Ecology of black flies (Diptera: Simuliidae) in Darjeeling area, India


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ABSTRACT

This paper incorporates observations on the ecology of sixteen species of black flies occurring in the Darjeeling area of India. Of the species of Simulium, himalayense was most abundant; rufibasis and grisescens moderately abundant; and dentatum, ramosum, nigrifacies and biforaminiferum confined to certain pockets of the area. Of the species of Eusimulium, praelargum was very abundant; gracilis moderately abundant; and purii, aureohirtum, nemovivagum and dasguptai almost rare. Of the species of Gomphostilbia, tenuistylum was moderately abundant, while darjeelingense and metatarsale were localized. The species of Simulium except nigrifacies and biforaminiferum selected rapid water; the species of Eusimulium, and biforaminiferum and nigrifacies, preferred very slow or sometimes quiet water, while the species of Gomphostilbia were often adapted to medium current for oviposition. Oviposition was exhibited by (i) freely dropping eggs from the air; (ii) tapping the abdomen through the water while hovering or (iii) while alighting; and by (iv) crawling under the water. The peak period of oviposition was normally in the evening before sunset. Hibernation was observed in the egg-stage in himalayense, rufibasis, grisescens (in a lowland river) and tenuistylum; and in the larval stage in praelargum, gracilis and probably grisescens (in upland streams). One generation per year was observed in tenuistylum; two generations in praelargum, gracilis and grisescens (in upland streams); three generations in rufibasis and grisescens (in a lowland river) and at least three generations in himalayense. Larvae of some species were found to remain in association with those of others, depending upon environmental conditions. Larvae of Eusimulium especially, almost always hid themselves under the substrata to get constant supply of sufficient oxygen from trickles of water they were found to inhabit.

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INTRODUCTION

Black flies are troublesome pests of man and animals in some parts of India\textsuperscript{1, 3, 4, 18, 28} and this necessitates ecological studies on these insects. Prior to the present investigation almost nothing has been known of the immature stages and, in general, of the ecology of black fly species in India. Mani\textsuperscript{17} and, Dubey and Kaul\textsuperscript{14} have given only some generalized ideas of torrenticolous insects, including black flies, mainly of the North-west Himalaya. A preliminary report on the ecology of black flies of the Darjeeling area has been made by Datta and Dasgupta\textsuperscript{9}. In this paper, observations are presented, whenever possible, on the distribution, oviposition, egg incubation and habitat preference of larvae and pupae of the species occurring in the Darjeeling area of India.

TOPOGRAPHY AND CLIMATE

The Darjeeling area defined here included Teesta Bazar (150 m), Pul Bazar (275 m), Rangeet (300 m), Badamtam (600 m), Singtam (750 m), Pankhabari (775 m), Tindharia (900 m), Kalimpong (1,190 m), Kurseong (1,350 m), Mungpoo (1,372 m), Happy valley (1,500 m), Takedah (1,500 m), Tung (1,500 m), Sueirel (1,520 m), Lebong (1,650 m), Manibhanjang (1,650 m), Sonada (1,660 m), Sukiapokhri (2,100 m), Kalpokhri (2,100 m), Gairabas (2,250 m), Birch Hill (2,250 m), Jalapahar (2,400 m), Ghoom (2,487 m), Tonglu (3,025 m), Sandakphu (3,580 m) and the adjoining localities within Darjeeling District. The entire area is rocky with deep valleys among towering hillslopes, often with deposited soil. The area is covered by variegated flora consisting of the lower monsoon forest, and the middle and upper evergreen forests with increasing \textit{Rhododendron} plants, and it abounds in pockets of watercourses of various nature from small trickles to a large plexus of rivers, mostly forming ideal breeding sites for black flies.

This area is a part of the eastern Himalaya and has very peculiar climatic conditions. The mean yearly maximum temperature is nearly 16° C and the minimum temperature nearly 10° C. January is the coldest month with the minimum temperature often falling below the freezing point. The humidity from June to September is near the saturation point but it is maximum in July. This area remains enveloped in thick clouds for much over half of the year and meets excessive rain-fall due to an uninterrupted sweep of moisture-laden south-west monsoon during the rainy season. It also experiences frequent snow-fall and good showers between December and March.
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Observations

Ecological observations on the sixteen named species so far described or recorded from the Darjeeling area by Datta are reported here subgenerically.

Simulium (Simulium) himalayense Puri

This is a wide-ranging and the most abundant species in the area (figure 1) and also in certain other parts of India. Females were observed ovipositing in varying breeding grounds from river to ditch. However, in no case did females lay eggs in a small trickle of water. Two methods of oviposition were observed in this species. Firstly, a group of five or six females hovered over stones, logs or sticks which were moistened or over-lain by a thin sheet of moving water with currents of 0-4-0.6 m/sec. Each female deposited eggs on the surface by tapping the abdomen briefly through the layer of water. If ovipositing females were disturbed by any means or they were washed off by the current, they soon came back to the original spot to lay eggs resulting in layers of egg-masses by these females on the same spot of the substratum. Secondly, females hovered about succulent plants beside the watercourse before eventually settling. They began to search for a suitable part of the plant which was splashed with water, and deposited eggs there, particularly on leaves which gradually submerged. Egg-laying occurred mostly just before sunset.

This species hibernated as eggs. Larvae were absent from mid-October. The first appearance of larvae was in early February but was delayed if the temperature of the water went down. The water temperature during hibernation varied between 0.8°C and 5°C and the temperature at which masses of eggs hatched, was 8°C-10°C. At least three generations occurred annually, of which first and second generations were prolonged.

Larvae and pupae occurred in moderately fast flowing watercourses having water currents of 0.5-0.8 m/sec., sometimes in association with grisescens, dentatum or very rarely with rufibasis. They were most frequent in clear water. They attached themselves to decaying leaves, twigs or decaying materials but rarely to green vegetation or stones.

Simulium (Simulium) rufibasis Brunetti

This species is moderately abundant in this area (figure 1) and mainly confined to North-east India. Females laid their eggs mostly in small upland streams, although a few ditches harbouried immature stages of this species. Females of rufibasis oviposited in shallow water. At the time of
Figure 1. Histograms showing comparative population density of sixteen species of Simuliidae based on field collections from the Darjeeling area of India (numerals on the ordinate denoting frequencies of specimens).

Oviposition, females in a group of two or three hovered about small plants including grass-blades by the side of the watercourse and after selecting a spot, each of the females simultaneously settled down separately on the plant. Ultimately they began to crawl to the parts of the plant just touching the surface of water where they laid their eggs dipping the abdomen into the water. They seldom oviposited on stones. Oviposition occurred in the late afternoon.

Hibernation occurred in the egg-stage. Larvae were absent from late October and appeared again in early March. The water temperature during hibernation was up to 6°C and was generally above 10°C when masses of eggs hatched. Three generations occurred per year.

Larvae and pupae were found to occur in rather slow watercourses having water currents of 0·3–0·5 m/sec., rarely in association with himalayense.
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or *dentatum* or with *darjeelingense*. They attached themselves to decaying leaves, twigs, green grasses or other leaves submerged in water.

*Simulium (Simulium) grisescens* Brunetti

This species is distributed almost all over India\(^24\) and is moderately abundant in this area. Females were observed laying eggs in both upland and lowland river, streams and rarely ditches with water currents ranging from about 0.3–0.9 m/sec. Two methods of oviposition were found in this species. Firstly, perhaps a dozen or so of females engaged themselves in flight, while they dropped eggs freely into the water approximately 2–3 metres away from the shore. Secondly, many of the females laid eggs, while alighted on the dark side of the logs or sticks, placed for crossing a wide stream. While ovipositing, the wings were held upwards and the hind legs were kept apart. The insect in this posture began to strike its abdomen against the log or stick in a regular rhythm. These substrata were often splashed with water and occasionally these eggs were washed away. If the insect was washed away during oviposition, it settled in another suitable spot and laid eggs. Oviposition occurred in the afternoon till sunset.

Overwintering in the egg-stage was observed in a lowland river but in upland streams hibernation might possibly occur in the larval stage. In the former case, larvae were absent from about mid-October and they reappeared in early February. The water temperature during hibernation varied between 1° and 6° C and temperatures above 8° C enhanced hatching. In the lowland river there were three generations annually and in upland streams probably two large generations.

Larvae and pupae were generally found in swift, strongly flowing clear water, sometimes in association with *himalayense*. They attached themselves to decaying leaves or twigs caught on obstructions in the current and rarely to aquatic vegetation or stones. It was curious to note that larvae of this species did not spread evenly over the substratum but crowded together in extraordinary dense masses. In the same way pupae accommodated themselves one on another irregularly, but often facing in the same direction.

*Simulium (Simulium) dentatum* Puri

The population of this species is very low in this area and mainly localized in certain pockets of the eastern Himalaya\(^23\). Experience in collecting led to the belief that this is an upland species. Females were not observed ovipositing and eggs are not definitely known. In one instance, a few egg-masses were found on stones in a moderately fast clear stream with a water
current of about $0.5 \text{ m/sec.}$, harbouring this species only and these egg-masses were considered to have been laid by this species. Hibernation in the egg-stage was quite probable. Larvae and pupae were collected along with those of *himalayense* and *rufibasis* in certain cases from decaying leaves and stones splashed with water both in stream and ditch. It was probable that oviposition occurred by tapping the abdomen through the layer of over-run water as in the case of *himalayense*.

**Simulium (Simulium) nigrifacies** Datta

This species is very rare and almost nothing is known of the biology of this species. In one instance, a single pupa was taken on a decaying leaf splashed with water of a small trickle (altitude 1,900 m) at Darjeeling on the 25th October, 1970.

**Simulium (Simulium) biforaminiferum** Datta

This is also a rare species. Oviposition is unknown. A few larvae and pupae were taken on stones and rarely on *Equisetum* plants in small trickles of water (altitude 2,031–2,050 m) with a water current of about $0.3 \text{ m/sec.}$ at Darjeeling. More pupae and fewer larvae were observed in these trickles till the middle of October but nothing is known after this time.

**Simulium (Simulium) ramosum** Puri

This species is localized in certain pockets of the Himalayas and is confined to uplands of this area. Oviposition is unknown. Larvae and pupae occurred in moderately fast clear streams having a water current of about $0.7 \text{ m/sec.}$ They attached themselves to decaying leaves. Larvae disappeared by about mid-October and reappeared in masses by early March when the water temperature rose above $7^\circ \text{C}$.

**Simulium (Eusimulium) praelargum** Datta

This species is so far known only from the eastern Himalaya and is very abundant in this area. It was adapted to survive much reduction in flow of water but disappeared when the flow stopped. Females oviposited in many breeding grounds mostly in forms of trickles of water with water currents of about $0.2–0.3 \text{ m/sec.}$ They did, however, oviposit in small streams with a more rapid flow above $0.3 \text{ m/sec.}$ but never in rivers with high velocity of water. At the time of oviposition, females, often in groups of two or three, crawled beneath the water to lay masses of eggs on the under-
surface of decaying leaves. Females were presumed to have oviposited also on the water-splashed stones, because a few egg-masses were noted under stones in a few trickles inhabited only by this species. Egg-laying began in the early afternoon, probably because of their occurrence in dark areas due to tall trees, and continued till sunset.

This species hibernated as larvae which hatched by November. Pupae first appeared in late February but were delayed if the water temperature went down. The water temperature during hibernation varied from 1° to 6° C and most pupation occurred at temperatures from 8° to 10° C. There were two generations per year, of which the first was prolonged.

Larvae and pupae, scattered all over the substrata, were found on decaying leaves or very rarely on stones in trickles of water mentioned above. These occurred sometimes in association with those of gracilis.

*Simulium (Eusimulium) gracilis* Datta

This is also known only from the eastern Himalaya and is moderately abundant in this area. It is also adapted, as in *praelargum*, to survive much reduction in flow but it disappeared when the flow stopped. Females were observed ovipositing mostly in trickles of water but never in large streams or rivers with high water velocity. This species laid eggs on the underside of the decaying leaves, as did *praelargum*. In addition, it oviposited also on the water-splashed grasses occurring beside watercourses. Ultimately, the grass-blades submerged. This species was almost always found to remain in association with *praelargum* so that it was adapted to the ecological conditions of *praelargum*. Oviposition of the two species occurred simultaneously. This species also hibernated as larvae which hatched in late November. Pupae first appeared in early March. Two generations occurred per year as in *praelargum*.

Larvae and pupae were scattered on certain foci of the substrata, such as decaying leaves or rarely on grass-blades in trickles. In rare cases, however, this species was found to remain in association with *purii* in small streams with a water current slightly above 0.4 m/sec. at a lower altitude.

*Simulium (Eusimulium) purii* Datta

This species as also of the following species of the subgenus *Eusimulium* Roubaud is rare. This species occurred in small streams or trickles (water velocity 0.4–0.6 m/sec.) of lower altitude than those of *praelargum* and *gracilis*. Oviposition is unknown. Larvae and pupae were attached to decaying leaves, rarely in association with those of *gracilis* as cited above.
Simulium (Eusimulium) nemorivagum Datta

This seems to be an upland species and is confined to certain foci of the area of investigation. Little is known about its biology. This species was, so far, found only in trickles of water with water currents of about 0.3–0.5 m/sec. Larvae and pupae were taken on stones and leaves, rarely in association with those of an allied undescribed species.

Simulium (Eusimulium) dasguptai Datta

This species appears to be an upland species and is limited only to certain pockets of the area. Ecological conditions were believed to be the same as for nemorivagum. Larvae and pupae were collected only from stones, rarely in association with those of an allied undescribed species.

Simulium (Eusimulium) aureohirtum Brunetti

Although this species is rare in this area (cf. figure 1), it is well represented almost all over India. In this area, it is a lowland species and was the only species which could live in almost stagnant water containing various kinds of suspensoids. Oviposition is unknown. Larvae and pupae occurred only in trickles and small streams. They attached themselves frequently to grasses in water courses and were usually the pupae covered with fine silt.

Simulium (Gomphostilbia) tenuistylum Datta

This is a moderately abundant species in this area (cf. figure 1). Females were observed ovipositing in certain small streams, ditches and trickles of water with water currents of about 0.3–0.7 m/sec. This species appeared to be specific in its choice of substrata, laying its eggs exclusively on green vegetation, mainly grasses. Parts of grass-blades, which simply floated on the surface of water, were used as substrata. Females flew over the floating grass-blades for some time and then settled on these blades where they laid their eggs in masses. When they were disturbed by the current of water, they began to fly and after some time they settled again to oviposit on the same spot. Oviposition occurred in the early evening.

The species overwintered in the egg-stage. Larvae were absent from November and new larvae appeared in May. The water temperature during hibernation varied between 0.8°C and 6°C, and when most eggs hatched it was 7–10°C. Only one prolonged generation occurred yearly.
Larvae and pupae were attached to green vegetation, or rarely to decaying leaves, in clear water.

*Simulium (Gomphostilbia) darjeelingense* Datta

This is a rare species in the area. Oviposition is unknown but females might lay their eggs on green vegetation, mainly grasses and follow the method of *tenuistylum*. Pupae were found to occur on green grasses only in slow upland water-courses having water currents of about 0.3–0.5 m/sec., rarely in association with *rufibasis*.

*Simulium (Gomphostilbia) metatarsale* Brunetti

This species is very rarely found in this area and appears to be a lowland species. A few pupae were taken on decaying leaves from a small stream at Singtam (altitude 750 m) on the 23rd May, 1971. Details of the biology of this species are unknown.

**DISCUSSION**

The present investigation of about four years reveals that simuliiid species of which the immature stages have adapted themselves to varied environmental conditions, such as, changes in volume of water, velocity of current, oxygen content of water, transparency of water, temperature, silting and light intensity, are abundant and widely distributed. This is the reason for the wide distribution and abundance of *himalayense* and *grisescens*. Usova, while working in Karelia and Murmansk region (USSR), has reported that simuliiid distribution is sometimes influenced by all factors together and sometimes by only one or more than one. Although *aureohirtum* is widely distributed, it is not abundantly available only because of its peculiar choice of ecological niches. Of the other species in the area, for which knowledge of distribution is limited, at least a few may eventually be shown to have a wider distribution.

Datta and Dasgupta in a preliminary report have already indicated that the species of the subgenus *Simulium* Latreille select rapid water for oviposition, while those of the subgenus *Eusimulium* Roubaud prefer slow water and the species of the subgenus *Gomphostilbia* Enderlein water with medium to slow current. This investigation implied that a few species of *Simulium*, such as, *nigrifacies*, *biforaminiferum* and probably also *rufibasis*, could survive a great reduction in the flow of water as *S. (E.) ornatipes* Skuse does in Queensland. It is curious to note that *aureohirtum* could survive...
almost still water probably as in the case of S. (E.) ruficorne Macquart reported by Crosskey\textsuperscript{2}. Generally, however, black flies oviposited in water with currents of $0.3-0.9$ m/sec.

Oviposition of black flies of this area was performed by four methods: (i) by freely dropping eggs from the air; (ii) by tapping the abdomen through the water while hovering; (iii) by tapping the abdomen into the water while settling on the substratum; and (iv) by crawling under the water. Davies and Peterson\textsuperscript{12} have indicated that there is an evolutionary sequence of oviposition in the Ontario black flies in that females of Prosimulium Roubaud, Cnephia Enderlein, and some Simulium species drop eggs into the water while flying and other Simulium species oviposit on water-covered surfaces either while flying or while landing, depending on conditions. Although most of the species, namely, himalayense, grisescens, rufibasis, gracilis, tenuistylum and probably also praelargum and darjeelingense oviposited on water-covered surfaces while alighting, grisescens and probably a few other species also oviposited freely in the air which is considered to be a primitive method\textsuperscript{12}. Oviposition from the air, however, occurred generally in the water with a rapid current while oviposition under the water occurred where current was almost quiet, as has also been reported by Usova\textsuperscript{30}. It was observed that praelargum and gracilis crawled upon the substrata submerged in water to lay their eggs. Ussing\textsuperscript{31} and Rubtzov\textsuperscript{27} have reported that entry into the water for oviposition is obligatory for Eusimulium latipes (auct. not Meigen), an allied species of gracilis but Zahar\textsuperscript{33} has observed oviposition of latipes in Scotland on water-splashed leaves. It is probably reasonable to believe that latipes, gracilis and possibly purii, another allied species of which oviposition is unknown, lay their eggs in both the methods which are very nearer to each other in the evolutionary sequence\textsuperscript{13}. According to Davies and Peterson\textsuperscript{12} mainly the species of Eusimulium oviposit on water-splashed surfaces while in flight but in this investigation probably all the species of Eusimulium, Gomphostilbia and most of the species of Simulium occasionally or always oviposited on alighting and a few species of Simulium, such as, himalayense and probably dentatum also while hovering. It is interesting to note that tenuistylum and probably darjeelingense also are very much selective in choice of substrata in that the species laid eggs on green vegetation as in the case of S. (S.) venustum Say, reported by Davies and Peterson\textsuperscript{12}. However, oviposition attained itself to its peak in the evening before sunset and declined with the fall of night in clear weather but it might be earlier on overcast days.

Edwards\textsuperscript{15}, while working with the British Simuliidae, for the first time has pointed out that black flies may overwinter in the egg-stage. Sub-
sequently, it has been found that many species of *Simulium* all over the globe hibernate in the egg-stage\textsuperscript{11,13,20,29,30,32}. In the Darjeeling area, some species of *Simulium*, such as, *himalayense*, *rufibasis*, *grisescens* and also probably *dentatum* at least and *S. (G.) tenuistylum* hibernated in the egg-stage. Their larvae were absent from mid-October or November until spring or late summer subject to specific variations. The species of *Eusimulium*, such as, *praelargum* and *gracilis*, and probably a few other species also including *S. (S.) grisescens* in the upland streams hibernated in the larval stage and their pupae appeared from late February to early March of the following year, subject to specific variations. These variations were again influenced by the temperature of the water as well as of the atmosphere. According to Rubtzov\textsuperscript{26} eggs of the Siberian black flies hatch at temperatures of water not below 4.5° C. Although in this investigation the range of temperature for hatching could not exactly be indicated, the optimum temperature for hatching as 7°–10° C and that for hibernation as 0.8°–6°C were recorded from the Darjeeling area. Each of *rufibasis* and *grisescens* (in the lowland river) showed three generations per year, *himalayense* at least three, each of *praelargum*, *gracilis* and *grisescens* (in upland streams) two, and *tenuistylum* one, while nothing is known of the others. The duration of a generation depends primarily upon the temperature of the water in which the immature forms reside but since the recording of the temperature was incomplete in this study, the detailed impact of water temperature on the duration of a generation requires further studies.

Larval association is another interesting feature in the *Simuliidae*. Larvae of different species associate themselves in certain common foci and this is probably due to the physical nature of the substratum and the chemical composition of the water they inhabit. Peterson\textsuperscript{19} has found larvae of the Utah black flies to occur on the undersurfaces of the sticks and leaves and, he has explained this occurrence probably as a mechanism to escape the sediments that have tended to accumulate on the upper surfaces. This may hold good for simuliiid larvae which inhabit watercourses with heavy current or directly exposed to full sun. But simuliiid larvae, particularly of *Eusimulium* which generally inhabited trickles of water, nearly free from silt, almost always hid themselves under the substrata. These trickles had feeble water current and, therefore, there was the least possibility of accumulation of sediments on the substrata. Moreover, these watercourses were prohibited from penetration of direct sunlight due to tall trees and were dark for the whole day. Thus, it was reasonable to believe that simuliiid larvae in these watercourses got constant supply of sufficient oxygen while they attached themselves to undersurfaces of the substrata.

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REFERENCES

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