Biology:

Effects of Tidal Stage on the Patterns of Fishing Activity in *Noctilio Leporinus*

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Abstract: The greater bulldog bat, Noctilio leporinus, forages for fish mainly at high tide, and may exhibit one of two types of fishing behavior depending upon the presence or absence of jumping fish. Using infrared binoculars, we observed bat hunting behavior to assess differences in fishing patterns at high and low tides. We followed individual bats and recorded the type of hunting pattern, time spent fishing, and number of fishing attempts. Bats showed target-orientated, circular-flight hunting behavior during high tide and linear-flight hunting behavior during low tide, probably in response to changes in fish abundance. This suggests that bats adjust their hunting modes according to resource availability, probably to maximize foraging efficiency.

Noctilio leporinus, the greater bulldog bat, is a nocturnal fishing bat that relies on echolocation to find its prey. After it locates a fish, it dips into the water, attempting to spear fish with its claws or scoop fish into the pouch between its legs (1). The bat is only successful in catching fish once in every 50-200 passes through a hunting area (2). *N. leporinus* has two main hunting modes. When fish are jumping, it performs circular high flight searches, dipping when it detects a fish. When fish aren't jumping, the bat flies low, sweeping in a linear, trawl-like fashion through areas where it has fished successfully in the past (3).

We studied bat hunting activity at the Río Sirena Lagoon at Corcovado National Park, Costa Rica, where the greater bulldog bat fishes predominantly at high tide (4,5). In the lagoon, fish abundance is higher at high tide than at low tide (6). We hypothesized that the hunting patterns of the greater bulldog bat would vary with the tidal cycle, and that the bats would prefer high-flying, circular patterns at high tide, when there are more fish, and low-flying, linear patterns at low tide, when there are fewer fish.

Table 1. Contingency analysis for observations of circular (n = 52) and linear (n = 37) fishing patterns during high and low tides. Column percentages represent the proportion of observations for the column patterns during the row tide; row percentages represent the relative proportions of circular and linear patterns observed during that tide.

Count	Circular	Linear	Total
High Tide	20	1	21
High Tide (Incoming)	10	5	15
High Tide (Outgoing)	13	1	14
Low Tide (Incoming)	9	21	30
Low Tide (Outgoing)	0	9	9
Total	52	37	89

Methods

We observed *N. leporinus* fishing behavior during two high and two low tides over the course of two nights, collecting data for a total of 8 hours. On 2 February 2005, we observed during a high tide from 21:00 – 23:00. On 3 February 2005, we observed during a low tide from 4:00 – 6:00, during a high tide from 17:30 – 19:30 and during a low tide from 23:30 – 25:30. Using infrared night vision binoculars, we watched individual bats, recording time spent fishing (i.e., run time), fishing pattern, and number of dips into the water (i.e., number of attempted fish captures) for each, until the individual was no longer visible. Number of dips and flight time were used to estimate fishing efficiency for each observed bat. Fishing patterns were determined to be either linear or circular. In a circular mode, the bat cycled over a given region of the lagoon at least twice; in a linear mode, the bat swept low over the lagoon once, sometimes dragging its feet in the water, and flew out of sight. Water velocity was assessed every 30 minutes by recording the travel time of a floating stick over 10 meters, and relative stage of the tidal cycle was assessed by observing water level.

A contingency analysis was performed to assess differences in hunting patterns between high and low tides. Differences in bat fishing patterns with respect to run length, number of dips, and dips per run were analyzed with multiple one-way ANOVAs. Data were analyzed using JMP v. 5.0.1.2 and met the assumptions of parametric tests.

Results

We observed more circular than linear fishing at high tide and more linear than circular fishing at low tide ($X^2 = 47.08$, df = 81, $P < 0.0001$; Table 1). Circular fishing runs lasted significantly longer (73.9 ± 10.1) than linear fishing runs (22.1 ± 2.6; F = 15.92, df =1, 85, P < 0.001; Fig. 1) and resulted in more dips per run (7.5 ± 1.2) than did linear pattern fishing (3.1 ± 0.5; F = 7.61, df =1, 87, P < 0.01; Fig. 2). However, the number of dips per minute did not differ between circular (7.9 ±1.1) and linear (8.7 ± 1.1) fishing patterns (F = 0.64, df =1, 85, P = 0.43; Fig. 3).

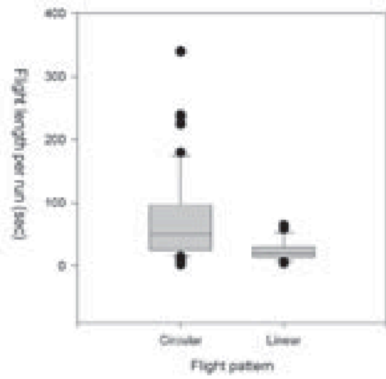

Fig. 1. Flight length per run (seconds) of bulldog bats as a function of flight pattern type. Circular flight patterns were significantly longer than linear flight patterns (n = 89, P < 0.001). Mean flight length and quartiles ± SE are shown for each flig ht pattern. Dots indicate observations >2 SE from the mean.

Discussion

As expected, the bats used high-flying, circular fishing patterns during high tide, when fish were more abundant. During low tide, when fish were scarce, bats used low-flying, linear fishing patterns, probably where they had previously been successful in obtaining fish.

The greater run length of circular fishing patterns may indicate that runs in this hunting mode are generally longer, or that the fishing bat performs longer runs during high tide. That we observed more dips per run in the circular fishing mode suggests that bats may make more attempts at catching fish during circular runs than during linear runs. However, bats were much easier to follow using binoculars during circular flight, and both of these relationships may have been due to this sampling bias.

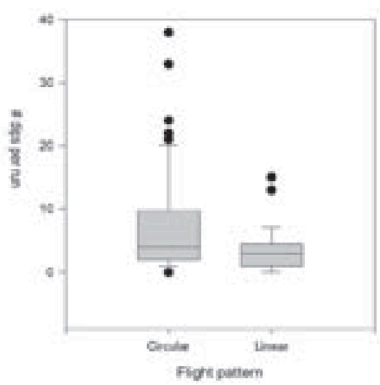

Fig. 2. Number of bulldog bat dips per run as a function of flight pattern type. Circular flights had a greater number of dips per run than linear flights (n = 89, P < 0.001). Mean dips/run and quartiles ± SE are shown for each flight pattern. Dots indicate observations >2 SE from the mean.

We were unable to determine the success of bat fishing attempts, because after catching a fish, the bats either transferred the fish to their mouths in flight or flew off to roost and eat (7). Therefore, the number of dips observed per minute was our only estimate of fishing efficiency. Based on this measure, our results suggest that, though the two fishing methods differ in flight pattern and degree of fish-targeting, they produce equal foraging efficiency.

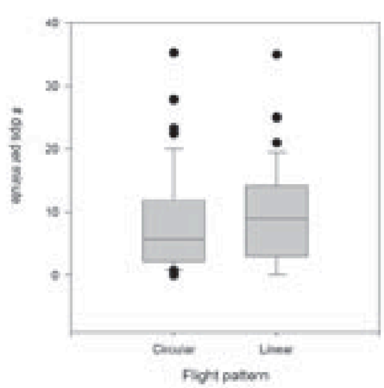

Fig. 3. The number of bulldog bat dips per minute during one run as a function of flight pattern type. The number of dips per minute during a circular run is not significantly different from the number of dips per minute during a linear run (n = 89, P = 0.96). Mean dips/minute and quartiles ± SE are shown for each flight pattern. Dots indicate observations >2 SE from the mean.

Our data demonstrate a difference in fishing patterns of the greater bulldog bat between high and low tide. The use of infrared binoculars allowed us to observe the fishing behavior of individual bats, an important first step in assessing the foraging efficiency of *N. leporinus*. The two fishing patterns may differ in fish-capturing efficiency. Further studies could assess this variable to provide a better understanding of how the greater bulldog bat is influenced by resource availability.

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