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A TECHNIQUE FOR SAMPLING FLYING INSECTS

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Abstract.—I describe a procedure for sampling flying insects. Using binoculars, a stopwatch, and a hand-held counter, an observer counts insects passing through a measurable focal volume for a set time. No insect identification skills are needed. I tested the accuracy and repeatability of the procedure under controlled conditions and found that with known limitations, it is a reliable way to sample flying insect abundance. I used the procedure to describe daily activity pattern of flying insects using a clearing adjacent to a neotropical lowland forest reserve. While flycatcher and flying insect activity patterns were not strongly correlated, similarities in activity were noted.

TÉCNICA PARA MUESTREAR INSECTOS VOLADORES

Sinopsis.—Se describe un procedimiento para muestrear insectos voladores. Utilizando binoculares, un cronómetro y contador manual, un observador puede contar los insectos que pasan a través de un volumen focal medible por un periodo de tiempo. Para utilizar esta técnica no es necesario tener destrezas para identificar los insectos. Puse a prueba la exactitud y repetividad del procedimiento bajo condiciones controladas y encontré que, aunque con limitaciones, es un método confiable para medir la abundancia de insectos. Utilicé el método para describir los patrones de actividad diaria de insectos voladores utilizando un claro adyacente a una reserva forestal de un bosque neotropical bajo. Aunque el halconeo (flycatching) y el patrón de actividad de insectos voladores no se correlacionaron, se notaron similaridades en el patrón de actividad.

Foraging ecology and habitat partitioning have been well studied in Tyrant flycatchers (Davies 1977, Fitzpatrick 1980, 1981, Hespenheide 1971, Robinson and Holmes 1982, Sherry 1984, Traylor and Fitzpatrick 1982). Many of these studies documented diet composition and foraging behavior, but few have quantified resource availability. Similar research on dragonfly foraging behavior also does not address the relationship between prey availability and predator activity (Corbet 1963; Higashi 1973, 1978; May 1980). One reason for this is the lack of a suitable sampling method for quantifying aerial insect abundance. Therefore, the goal of this study is to develop a new method to quantify daily fluctuations in flying insect numbers.

METHODS

Sampling procedure.—The sampling procedure requires a pair of binoculars, a hand-held counter, and an alarm stopwatch. The observer lays against a horizontal surface (such as the ground) for a set period of time, looks up at the sky (whether cloudy or clear) through binoculars, and counts insects with the hand-held counter. Insects are counted as they pass though the focal volume visible through the binoculars (Fig. 1a). Observer concentration and hence visual acuity may decline if the sampling period exceeds approximately 3 min. With the binoculars set to a

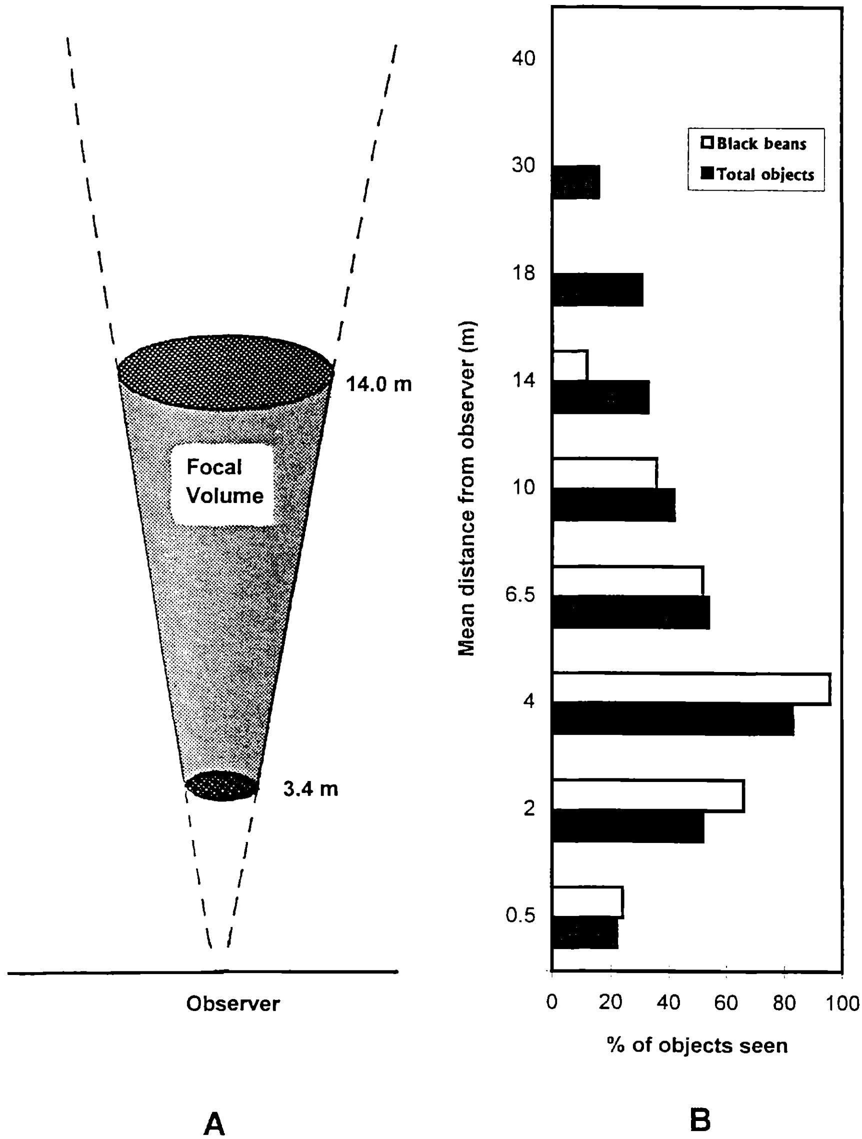

FIGURE 1. Graphic representation of insect sampling method (a). Observer detection rates will vary in accordance with a detection function within the focal volume. The detection function (b) was calculated for total objects and black beans (total objects: n = 1750, black beans: n = 350). Each point on the y-axis represents the mean distance through which a set of objects were thrown (note that the spacing of mean distances is roughly regular until the last two sampling distances). Each point on the x-axis represents the percent of objects seen by an observer.

known focal distance, all insects detected during the count period are tabulated on the counter and when the alarm sounds, counting stops.

Because the magnification and focal distance of the binoculars used will determine the minimum size of insects seen, one must establish the range of distances within which small objects, such as insects, are visible. This is done by choosing an object approximately the size of the smallest insects one wishes to count. In this study, I was interested in knowing the abundance of the flying insects most likely to be preyed upon by medium-size flycatching birds. Therefore, when calibrating my binoculars, I chose a 0.15 cm^2 object to represent the smallest prey size normally captured by the flycatchers included in this study.

I attached a 0.15 cm^2 circle of black paper to a pale vertical surface (such as an exterior white wall) and set my binoculars at their nearest focus. Starting close to the wall, I backed away while watching the area on the wall until the black circle first came into view, at which point it was blurry but clearly visible. The distance from the binoculars to the wall is the minimum distance at which insects will be detected. When determining minimum and maximum distances of visibility, it is useful to simulate the motion of the insects across the field of view by moving the binoculars slightly from side to side. By doing this, one can accurately determine the distance at which a moving object of a given size can be seen.

I continued to back away from the wall until the black circle came into sharp focus. As I continued to back away, the black circle remained in sharp focus for a measurable distance, then blurred and disappeared. The point at which the blurry black circle disappears is the maximum sampling distance. The minimum and maximum sampling distances are represented by circular planes between which a truncated cone is formed. This cone represents the sampling volume (Fig. 1a), and is specific to the size object/insect you are observing. Insects of a given size passing through this volume will be seen and counted while those passing above and below it will not be detected. Detectability within this volume varies as a function of distance from the observer and size of insect. The volume will vary with binocular magnification, aperture opening, focal adjustment and insect size.

I restricted sampling to the 12 h period between 0600–1800 h which roughly corresponded to sunrise to sunset. While the method was being used and later tested, conditions were mostly clear with occasional clouds passing across the field of view. Sky conditions did not seem to alter my ability to see and count flying insects because I could easily follow insects across a background of mixed clouds and sky. Occasionally, a bird would fly through the field of vision either within the focal volume or far above. The motion of the bird's wings made it easy to differentiate it from an insect. Hummingbirds may be counted as insects as they pass through the observer's view. A period of careful observation of hummingbird activity in the sampling area prior to sampling would allow one to estimate the potential for this type of sampling error.

In order to test the accuracy and repeatability of this sampling technique, I simulated the technique using a known number of objects of known sizes. Objects were chosen to reflect the range of insect sizes that might be encountered. The five objects were, in ascending order with approximate surface area of their broadest profile: brown rice (0.15 cm^2), lentils (0.25 cm^2), black beans (0.5 cm^2), red beans (1.25 cm^2), and almond meats (2.25 cm^2). A single thrower threw 50 of each size object across the field of view while the observer counted the objects and notified the thrower who tallied the objects seen. Thus, 250 objects (50 of each of the five sizes) were thrown across seven zones, each a different distances from the observer. The thrower randomized the objects so that the observer could not anticipate the order in which objects were thrown. Because red beans and almond meats were visible at distances well beyond the other objects, I determined the distance at which they cannot be seen by having the thrower send one through the field of view at increasing distances until I could no longer see them. Care was taken to ensure that all objects were thrown at a relatively constant speed and that they passed through the viewing area. Comparisons of the speed of the thrown objects with that of insects passing through the sampling area showed that they were similar.

In order to generate a detection function for objects seen, the number of each size object was converted to a percent of the total thrown. Zones of varying distances from the observer were chosen and the range within each zone was then averaged to give a mean distance from observer for that zone.

Insect activity and flycatcher foraging.—I used the insect sampling method described above to test the hypothesis that aerial insect abundance is correlated with flycatcher foraging activity throughout the day. I conducted this research at the La Selva Biological Reserve (10°26′N, 83°59′W), Costa Rica. Data were collected in a clearing (0.2 ha) along the entry road to the Reserve. During the three days of data collection weather conditions were consistent, with clear to partly cloudy skies, no rain and wind speeds zero to light.

On 10–11 Mar. 1993, I measured the abundance of flying insects throughout the day at half-hour intervals at two points, one in the clearing and one at the forest edge adjacent to the clearing. I counted all insects seen passing through a focal volume of 28.7 m^3 for a 3-min period every half hour from 0600–1800 h. For statistical purposes, I used the mean number of insects counted at these two points as a measure of the relative abundance of flying insects.

On 9 Mar. 1993, total sallies of four flycatcher species (Tropical Pewee, *Contopus cinereus*; Gray-capped Flycatcher, *Myiozetetes granadensis*; Social Flycatcher, *M. similis*; and Tropical Kingbird, *Tyrannus melancholicus*) were counted continuously from 0600–1800 h and grouped into 23 30-min periods. I used correlation analysis in SYSTAT version 5.01 (Wilkinson 1990) to assess whether the daily pattern of flying insect abundance was correlated with the daily pattern of sallying activity for four flycatcher species.

RESULTS AND DISCUSSION

Using size classes of a known number of objects generated a detection function (Fig. 1b). The shape of the detection function demonstrates how distance from observer affects object detectability, with highest detectability for all size objects at the center of the zone of sharp focus (approximately 5 m). Object size also affected the shape of the function. The shape of the detection function for black beans, lentils, and rice was similar. Large objects (red beans and almonds), also had similarly shaped functions which resembled that for total objects; red beans and almonds accounted for all observations beyond 20 m. Large objects/insects can be seen well beyond the zone of sharp focus while small objects/insects rapidly become invisible to the observer as one moves away from this zone. Because small insects are often more common than large insects, this characteristic of the sampling technique may prove beneficial by generating adequate sample sizes of rarer large insects and minimizing counting difficulty of abundant small insects. Because the focal volume varies with insect size, data generated using this method should not be used to compare the relative abundance of insects of greatly different sizes. However, this technique does provide a way to estimate abundance of a given size class of insect across time and between locations.

To explore how binocular magnification, aperture diameter and optical quality influence focal distance, I tested two binoculars of different magnifications: 10×50 and 7×42. With the 10×50 binocular set on the nearest possible focus, I was able to see a stationary 0.15 cm^2 black object between the distances of 3.4–14 m, with sharp focus between 5.9–9.5 m. This setting gave me a conically-shaped focal volume of 28.7 m^3 (Fig. 1a). Using the 7×42 binoculars on their nearest focus setting, I was able to see the same object between the distances of 2.1–10.0 m with sharp focus between 3.2–5.8 m. The focal volume of the 7×42 binoculars was 13.9 m^3. This method can be used to calculate relative abundance. To generate an estimate of absolute density one would need to combine the detection function with the physical characteristics of the detection volume.

Because large, distant insects can be mistaken for small near insects, use of this method for size-class specific studies is not recommended. Duration of the sampling period should be adjusted relative to insect abundance. At low insect density, the period may need to be longer to reduce sampling error. One can choose an optimal period by plotting the coefficient of variation in abundance estimates for a variety of sampling periods and choosing a period where variance declines or stabilizes.

The data collected via the sampling procedure describe a common pattern of daily activity for flying insects (D. K. Young, pers. comm.). Abundance of flying insects did not show a correlation with total sallying frequency for the four species studied ($r = 0.34$, df $= 1$, $P = 0.11$) (Fig. 2).

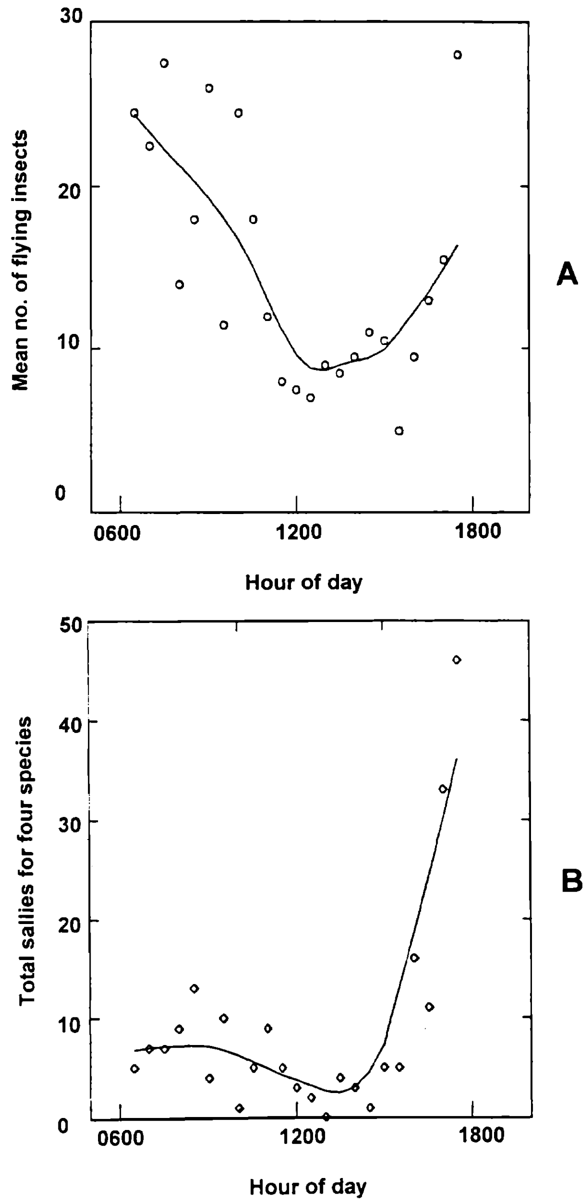

FIGURE 2. Abundance of flying insects (a) and total sallies of four species of birds (b) as a function of time of day. Insect abundance is the mean of two estimates taken from different points 7 m apart. Bird activity represents the number of sally attempts in a 30-min period prior to the graphed point. I used robust locally weighted regression (lowess) (Cleveland 1985) to generate a line through the data.

However, a general pattern of greater activity in the morning and evening for both insects and flycatchers was apparent.

Fitzpatrick (1981) reported that neotropical flycatchers studied in Peru, Venezuela, and Brazil displayed morning and late afternoon activity peaks. In this study, flying insects showed peak abundance early in the morning and late in the afternoon. The four flycatchers studied also showed a pattern of higher activity in the morning and again in the afternoon. While insect activity patterns were not strongly correlated with flycatcher sallying activity, increases in sallying frequency in the afternoon may be related to increased activity of flying insects. Data on insect and flycatcher activity were collected on different consecutive days. However, because weather conditions during the three days of data collection in Costa Rica were virtually identical I believe that activity patterns for both birds and insects were similar for the entire sampling period. Flycatcher foraging activity is influenced by a number of factors including hunger, preference for favored insect prey, weather, and seasonal breeding events, and some of these factors may exhibit a stronger influence on daily activity patterns than insect abundance alone. The daily activity patterns of bird, mammal, and insect predators that forage for flying insect prey are influenced by the availability of flying insects. The activity and, therefore, availability of flying insects is affected by many factors such as ambient temperatures, wind, and precipitation.

The sampling procedure presented here can be used to determine daily activity patterns of flying insects of specific size ranges and at specific distances above the ground. This technique has applications for ornithological, entomological, and mammalian (bat) research. My method of indexing flying insect abundance provides a means to further understand the relationship between aerial foraging species and their prey.

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