Micro-distribution of *Simulium ochraceum* Walker (Diptera: Simuliidae) larvae in relation to stream depth and current velocity*

Yoichi YAMAGATA***, **** and Akihiro KANAYAMA***, ****

**Laboratorio de Investigación Científica para Control de la Onecercosis, SNEM, 5a. Avenida 11-40, Zona 11, Guatemala, Guatemala

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Key words: *Simulium ochraceum*, distribution, larva, stream depth, current velocity.

Abstract: In a quadrat sampling made in a 2.4-m stretch, *Simulium ochraceum* larvae were recovered only from shallow rapids. Lead plates were designed for collecting larvae attached on them. The highest larval density was recorded from the lowest depth (0.2-2.0 cm) and the highest velocity (41-66 cm/sec). The density increased with velocity increment, but decreased with depth increment. No larva was recorded in the stream of the current velocity less than 10 cm/sec. Comparing among the five sampling stretches of 20 m each, the increase in discharge was associated with increase both in depth and current velocity, but decrease in larval density, while increase in slope was associated with decrease in depth but increase in both current velocity and mean larval density.

INTRODUCTION

Larval distribution of 38 Guatemalan species of blackflies was extensively studied by Dalmat (1955), who showed that *Simulium ochraceum*, the principal vector of onchocerciasis in Guatemala and Mexico, prefer infant to young streams with small discharge and depth. In 1975, the Guatemala-Japan Cooperative Project on Onchocerciasis Research and Control was commenced in Guatemala and larviciding operation was planned against *S. ochraceum*. For the purpose of establishing an effective and economic scheme of larviciding operation, studies were made on larval distribution in relation to various ecological factors in different scales. In the first study of the series made in an area of 477 km², Yamagata *et al.* (1984) showed that *S. ochraceum* larvae are bound to particular geologic formations rich in perennial streams, and that they breed almost exclusively in the upstream parts of the perennial streams. In the following study, Yamagata (1984) defined the sampling unit as 20 m along streams, and demonstrated that larvae of *S. ochraceum* prefer particular combination of large chan-
nel slope (20-40°) and small stream discharge (0.3-3 l/s). Such a condition was most frequently found at upstream parts.

As the third part of the series, the present study describes micro-distribution of *S. ochraceum* larvae within 20-m stretches. Dimension of a sampling unit was as small as 20 cm × 20 cm in the quadrant method or 2 cm × 5 cm in the substrate method. Among the factors measurable in the field, stream depth and current velocity were measured, because they were most variable between sampling units, and thus, most likely to affect the larval distribution in such a small scale.

In general, both stream depth and current velocity increase as the discharge increases. In a stream with uniform discharge, velocity becomes greater but depth becomes smaller as the channel slope increases. In the present study, mean depth, mean velocity and mean larval density were compared among sampling stretches in relation to their slope and discharge.

**Materials and Methods**

**Quadrat sampling**

Sampling was made in July 1982 in a 2.4-m stretch of a perennial stream with 0.95 l/s discharge and 10° slope, in the Rincon valley, Municipality of Villa Canales, Department of Guatemala. The sampling stretch was divided into 34 quadrats measuring 20 cm × 20 cm each. Stream substrates (stones, sands and organic debris) from each quadrat were collected in a plastic bag and transported to the laboratory. In the laboratory, immature blackflies were removed from the natural substrates and preserved in screw vials with 70% ethanol solution. The immatures were identified under binocular microscope.

Plan and profile of the sampling stretch were made by measuring the vertical distance from a horizontally fixed grid with 10 cm × 10 cm quadrats to both the water surface and stream bed. Current velocity was measured with a propeller current meter (Kenek VC-301, Keisokugiken, Tokyo). The axis of the four-winged propeller (20 mm in diameter) was placed 1 cm above the stream bed at the center of each quadrant.

**Sampling with artificial substrates**

Larval sampling with artificial substrates was made from June to September, 1982 in Rincon valley. Lead plates measuring 5 cm long, 2 cm wide, 2 cm thick, and weighing about 13 g, covered with yellow plastic insulating tape, were used as artificial substrates. They were left during two to five days on the stream bed of five sampling stretches each consisting of 20 m in length. The plates were recovered individually into plastic bags, and transported to laboratory. Immediately after recovery of a lead plate, stream depth and current velocity were measured on a dummy plate which replaced the recovered one. The same current meter was used. In the laboratory, the lead plates and plastic bags were examined under binocular microscope and immatures were counted for species.

**Results**

**Quadrat sampling**

Of a total of 34 quadrats, four (11.8%) were positive of *S. ochraceum*, from which 16 larvae and eight pupae were recovered. Those *ochraceum*-positive quadrats recorded small depth (1-3 cm) and large velocity (19-49 cm/s), while the negative ones recorded wider range of depth (1-9 cm) and smaller velocity (3-17 cm/s) (Fig. 1).

**Sampling with artificial substrates**

Of a total of 258 lead plates recovered from five sampling stretches 132 (51%) were positive, from which 442 *S. ochraceum* larvae were recovered. While the whole plates recorded the range of 0.2-9.8 cm in depth and 4-66 cm/s in velocity, those infested with *S. ochraceum* were found at 0.2-6.0 cm in depth and 12-66 cm/s in velocity.

Geometric mean density of *S. ochraceum* larvae were calculated by means of log (n + 1) transformation for each of the combined classes of the depth in 2-cm interval and the current velocity in 20-cm/s interval (Table 1). For a given depth class, the mean larval density increased with incre-
Fig. 1 Plan and profile of the stretch of a stream where quadrat sampling was made. Arrows show direction and velocity of the current. The quadrats with thick arrows were positive of *S. ochraceum*, and those with thin arrows were negative. Curves in the plan show the stream depth in cm.

Table 1 Geometric mean density of *S. ochraceum* larvae on lead plate (cm⁻²) in relation to stream depth and current velocity. Figures in parentheses show the number of examined plates.¹)

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Velocity (cm/s)</th>
<th>4-20</th>
<th>21-40</th>
<th>41-66</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2-2.0</td>
<td>0.094 (55)</td>
<td>0.169 (59)</td>
<td>0.217 (7)</td>
<td>0.134 (121)</td>
<td></td>
</tr>
<tr>
<td>2.1-4.0</td>
<td>0.020 (25)</td>
<td>0.092 (44)</td>
<td>0.119 (17)</td>
<td>0.072 (86)</td>
<td></td>
</tr>
<tr>
<td>4.1-6.0</td>
<td>0.016 (17)</td>
<td>0.037 (26)</td>
<td>0.041 (2)</td>
<td>0.029 (45)</td>
<td></td>
</tr>
<tr>
<td>6.1-9.8</td>
<td>0.000 (9)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.000 (9)</td>
</tr>
<tr>
<td>Total</td>
<td>0.051 (106)</td>
<td>0.109 (129)</td>
<td>0.134 (26)</td>
<td>0.085 (261)</td>
<td></td>
</tr>
</tbody>
</table>

¹) Geometric mean was calculated by log *(n+1)* transformation.

Effect of channel slope and stream discharge on stream depth, current velocity and larval density

Table 2 shows the mean depth, mean current velocity and geometric mean density of *S. ochraceum* larvae in each of the five sampling stretches in relation to their channel slope and stream discharge. Comparing the stretches with similar slope but different discharge (stretches A, B and C), increase in discharge (7.6 fold) caused increase in both the mean depth (2.4 fold) and mean current velocity (1.3 fold). According to Table 1, depth and velocity had opposite effect on larval density, i.e., increase in depth might have negative effect on larval density, while increase in velocity might have positive one. Since the geometric mean larval density was greater at stretch C than at stretch A, in spite of greater current velocity, it was concluded that the larval density was

ment of velocity. For a given class of velocity, the density decreased with increment of depth. The maximum mean density of larvae was obtained at the smallest depth (0.2-2.0 cm) and the largest velocity (41-66 cm/s). All the nine plates recovered from the largest depth (6.1-9.8 cm) and the smallest velocity (4-20 cm/s) were negative.
Table 2  Mean stream depth, mean current velocity and geometric mean density of *S. ochraceum* larvae at five sampling stretches with different channel slope and stream discharge.

<table>
<thead>
<tr>
<th>Sampling stretch</th>
<th>Channel slope, degree</th>
<th>Discharge (1 s⁻¹)</th>
<th>Mean stream depth (cm)</th>
<th>Mean current velocity (cm s⁻¹)</th>
<th>Geometric mean density (cm⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>8.5</td>
<td>0.25</td>
<td>1.1</td>
<td>19</td>
<td>0.130</td>
</tr>
<tr>
<td>B</td>
<td>10.0</td>
<td>0.95</td>
<td>2.2</td>
<td>21</td>
<td>0.117</td>
</tr>
<tr>
<td>C</td>
<td>9.3</td>
<td>1.9</td>
<td>2.6</td>
<td>25</td>
<td>0.097</td>
</tr>
<tr>
<td>D</td>
<td>7.5</td>
<td>4.1</td>
<td>3.8</td>
<td>26</td>
<td>0.061</td>
</tr>
<tr>
<td>E</td>
<td>11.9</td>
<td>3.2</td>
<td>2.3</td>
<td>33</td>
<td>0.074</td>
</tr>
</tbody>
</table>

influenced more by the stream depth than by the current velocity. Comparing the stretches with similar discharge (stretches D and E), combination of increase in channel slope (1.6 fold) and slight decrease in discharge (1.3 fold) was associated with decrease in the mean depth (1.7 fold) but increase in both the mean current velocity (1.3 fold) and the geometric mean larval density (1.2 fold).

The highest larval density was recorded in the stretch A where the discharge and the mean depth were the smallest. The lowest density was recorded in the stretch D where the discharge and mean depth were the greatest. Within the range of observation in the present study, it was concluded therefore, that the larval density was affected mainly by the mean depth, which itself was affected by the stream discharge.

**Discussion**

Current velocity is one of the earliest factors recognized to affect the distribution of blackflies (Colbo and Wotton, 1981). Phillipson (1956, 1957) demonstrated that a particular range of velocity is optimal for each species of *S. ornatum*, *S. variegatum* and *S. monticola*. Effect of depth was studied by Lewis and Bennet (1975) with nine simulid species in Newfoundland. They recovered greater number of larvae form artificial substrates placed just under the surface of stream than those at greater depth. Because the current velocity was greater just under the surface than at greater depth, the results were considered to demonstrate preference for both depth and current velocity.

It should be noted that the term "depth" in the present paper has different meaning from that by Lewis and Bennet (1975) due to different method of locating the artificial substrates. In the study by Lewis and Bennet (1975) the term "depth" refers to a relative position between surface and bottom. In the present study, "depth" means an absolute distance from surface to bottom, since all the artificial substrates were placed on the bottom.

The present study showed that depth is a factor as important as the current velocity for determining the benthic distribution of *S. ochraceum* larvae. Small depth and great velocity in combination were preferred by the larvae. A mosaic of the depth-velocity combination in a stretch was responsible for the microzonation of larvae. Availability of micro-habitats in a stretch was regulated by combination of slope and discharge. From the biological viewpoint, depth and velocity may directly influence the behavior of individual larva. From the operational viewpoint, however, the combination of slope and discharge in larger scale is a better criterion for classification of streams in terms of *S. ochraceum* productivity.

In Guatemala, Dalmat (1954, 1955) showed optimum range of stream depth (2.5-12.5 cm) and current velocity (2.5-25 cm) for *S. ochraceum*. Comparing with those data, the optimum depth in the present paper (0.2-2.0 cm) revealed to be smaller, and optimum velocity revealed to be greater (41-66 cm/s). The difference in optimum range by different authors may be due, at
least partially, to the difference in sampling methods. The lead plate designed in the present study may be one of the smallest artificial substrates for ecological study of the blackfly larvae. In the study by Dalmat, depth and velocity were measured as average values in sampling sites of indefinite length.

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References


摘要

水深と流速のグアテマラ産ブシ

Simulium ochraceum 幼虫の微細分布に与える影響

S. ochraceum が生息する水深は 2.4 m を選んで、コードラットによる幼虫分布調査を行った。調査したコドラットのうち、幼虫が検出された水深 0.2 cm の流速 3 cm/秒以上の 4 コードラットだけであった。幼虫採集用の人工基物として、幅 2 cm、厚さ 2 m の鉛板を用いた。この基物を溪流に 2～5 日間放置した後、回収して付着した幼虫を集計し、基物の位置における水深と流速を測定した。基物上の幼虫密度は水深 0.2～2.0 cm で、流速 61～66 cm/秒の組合せで最高となり、これより水深が増すごとに、あるいは流速が減少することに、減少した。流速 10 cm/秒以下では、幼虫が検出されなかった。基物 20 cm からなる五つの調査区で比較すると、流速が大きい調査区ほど、平均水深が大きくなり、Buttler平均による幼虫密度は小さくなった。