those of mine, but as the proper elucidation of the subject required further observations in the field, no reference was made to Pruthi's article in my monograph[5] on the "Ecology, Bionomics and Evolution of the Torrential Fauna." Since 1930, the bionomics of these insects has been studied by me on three different occasions in the Tista Valley where torrential Lepidoptera are found in great abundance in suitable places in all the streams of the Valley. It has thus been possible to check and verify observations made at different places on different occasions and the results given below are based on a thorough and extensive investigation of the problem. Some of these results have been briefly referred to in my account of the "Silken Shelters of Torrential Insect-Larvae "[6].

HABITAT.

In February 1927, torrential Lepidopterous larvae were found by me in great abundance in the Nerbuda river near Pharisemar in the Rewa State, Central Provinces. In places the bed of the shallow stream was stony without any large boulders and the current was fairly rapid. The stones had a profuse growth of filamentous algae and such places were the chief haunts of the larvae of *Aulacodes ;* their silken shelters were covered with a rich growth of algae. In other parts of the river, where the rocks were without any visible vegetation but had a cover of slimy

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[1] Poulton, *Trans. Ent. Soc. London,* pp. xl-xliv (1909).
[2] Lloyd, *Journ. N. Y. Ent. Soc.*, XXII, pp. 145-152 (1914).
[3] Hora, *Journ. Bombay Nat. Hist. Soc.*, XXXII, pp. 124-126 (1927).
[4] Pruthi, *Rec. Ind. Mus.*, XXX, pp. 353-356 (1928).
[5] Hora, *Trans. Roy. Soc. London,* (B) CCXVIII, pp. 201, 202 (1930).
[6] Hora, *Current Science,* I, p. 341 (1933).

matter, only a few larvae in suitable situations were found. In places the bed of the stream consisted of a single, flat rock over which the water flowed with considerable speed. Such places were also found to be the favourite resorts of the *Aulacodes* larvae. These observations on the habitat of the larvae have been confirmed by visits to the Tista Valley. It was found that the larvae prefer rapids, but are not usually found in very fast currents, such as on the lips of falls or rocks at the bases of water-falls.

Smooth rocks are usually devoid of silken shelters, but only rough rocks, especially those with small fissures and crevices, are preferred by the Lepidopterous larvae. The young larvae take shelter in these unevennesses of the rocks and cover themselves with silken sheets which they go on extending according to their requirements. As a rule, the silken shelters are more extensive on bare rocks than on algae-covered rocks. The significance of this is explained later (p. 343).

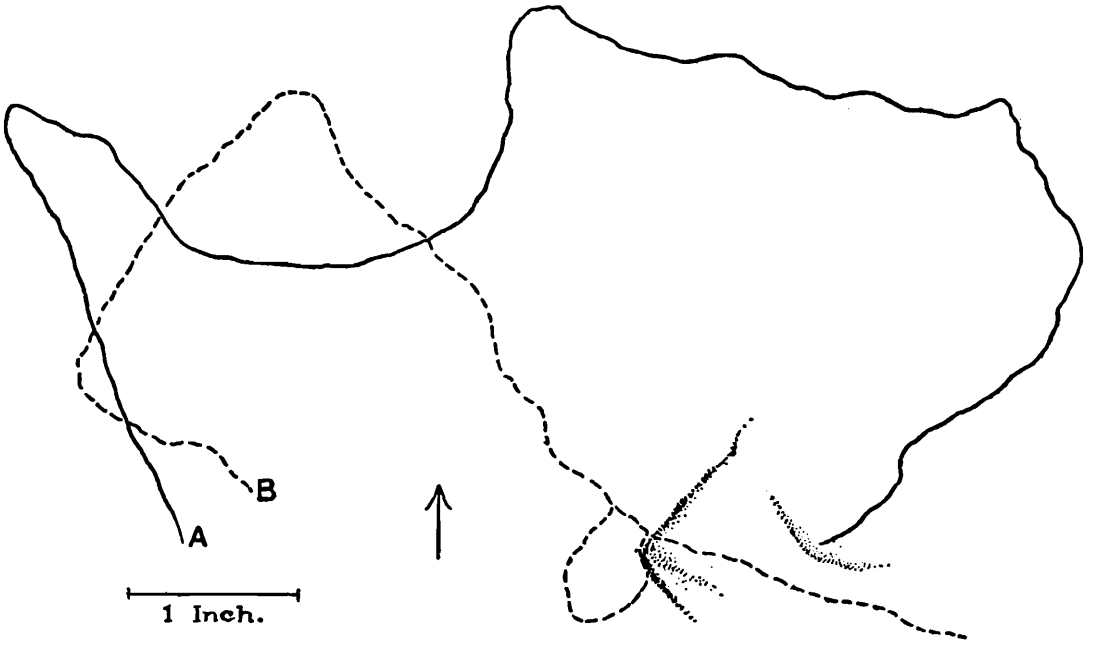
Apparently, therefore, there are two factors which determine the presence or absence of Lepidopterous larvae in a suitable stream, (i) the rapidity of the current and (ii) the nature of the surface of the rocks forming the beds. Thus the torrential Lepidopterous larvae and pupae show a marked habitat preference. In suitable places, I have found small pieces of stones with six or seven larvae (plate vi, fig. 2) and in the Lupchu-Jhora under the bridge on the Rangit-Darjeeling Road I found about 60 pupal cases on a rock with a surface of about 2 square feet exposed to the current. The rock was lying on the edge of the stream and only a portion of it was being washed by a moderate current. The biological factors, such as food, enemies, etc., have not been considered in the above account.

Silken Shelters.

The silken shelters are turgid and fully distended under water in swift currents, but they collapse partially when taken out. I have explained elsewhere (*op. cit.*, 1933) the physical principles that bring this about, but it is necessary to reiterate that the water flows with greater speed over the shelter than underneath the silken sheet. This differential rate of flow produces low pressure above the shelter and pulls it upwards.

Efforts were made to study the process of manufacture of the silken sheet by the larva, but it was difficult to observe the animal under natural conditions for a long period. A suitable piece of stone was selected, and all the larval shelters were removed from it. It was then placed in its old position in a rapid. After obstructing the current from flowing over this piece, a larva was placed on it and as soon as it had secured a firm hold on the stone, the current was allowed to run over it with full force. The animal at first crawled towards the leeward edge of the stone and then turned back from the edge. On finding a groove in the stone, it lay there quietly. A second larva was then placed on the same stone and it behaved in the same way, except that on finding a groove, it did not abandon its search for a more suitable place. It made periodic excursions, but finding no other place more suitable, it returned to the

same groove. It became dark and the observations could not be continued, but a few larvae were brought to the camp and left in water in petrie dishes. By morning all the larvae, whether young or old, had formed silken shelters (plate vi, figs. 1 & 3) of a somewhat flimsly nature between the bottoms of the dishes and their walls. In manufacturing the sheets the larvae must have touched the bottoms and the sides of the dishes alternately in a criss-cross fashion so that a meshed pattern was formed by the salivary threads. The older larvae spun a more



Tracts of two Lepidopterous larvae (A and B) marked on a piece of stone as it lay in a rapid, Kalijhora stream, Tista Valley.

close-meshed sheet than the younger ones. The silken sheets (plate vi, fig. 6) of the natural shelters manufactured in the course of the swift currents are fairly thick and consist of several of layers of threads closely placed together in the manner indicated above. These sheets become covered with algae, Diatomes, slime and fine particles of sand, etc., that drift in the current and become fairly compact structures for the larvae to live in safety. The grooves on pieces of stones, no doubt, provide starting places for the manufacture of silken sheets.

At the time of pupation, a larva strengthens a part of the larval shelter which then becomes somewhat brownish in colour. The entire complicated structure of the cocoon[1], including the pillars, strands, etc., is manufactured with the help of the salivary secretion and is not due to any mineral deposition on the web. The cocoon was kept in strong nitric acid for several minutes and no effervescence was noticed. The cocoon did not suffer in any way by this treatment. The outer brownish wall of the cocoon (plate vi, fig. 5) is very thick and tough, almost leathery, and appears to be composed of several layers of silken sheets.

The above observations do not bear out Pruthi's statement that the " power of secreting silk for making a fresh shelter is very much limited "

[1] For the details of the structure of the cocoon, see Pruthi, *Rec. Ind. Mus.*, XXX, p. 355 (1928).

in mature larvae. In captivity, without food, the mature larvae manufactured shelters again and again though, through mere exhaustion, the mesh became flimsier with every fresh effort. The capacity for the production of silk is probably greatest in the larvae just before pupation.

Progression.

The caterpillar usually lies quietly under its silken shelter and I have never observed it moving about. If, however, it is disturbed, it moves from one part of the shelter to another and is very reluctant to leave it. When forced out or when the silken sheet is removed, the larva moves towards the under side of the rock, especially if the day light is strong. Progression is effected in the usual way with the help of the thoracic legs and the abdominal prolegs. The larva moves fairly quickly in a series of forward waves. In the case of larvae kept in a petrie dish, it was observed that they poured out salivary secretion along the paths (plate vi, figs. 1 & 4) of their progression, so that the claws of the thoracic legs and hooks of the abdominal prolegs could take a firm hold of the substratum. When a larva was lifted from a dish, a salivary thread was pulled out with it. It seems probable that in nature the caterpillar behaves like a *Simulium* larva which uses its hooks and salivary secretion for progression [1]; the latter helps in providing a secure substratum in which sharp points can be fixed. It also seems probable that, in nature, if a caterpillar is detached from its moorings, it hangs on to the rock by means of its salivary thread, by which it can probably crawl back to its shelter.

It is known that "tent-caterpillars" (*Malacosoma*, Family Lasiocampidae) lay out extensive paths of silky secretion over which they travel during their foraging expeditions. The silky secretion of the larvae of torrential Lepidoptera provides a suitable substratum on which the animal can progress securely and rapidly. I believe the larvae come out from underneath the silken sheets at night and wander about on it for feeding purposes (*vide infra*).

In a dish of water, when not crawling at the bottom, the larvae were observed to move fairly fast by means of the jerking movements of the body. There are no special organs for swimming and in nature the larvae probably never swim at all.

Food and Mode of Feeding.

Recently I [2] advanced the view that the silken shelters of torrential insect larvae serve to snare or entangle food particles. The extensive sheets of the Lepidopterous larvae, when examined under a microscope, show a large amount of extraneous matter entangled in them and some are even thickly covered with a growth of filamentous algae. It has further been observed that whether the algal growth on the silken sheets is visible or not, its presence is readily detected by keeping a silken sheet in spirit which dissolves the chlorophyll and turns green instantly. Mr.

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[1] Hora, *Phil. Trans. Roy. Soc. London*, CCXVIII, p. 213 (1930).
[2] Hora, *Cur. Sci. I.*, p. 341 (1933).

K. P. Biswas, Curator of the Herbarium, Royal Botanical Garden, Sibpore (Calcutta), has very kindly studied the algae growing on the rocks harbouring Lepidopterous larvae and compared them with the algae growing on or entangled in the sheets and also with those found in the gut of the larvae. The material was, in all cases, collected from the Kalijhora stream below the bridges in the Tista Valley. Mr. Biswas has informed me that the species of algae, Desmids and Diatomes obtained from the three sources are the same. When mature larvae were put in spirit, some ejected from the mouth bundles of long filamentous algae, and this leaves no doubt that the larvae feed on the food they find in their neighbourhood. From an examination of the gut-contents of several individuals, Pruthi[1] found that " they mostly consist of, besides water, extremely minute particles of vegetable matter which are quite different in appearance and size from those usually found in the gut of a typical terrestrial caterpillar. It is highly probable, therefore, that the larvae depend for their nourishment on *minute bits of algae suspended in the surrounding water* " (Italics are mine). Pruthi and I are in agreement in regard to the nature of the food of these larvae, but we differ regarding the mode of collection of the same by the larvae.

Among the brook inhabitants, which I have studied for a number of years, I have found that those which have taken to feeding on microplanktonic organisms, have evolved complicated and ingenious devices to strain minute particles of food out of the rushing current. Among insects[2] reference may be made to the snares of the water-spiders (*Hydropsyche*, Trichoptera), to the fans of Simulium (Diptera) and to the bristle-fringed legs of *Chirotenetes* (Ephemeroptera) and *Brachycentrus* (Trichoptera). Reference may also be made to the feeding mechanism of the funnel-mouthed tadpoles of *Megalophrys*[3]. The mouth-parts of the torrential Lepidopterous larvae " are exactly like those of typical terestrial caterpillar suitable for masticating tough leaves, etc." (Pruthi, p. 355). Thus there would seem to be no mechanism in the mouth-parts of these larvae to collect planktonic food, but there is no doubt that their larval shelters act as snares or gardens. The animals feed by making periodic excursions to the upper surfaces of the sheets; the under surface is usually devoid of vegetable growth. It is also possible that the larvae wander about at night on the parts of the rock in the vicinity of the shelters and pick up algae and other food material. In any case, the larva has to bite off its food from a solid substratum and not to pick up the floating particles.

In the parts of the streams where there is a rich growth of algae, etc., the silken shelters of the Lepidopterous larvae are small and covered with filamentous algae; whereas the shelters on the bare rocks are vast and extensive. This shows that with the presence of abundant food-material in the form of algae, etc., small sheets are enough to entangle sufficient quantities of food for the requirements of the larvae inhabiting them.

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[1] Pruthi, *Rec. Ind. Mus.*, XXX, p. 354 (1928).
[2] Needham & Lloyd, *Life in Inland Waters*, p. 365 (1916).
[3] Hora, *Rec. Ind. Mus.*, XXX, pp. 139-144 (1928).