Introduction

A number of behavioural and neurophysiological experiments have demonstrated that certain moth species possess tympanic organs (ears) primarily, however, not exclusively; see Spangler et al. 1984; Strylkke and Gogola 1986) for detecting echolocation calls of insectivorous bats (for reviews, see Roeder 1967, 1974). It is a curiosity that some taxa of Macroglossinae, namely those belonging to the superfamilies Bombycoidea and Sphingoidea, do not possess tympanic organs (Eggers 1919) or any other apparent means of detecting bats (Roeder 1974). Since moth ears are assumed to be the result of selection pressure by bats (Fullard 1987), the existence of deaf moths poses an interesting problem.

Specifically, how might these groups experience reduced selection pressure by bats? Roeder (1974) has speculated that the Lasiocampidae (tent caterpillar and lappet moths) may avoid bats by flying close to the ground while the large Saturniidae (giant silkworm moths) are protected by their size.

Another possibility is that deaf moths are temporarily isolated from bats. Strylkke and Gogola (1986) have suggested that Thecaphora foecia, a noctuid moth which communicates acoustically and therefore is potentially vulnerable to detection by bats, has found a "bat-free niche" by emerging late in the year. Fullard (1977) has shown that sound production, a defensive behaviour against bats in arctiid moths, is absent in species that are temporarily isolated from bats.

The purpose of the present study was to test the "temporal isolation" hypothesis by comparing sample sizes of atympante moths with bat activity levels throughout a summer in southeastern Ontario.

Materials and methods

During the summer of 1985 I collected all atympante moths (Eggers 1919) (i.e., Saturniidae, Lasiocampidae, and Sphingidae) from two ultraviolet lights at the Queen's University Biology Station, near Chaffey's Lock, Leeds County, Ontario (44°34'N, 79°15'W). Both lights were located near a lake (Lake Omete), one was within a forested area, while the other was on the shore of a small bay surrounded by forest. The lights were inspected each evening between 23:00 and 00:30; all atympante moths were removed and subsequently identified using criteria in Covell (1984), Ferguson (1971), Franclemont (1973), Hodges (1971), and Holland (1968).

Between collections, bat activity was monitored near the second light, where bats commonly foraged. The number of bat passages were counted during a 15-min period using a high-frequency heterodyne transducer (bat Mini-detector, QMC Instruments Ltd.) tuned to 45 kHz. This setting allows detection of most bat echolocation calls in the area with the exception of those of Lasiurus cinereus, which have a peak frequency at 25 kHz (Fullard et al. 1983). Collections were made nightly from May 1 to August 28 with the exception of 12 nights.

Results

A total of 426 atympante individuals were captured throughout the summer (Table 1). This total included representatives from all species (except for a few rare sphingids) known to occur in that locality (Ward et al. 1974). Of the total, 145 individuals were lasiocampids (5 species), 135 were saturniids (7 species), and the remaining 146 were sphingids (14 species). The number of moths of a particular group captured over 4 consecutive collection days were summed and this number was expressed as a percentage of the total number in...
Table 1. List of species captured

<table>
<thead>
<tr>
<th>Date of capture</th>
<th>Earliest</th>
<th>Latest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lasiocampidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malacosoma americanum</td>
<td>83</td>
<td>June 18</td>
</tr>
<tr>
<td>Malacosoma disstria</td>
<td>34</td>
<td>June 18</td>
</tr>
<tr>
<td>Phyllodesma americana</td>
<td>16</td>
<td>May 1</td>
</tr>
<tr>
<td>Tophyra laticl</td>
<td>7</td>
<td>July 30</td>
</tr>
<tr>
<td>Tophyra velleda</td>
<td>3</td>
<td>Aug. 14</td>
</tr>
<tr>
<td>Saturniidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actias luna</td>
<td>23</td>
<td>May 5</td>
</tr>
<tr>
<td>Anisota virginiensis</td>
<td>8</td>
<td>May 25</td>
</tr>
<tr>
<td>Antheraea polyphemus</td>
<td>6</td>
<td>May 29</td>
</tr>
<tr>
<td>Automeris io</td>
<td>27</td>
<td>May 20</td>
</tr>
<tr>
<td>Dryocampa rubicunda</td>
<td>50</td>
<td>May 13</td>
</tr>
<tr>
<td>Eacles implelalis</td>
<td>4</td>
<td>June 25</td>
</tr>
<tr>
<td>Hyalophora cecropia</td>
<td>5</td>
<td>June 2</td>
</tr>
<tr>
<td>Sphingidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceratonia amynor</td>
<td>1</td>
<td>July 20</td>
</tr>
<tr>
<td>Ceratonia undulata</td>
<td>50</td>
<td>May 25</td>
</tr>
<tr>
<td>Cressonia juglandis</td>
<td>2</td>
<td>May 22</td>
</tr>
<tr>
<td>Daropa myops</td>
<td>31</td>
<td>June 8</td>
</tr>
<tr>
<td>Daropa piliata</td>
<td>1</td>
<td>July 19</td>
</tr>
<tr>
<td>Daropa varicolor</td>
<td>3</td>
<td>July 9</td>
</tr>
<tr>
<td>Lapara bombycoides</td>
<td>5</td>
<td>June 9</td>
</tr>
<tr>
<td>Pachyphincta modesta</td>
<td>5</td>
<td>May 5</td>
</tr>
<tr>
<td>Paonias exocœcatus</td>
<td>10</td>
<td>May 15</td>
</tr>
<tr>
<td>Paonias myops</td>
<td>16</td>
<td>June 3</td>
</tr>
<tr>
<td>Smerinthus cerisyi</td>
<td>2</td>
<td>June 4</td>
</tr>
<tr>
<td>Smerinthus jamacense</td>
<td>5</td>
<td>June 1</td>
</tr>
<tr>
<td>Sphecodina aegroti</td>
<td>1</td>
<td>May 14</td>
</tr>
<tr>
<td>Spinincta kalmae</td>
<td>14</td>
<td>May 16</td>
</tr>
</tbody>
</table>

*Possible second brood.

that group collected throughout the summer. Figure 1a illustrates the relationship between the proportion of all atypoman moth and the proportion of bat passes throughout the summer. The data indicate that bat activity increased slowly from mid-May to early July, then increased rapidly until mid to late July, when it reached a peak. Compared with the incidence of bat activity, atypomate moths as a group were more frequent between mid-May and mid-June; then reflected bat activity until mid-July, when their numbers declined.

More distinct patterns appear when the incidence of individual families are plotted. Figure 1b indicates that the saturniids occurred most frequently between mid-May and mid-June, when bat activity levels were lowest. Correspondingly, between late June and the end of August, bat activity levels were high while saturnid captures were low. Figure 1c illustrates the separate capture times of three genera in the Lasiocampidae. One species, Phyllodesma americana, was last collected May 28, the tent caterpillars Malacosoma americana and Malacosoma disstria emerged between mid-June and the beginning of July, just before the increase in bat activity, while the month of August was marked by the emergence of both Tophyra laticl and Tophyra velleda. Figure 1d shows that the incidence of sphingid reflected levels of bat activity; both peaked during mid to late July, with the sphingids having slightly higher levels between late May and early June.

Discussion

The pattern of increasing bat activity throughout the season agrees with bat activity levels recorded by Fullard (1977) and with population numbers of Myotis lucifugus obtained by Fullard and Barclay (1980) at the same locality. The latter authors surmised that increased bat predation from mid-May through the end of July is a result of the foraging patterns of lactating females and, subsequently, their young. From my data no distinctive seasonal relationships between bats and atypomate moths were apparent when the moths were considered as a single group. When the data were separated according to major families, however, seasonal trends became apparent. The Saturniidae are most abundant during the beginning of the spring when bat activity is low, suggesting that these moths may be at a lower risk of predation than moths emerging later in the season. The Lasiocampidae also emerged outside the period of increased bat activity. Both tent catterpillar species occurred during a 3-week period just before the highest bat activity levels of the summer. The other three species were captured only at the tail ends of the season. According to Ward et al. (1974), P. americana is one of the earliest moth species to appear in the spring, while T. laticl and T. velleda are two of the latest species.

The distribution pattern of the sphingids suggests that they are not temporally isolated from bats. The majority of Sphingidae captured were large (wingspans ranged from 2.8 to 17.5 cm) and it may be that this group is protected by their large size and rapid flight (Covell 1984). Roeder et al. (1968) found that certain sphingid moths of the subfamily Choerocampinae (moths that are characteristically crepuscular and hover while feeding on the nectar of flowers) are nutritive. While hovering and feeding they may be easy targets for a bat's sonar system, and may thus require some means of detecting bats (Roeder 1974). None of the moths in that group are native to my study site, however, and therefore all sphingids in this study are considered deaf.

These preliminary findings suggest that various taxa of
A food delivery system for laboratory streams

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Received April 30, 1987


We describe a simple and inexpensive food delivery system for use in laboratory streams. The pattern of food delivery from the system results in normal behavior and distribution of territorial fish within the stream.


On trouveront la description d’un système simple et peu coûteux de distribution de nourriture dans les ruisseaux de laboratoire. Les résultats démontrent que le système assure une répartition et un comportement normaux des poissons territoriaux dans le ruisseau.

[Traduit par la revue]