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Big brown bats and June beetles: Multiple pursuit strategies in a seasonal acoustic predator–prey system

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Abstract: Infrared video and ultrasonic recordings were made of echolocating big brown bats hunting for June beetles in the short May–June "beetle season." Adult beetles emerge from the ground at twilight, beat their wings to warm up, and fly into nearby trees, where they swarm actively for ~1 h. Beetles are attacked by bats while buzzing in the grass, while flying in the open during their brief ascent, and while still active among the leaves of trees. Bats routinely used different capture strategies during the course of a few minutes and may hear the beetles' buzzing to guide attacks in vegetation.

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1. Introduction

Our understanding of the behavior of echolocating bats (*Microchiroptera*) has long been impeded by the difficulty of making real-time visual observations at night. Until recently, studies of the natural behavior of bats instead were done by *listening* to bats with ultrasonic detectors.[1–3] With some exceptions,[4] visual observations of bats at night took place mainly with the aid of marking techniques,[5] and video records were not made. Consequently, the principal body of information was acoustic—describing the elegant variety and adaptive changes of sonar signals used by different species of bats in relation to behavior.[6,7] Nevertheless, sufficient information accumulated to discern the different foraging strategies that bats used to find prey: (1) aerial pursuit in the open; (2) aerial pursuit near obstacles or surfaces; (3) capture in clutter; and (4) detection of fluttering prey.[8,9] Subsequent comparisons of feeding behavior and echolocation sounds with flight morphology,[10] auditory physiology,[11] or sound structure,[12,13] combined with field observations made possible by better photographic and video techniques,[14–16] have confirmed the use of these strategies and provided detailed examples for each. The real-time capability of low-light video methods has, in addition, provided qualitatively new insights not possible with off-line viewing.[4,17] Most recently, thermal-imaging video cameras make it possible to watch and record bats without the illumination constraints of other video methods.[18] This paper illustrates different capture behaviors from recordings made with infrared cameras that "see" bats and large flying insects from their own body heat. Observations are directly documented as video/audio files rather than as verbal descriptions augmented by multiple-exposure strobe photographs and measurements of selected parameters of the maneuvers, as has been the practice in most prior research. The videos replace anecdotal descriptions of the bat's behavior that accompany even the most thorough publications of quantitative information about such parameters as distances from bat to prey and to background in relation to features of the sonar broadcasts. Video clips are intrinsically quantitative rather than anecdotal because they are real-time visual and auditory renderings of the tracks of bats in relation to prey and to vegetation—they are animated graphs.

2. Methods

Recordings of big brown bats (*Eptesicus fuscus*)[19] hunting for June beetles (*Phyllophaga sp.*; also called May beetles) were made at several sites in Rhode Island from mid-May to late June 1999–2004. The beetles were not present at these locations in April–May and July–September,

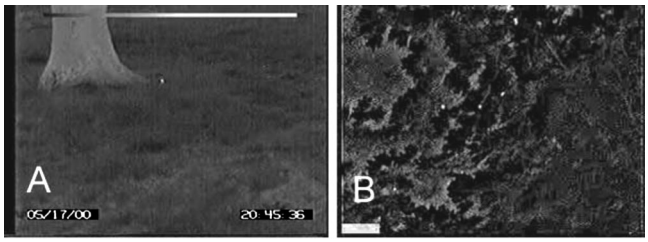

Fig. 1. Warm-up and take-off of June beetle from grass to ascend into tree (A), and swarming of June beetles in tree (B). The soundtrack displays beetle buzzing translated into audio by a bat detector tuned to 28–30 kHz (see Mms. 1–2).

when the bats also behaved differently. A hand-held "Merlin" midrange infrared thermal-imaging camera (Indigo Systems, Inc.; spectral sensitivity X–Y μm) was used to watch and make video recordings of both bats and beetles in flight. The bats' sonar sounds were picked up by ultrasonic condenser microphones (Titley Electronics, Ltd.) operating with an Aco-Pacific microphone power supply, amplified with a Reson model VP-2000 amplifier/filter (3-dB points set at 10–100 kHz), and recorded along with the infrared video on a Sony wideband SIR-1000W digital instrumentation recorder with a SVB-10 video board. A separate video recording was made with a Sony GV-D800 Digital Video Walkman. To provide a sound track for this second videotape, which was limited to audio frequencies, the bats' broadcasts were picked up with a bat detector (Mini-3 model, Ultra-Sound Advice) that heterodynes the bat's ultrasonic broadcasts against a tuned frequency (set to 28–30 kHz) to deliver an audible display.[1,4] Both of these systems could record video and sound continuously for up to 60–90 min. Most of the present observations were made of bats at distances of 5 to 25 m using a 25-mm lens (1× magnification) or a 13-mm lens (0.5×, or slightly wide angle). Time registration was achieved by writing SMPTE time/frame counts onto the video frames of both video recordings using battery-powered Hirata VG-50 and TRG-50 coding units. Specific events of interest were noted by voice at the time of observation or located subsequently by playing the tape back on the Sony Video Walkman while listening to the heterodyned bat sounds. Corresponding segments of the video/ultrasonic recording were then downloaded as binary files and MPEG video clips into a Pentium-3 PC using software supplied with the digital instrumentation recorder.

3. Results

Figure 1(A) shows a June beetle glowing in the infrared image while it warms up in the grass by beating its wings. The corresponding multimedia file (Mm. 1) shows this beetle taking flight and ascending into the nearby tree, where it joins others already swarming in the vegetation. Figure 1(B) shows several June beetles together among the leaves. The corresponding multimedia file (Mm. 2) shows their swarming, and their buzzing is audible from the bat-detector sound track. After about 1 h, the beetles cease swarming and remain quiescent on the leaves.

Mm. 1. Beetle ascent (2168 Kb)

Mm. 2. Beetle swarm (996 Kb)

The behavior of the bats as predators complements that of the beetles as prey. Figure 2 illustrates different types of attacks made by big brown bats on these populations of June beetles. During the hour or so after sunset when beetles are seen flying out of the grass and upward to reach the trees, big brown bats chase them and make successful aerial interceptions 2 to 10 m above the ground. Figure 2(A) shows a single video frame from such an aerial capture, and the corresponding multimedia file (Mm. 3) shows the entire maneuver. Over 100 video clips showed aerial interceptions that both started and ended well away from the vegetation. In addition, bats sometimes detected and then pursued beetles that were near the vegetation [Fig. 2(B) and Mm.

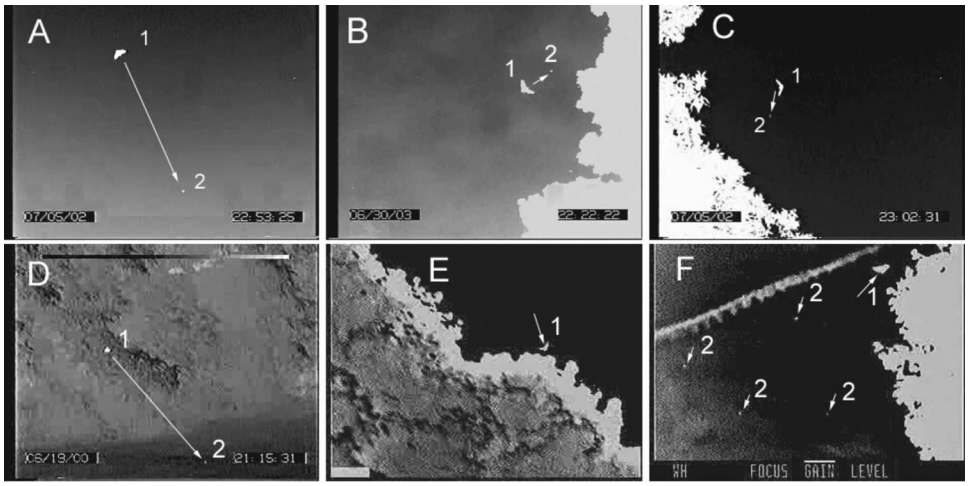

Fig. 2. Individual video frames from recordings of (A) an aerial interception in the open; (B) an aerial interception close to vegetation; (C) a pursuit initiated in the open but where the beetle flies towards the vegetation and ultimately eludes capture after nearly being caught; (D) a bat flying in circles above a beetle warming up in the grass, with an ambush—an aerial capture—after the beetle takes flight; (E) a bat flying into vegetation and maneuvering through the beetle swarm without emitting sonar sounds intense enough to be recorded; and (F) a bat flying towards and into vegetation while several beetles simultaneously fly out and away. Corresponding video clips are Mms. 3–8. The locations of bats are numbered "1" and the locations of beetles are numbered "2." The arrow connects the bat with the beetle in (A)–(D), indicates the bat in (E), and indicates the bat and the beetles in (F). Soundtracks are from a bat detector.

4] or that flew towards the vegetation when the bat approached [Fig. 2(C) and Mm. 5]. These maneuvers (14 video clips) nevertheless still were recognizable as aerial interceptions or attempts at aerial interception because the bat made a "buzz" of rapidly accelerated broadcasts that is characteristic of the terminal stage of capture in the open.[1] In Fig. 2(B), the bat flying in the open appears to detect the beetle when it is near the tree and then turns to close in from several meters away, in spite of the presence of the screen of dense vegetation immediately behind the beetle. In Fig. 2(C), the beetle moves towards the trees when attacked by the bat, and the bat eventually breaks off the chase after following the beetle along the margin of the vegetation.

Bats were sometimes observed to fly in circles about 1 m above the grass (23 clips). When approached on foot with the camera, the circling bat usually proved to be flying back and forth over a beetle that was warming up in the grass. When the beetle took off to fly up into the trees, the bat ambushed it with an aerial interception. The multimedia file for Fig. 2(D) (Mm. 6) shows such an ambush of a June beetle by a big brown bat. On some occasions circling bats would suddenly dive to the ground, making an audible sound when striking the grass, but in none of these instances was the camera near enough to determine whether a beetle was warming up where the bat landed.

Mm. 3 Aerial catch (319 Kb)

Mm. 4 Catch near tree (523 Kb)

Mm. 5 Miss near tree (955 Kb)

Mm. 6 Ground ambush (630 Kb)

Mm. 7 Flight into tree (607 Kb)

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Mm. 8 Flight into tree, w/beetles leaving (1164 Kb)

After numbers of June beetles had flown into the vegetation and begun to swarm [Fig. 1(B) and Mm. 2], individual bats frequently flew into the vegetation, too (26 clips). Figure 2(E) and the corresponding multimedia file (Mm. 7) show an example of the bat's maneuvering, which often involved repetitive passes into and around the same location in the tree. The buzzing sounds of June beetles are both audible and distinctive to big brown bats,[20] and one prior study has shown that these bats orient towards the sounds of insects when hungry.[21] It seems likely that the bats were flying into the vegetation to catch beetles after hearing them flying among the leaves. However, the only evidence that bats might be taking the beetles off the vegetation was their dropping of warm beetle body parts (mostly June beetle elytra, or wing covers) when they emerged to fly away over the grass. Beetle parts frequently are dropped during intervals of 5–10 s following successful aerial interceptions, which makes it probable that beetles are captured directly from the vegetation, too. Such flights of bats into the trees are not observed at the same sites either earlier in the spring, before beetles emerge, or later, in July–September, when beetle swarming no longer occurs. Figure 2(F) and the corresponding multimedia file (Mm. 8) from a previous report show not only the bat entering the vegetation but also several beetles leaving.[18] These flights into vegetation were different from aerial pursuits in that the bat's echolocation sounds often were not detected when the bat was in proximity to the vegetation (audio tracks of Mm. 7 and 8), whereas bats intercepting beetles in the open produced the full complement of search, approach, and terminal signals characteristic of pursuit (audio tracks of Mm. 3–5). It is not clear whether the bats stopped emitting entirely or just emitted weaker sounds when entering the vegetation. In the next season, placement of microphones in the trees will be done to examine this behavior further.

4. Conclusions

Big brown bats were observed to use several different methods to capture June beetles. First, aerial interceptions of beetles in the open (Mm. 3) and beetles near vegetation (Mm. 4), occurred each night. Second, bats also flew low and captured by ambush, after circling over a beetle that was warming up in the grass and waiting until it took flight (Mm. 6). Bats sometimes swooped down to strike the ground and may have captured beetles directly from the grass while they were warming up, although this could not be confirmed. Third, when enough beetles had ascended into the vegetation to swarm noisily, bats would fly into the vegetation, maneuver closely around particular locations multiple times, and emerge back into the open (Mm. 7 and 8). Sometimes a bat would persist in reentering the same location in the vegetation several times before flying away from the trees. From the bat's dropping of prey parts in flight, at least some of these close passes through vegetation probably resulted in capture of beetles. Moreover, not only would big brown bats catch beetles in different ways, but the same bat would use different methods in rapid succession. Individual bats often remained in view and could be watched for as much as several minutes. Over the course of a few tens of seconds, the same bat might catch a beetle flying in the open, then fly into vegetation, presumably to try to catch a beetle from the swarm, and then emerge into the open to chase other beetles. The prominence of strong recorded echolocation sounds from bats making aerial captures is in marked contrast to the weakening of signals or the apparent absence of detectable signals from bats making flights into vegetation. Further studies with microphones placed in the vegetation should establish whether bats merely weaken or sometimes actually omit their broadcasts. In this regard, other species of beetles in the same family as June beetles (*Scarabidae*) can hear the ultrasonic sounds of bats and take countermeasures.[22] The bats may have adapted by minimizing the ultrasonic cues they give the beetles during flights into vegetation.

Acknowledgments

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