A CRAB-HOLE MOSQUITO, OCHLEROTATUS BAISASI, FEEDING ON MUDSKIPPER (GOBIIDAE: OXUDERCINAE) IN THE RYUKYU ISLANDS, JAPAN

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ABSTRACT. Ochlerotatus baisasi was observed and photographed feeding on a mudskipper (Periophthalmus argentilineatus). Origin of blood meals in the stomachs of female mosquitoes collected at burrows of land crabs and mud lobsters in the mangrove forests of Oura, Okinawa, and Komi, Iriomote (the Ryukyu Islands), was determined by enzyme-linked immunosorbent assay to be from a fish source.

KEY WORDS Ochlerotatus baisasi, feeding behavior, blood meal source, mudskipper, Periophthalmus argentilineatus, Ryukyu Islands

INTRODUCTION

In the Ryukyu Islands of Japan, adult and immature of Ochlerotatus (Geoskusea) baisasi (Knight and Hull) are commonly found in holes made by land crabs of the family Grapsidae and the mud lobster, Thalassina anomala, near mangrove forests (Miyagi and Toma 1978, Tanaka et al. 1979, Miyagi and Toma 1980, Mogi et al. 1984, Toma and Miyagi 1986, Ng and Kang 1988). However, no information is available on the blood meal source and the feeding behavior of this mosquito.

According to Belkin (1962), 9 species of mosquitoes belonging to the subgenus Geoskusea have been reported from South Pacific Islands and Southeast Asia—tonus (Edwards) and kabaensis (Brug) from Indonesia; baisasi from the Philippines and Ryukyu Islands, Japan; fimbripes (Edwards) from New Guinea and the Bismarck Archipelago; dalienensis (Taylor) from northern Australia; becki (Belkin), perryi (Belkin) and longiforceps (Edwards) from the Solomon Islands; and daggyi (Stone and Bohart) from Vanuatu. All species use holes made by land crabs near the coast for breeding and resting. Ochlerotatus (Geoskusea) longiforceps, which is closely related biologically and morphologically to Oc. baisasi, has been reported to bite mudskipper (Periophthalmus argentilineatus) on Gizo Island, in the Solomon Islands (Stooff and Marks 1965). To our knowledge, although several mosquito species have been reported to feed on reptiles and amphibians (Reington 1945, Henderson and Senior 1961, Hayes 1965, Nalan et al. 1965, DeFoliart 1967, Miyagi 1972), feeding on fish is quite rare.

Ochlerotatus longiforceps is the 1st authentic record of a mosquito biting a fish (mudskipper).

The use of immunological techniques to identify blood meals is a valuable aid in determining the blood source animal (Sasaki 1988). This paper presents observations on the feeding behavior of Oc. baisasi in mangrove forests in Oura, Okinawa, and Komi, Iriomote (Ryukyu Islands), and in the laboratory as well as the results of enzyme-linked immunosorbent assays (ELISAs) of blood meals in the stomachs of wild-caught mosquitoes.

MATERIALS AND METHODS

Observation on biting behavior of Oc. baisasi vis-à-vis mudskipper in the laboratory: Mosquito larvae were collected from crab holes in the mangrove forest of Oura on September 21, 2002, by hand pump and reared to the adult stage in the laboratory. A mudskipper (Periophthalmus argentilineatus) was also collected at a tide pool in the mangrove forest of Oura. The mudskipper was confined in a cage (20 × 20 × 30 cm) with about 148 newly emerged female and male mosquitoes. All species use holes made by land crabs near the coast for breeding and resting. Ochlerotatus (Geoskusea) longiforceps, which is closely related biologically and morphologically to Oc. baisasi, has been reported to bite mudskipper (Periophthalmus argentilineatus) on Gizo Island, in the Solomon Islands (Stooff and Marks 1965). To our knowledge, although several mosquito species have been reported to feed on reptiles and amphibians (Reington 1945, Henderson and Senior 1961, Hayes 1965, Nalan et al. 1965, DeFoliart 1967, Miyagi 1972), feeding on fish is quite rare.

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Table 1. Feeding habits of *Oc. baisasi* on a caged mudskipper, *P. argentilineatus*.

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Feeding location</th>
<th>Time feeding took place (h)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Between eyes</td>
<td>~2200</td>
<td>Penetrated tissue but no bloodfeeding took place</td>
</tr>
<tr>
<td>2</td>
<td>On the head</td>
<td>~2200</td>
<td>Bloodfeeding interrupted by host movement, mosquito returned and completed feeding</td>
</tr>
<tr>
<td>3</td>
<td>Between eyes</td>
<td>~2200</td>
<td>Flew away from the host immediately after full bloodfeeding</td>
</tr>
<tr>
<td>4</td>
<td>On the pectoral fin</td>
<td>~2200</td>
<td>Flew away from the host immediately after full bloodfeeding</td>
</tr>
<tr>
<td>5</td>
<td>On the head</td>
<td>1947</td>
<td>Feeding interrupted by host, no blood taken</td>
</tr>
<tr>
<td>6</td>
<td>Near mouth opening</td>
<td>2007</td>
<td>Feeding interrupted by host, no blood taken</td>
</tr>
<tr>
<td>7</td>
<td>On the head</td>
<td>2031</td>
<td>Rested on the host for a few minutes after full bloodfeeding accomplished</td>
</tr>
<tr>
<td>8</td>
<td>On the back near the dorsal fin</td>
<td>1952</td>
<td>Rested on the host for a few minutes after full bloodfeeding accomplished</td>
</tr>
</tbody>
</table>

1 Average time per blood meal was 10 min.
2 Experiments were conducted October 3–16, 2002.

RESULTS AND DISCUSSION

Eight observations of feeding activity are shown in Table 1. Male and female *Oc. baisasi* seem to be nocturnal or crepuscular in activity, resting by day in the black paper tube provided in the cage. Mating swarms were observed to take place above the opening of the tube at dusk and dawn. Some female mosquitoes were observed to hover over the mudskipper and alight on the dorsal part of the fish, walking around and eventually feeding between the dorsally protruding eyes or the pectoral fin musculature of the mudskipper.

Feeding usually lasted about 10 min for a full bloodfeeding. The female appeared to be motionless during the feeding, and the fish did not appear

Fig. 1. *Ochlerotatus baisasi* feeding on a mudskipper, *P. argentilineatus*. 
Table 2. Number of Oc. baisasi for which the blood meal was determined by ELISA to be from fish.

<table>
<thead>
<tr>
<th>Collection site</th>
<th>Collection date (2002)</th>
<th>Engorged females testing positive for a fish blood meal</th>
<th>Engorged females testing negative for a fish blood meal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oura, Okinawa</td>
<td>July 6</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Oura, Okinawa</td>
<td>July 13</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Komi, Iriomote</td>
<td>August 11</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Komi, Iriomote</td>
<td>August 12</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Komi, Iriomote</td>
<td>August 13</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>10</td>
<td>17</td>
</tr>
</tbody>
</table>

to be disturbed during the process (Fig. 1). Three females (case nos. 2, 5, and 6) interrupted their blood feeding because of movement of the host; 1 female (case no. 2) subsequently returned to the fish for a full feeding. The engorged females laid a batch of 10–40 eggs; most eggs hatched and developed to the adult stage.

One of us (Okudo) often exposed his hand to about 100 mature Oc. baisasi females in the rearing cage, but the females did not attempt to bite his hand. The females did not seem to be attracted to warm-blooded animals while confined.

Blood meal sources of Oc. baisasi as determined by ELISA are shown in Table 2. Ten (37.07%) blood meals of 27 tested females were determined to have been taken from fish. The small volume of blood meal in the stomach could be the cause of the low determination rates for fish, or the female of Oc. baisasi might take blood not only from fish but also from other sources such as reptiles and amphibians. In this study, only 1 commercial antiserum produced from fish was used to determine blood source. Further close observation of feeding behavior and determination of blood meal sources of this mosquito species should be carried out in the field and laboratory.

In the field, it was often observed that when the crab hole was disturbed in daytime, the resting mosquitoes flew out of the hole, but did not fly far and promptly returned to the same hole or neighboring holes. Most of the resting females collected at the holes in Oura mangrove forest were gravid, having mature eggs in their abdomens. A few of them had fresh blood meals, and others were newly emerged nulliparous. It can be assumed that Oc. baisasi females feed fully on a mudskipper at night. Because of the heavy weight of blood, she will land on the nearest hollow and rest for several hours until the blood meal in her stomach has been digested to a certain extent. The half-gravid female will fly to crab and mud lobster holes for oviposition and to rest until morning.

Mudskippers (Oxudercinae) are a terrestrially adaptable fish. They are exposed to air for long periods of time and rest on plant roots in tidal mudflats and mangroves at night (Clayton 1993). Because many mudskippers breed in tide pools scattered in the forest, they might be the most readily accessible source of a vertebrate blood meal for the crab hole–dwelling mosquitoes. Although the feeding habits of the 9 species of subgenus Geoknosea are not known, except for baisasi and longiforceps, most of these species could feed readily on a mudskipper in the tidal zone.

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