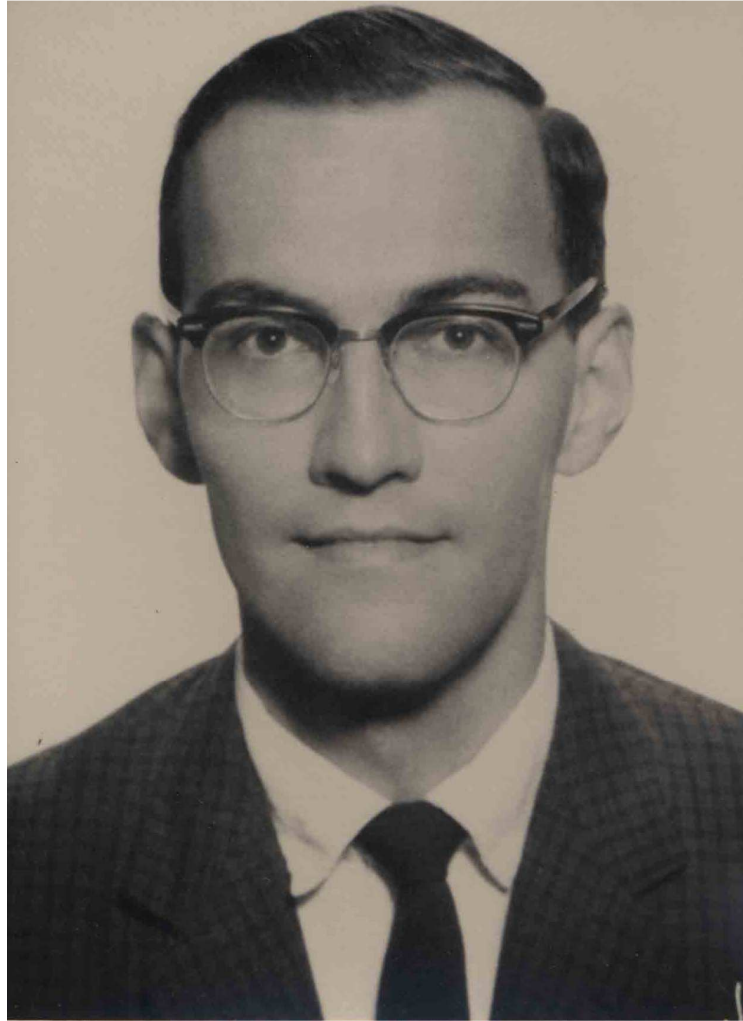


**Half a Century of Ornithology in Texas:  
the Legacy of Dr. Keith Arnold**



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**Swainson's Hawk (*Buteo swainsoni*) hunting behavior at  
an urban population of Free-tailed Bats (*Tadarida brasiliensis*)**

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**Abstract** – We examined Swainson's hawks (*Buteo swainsoni*) hunting and feeding on free-tailed bats (*Tadarida brasiliensis*) during the summers of 2014 and 2015 in Houston, Texas. We documented activity patterns for bats and hawks, as well as aerial hunting and post-catching techniques of the hawks. Hawk hunting attempts significantly correlated with date (cumulative experience) during 2015, temperature and relative darkness during hawk arrival. Hawk hunting success correlated with date (cumulative experience) during 2015 only. Results are discussed in comparison to other studies. To our knowledge, this study investigated the first known sustained predation of free-tailed bats by Swainson's hawks in an urban setting.

Predation is assumed to act as a selective evolutionary force by impacting the fitness of both the predator and the prey at individual and community levels (Abrams 2000, Stevens 2010). Individual predators kill and consume prey for energy and sustenance, and those that catch enough food to survive and reproduce have opportunities to pass their genetic traits to future generations. Conversely, prey must avoid being captured and killed by predators in order to survive and reproduce. Models of optimal foraging predict that predators will maximize their rate of energy intake by selecting the most profitable prey (i.e., the young, sick, weak, or old; Greene 1986, Giraldeau and Caraco 2000). Consequently predation acts to cull vulnerable and weaker individuals from prey populations, leaving resources for fertile and healthy individuals and improving the overall health of the population as a whole (Genovart 2010).

Large bat colonies are known to attract a variety of predators, including many species of reptiles, birds and mammals (Davis et al. 1962, D. Brooks pers. obs.). In their daytime roosts bats are mostly inaccessible to terrestrial predators; terrestrial predators are opportunistic foragers, capturing vulnerable bats that fall to the ground (Baker 1962). Primarily volant predators (e.g., raptors) actively pursue and capture bats in flight during mass emergences (Davis et al. 1962). Baker (1962) reported the avian predators of Free-tailed Bats (*Tadarida brasiliensis*, hereafter *Tadarida*) including: Cooper's Hawk (*Accipiter cooperii*), Sharp-shinned Hawk (*Accipiter striatus*), Swainson's Hawk (*Buteo swainsoni*), Red-tailed Hawk (*Buteo jamaicensis*), Ferruginous Hawk (*Buteo regalis*), Hen Harrier (*Circus cyaneus*) and Great Horned Owl (*Bubo virginianus*). Another study documented Barn Owl (*Tyto alba*), American Kestrel (*Falco sparverius*) and Greater Roadrunner (*Geococcyx californianus*) as predators of *Tadarida* (Wilkins 1989). Harris's Hawk (*Parabuteo unicinctus*) and Merlin (*Falco columbarius*) have also been observed preying upon urban populations of *Tadarida* (Ortega-Álvarez and Calderón-Parra 2014, Martinez and Lee 2013).

*Tadarida* are abundant and widely distributed throughout North, Central and South America (Wilkins 1989). In the southwestern United States these bats form the largest colonies that have been reported for any mammal (e.g., Bracken Cave, Texas, ~20 million individuals; Davis et al. 1962). They roost in natural recesses such as caves and tree cavities or in anthropogenic structures such as culverts, bridges, attics and buildings (Wilkins 1989). They emerge *en-masse* from their dwellings around sunset and travel long distances to hunt for various insects throughout the night (Lee and McCracken 2005). Moths, beetles and true bugs are their most common prey (Lee and McCracken 2005).

Swainson's hawks (*Buteo swainsoni*, hereafter SWHA) are diurnal *Buteo* hawks that inhabit North America during the spring and summer, and migrate long distances to winter in southern South America (England et al. 1997). They have flexible diets that can include small mammals, birds, reptiles, amphibians and insects (England et al. 1997). They are primarily insectivores during the non-breeding season, consuming mainly grasshoppers, crickets and dragonflies (Johnson et al. 1987). There are limited published accounts of this species preying on *Tadarida*, exceptions being studies of Looney (1972) and Baker (1962). The importance or mechanisms of *Tadarida* in the diet of SWHAs has not been investigated in these studies however.

Although *Tadarida* play ecological roles as both predator and prey, in the context of this study we investigated this species in its role as the prey of SWHAs. Specific objectives are: 1) describe and document the sustained predation of *Tadarida* by SWHAs in an urban habitat; 2) determine what (if any) factors correlated with predation attempts and successes of SWHAs; and 3) examine and document hunting and post-catching techniques of SWHAs on *Tadarida*.

## METHODS

A *Tadarida* colony of ~250,000 individuals roosts in crevices underneath the Waugh Drive Bridge in urban Houston, Harris County, Texas (29°45'42.5"N, 95°23'54.0"W). This bridge is located in a densely populated area of the city with city park spaces, storefronts, and office and apartment buildings. The bridge spans Buffalo Bayou, and is utilized by vehicles, pedestrians and cyclists. At nighttime streetlights, vehicle headlights and storefront signage provide artificial light in the immediate area. In the absence of extreme weather conditions, these bats emerge from their roost nightly to hunt. Observations were conducted from the center of Waugh Drive Bridge on the pedestrian sidewalk.

Data collection was during summer when SWHAs were at their peak hunting activity, and bats were at their peak flight activity. Data collection took place during July – September 2014 and April – August 2015. We sampled during bat emergence, from just before dusk until full nightfall.

Two SWHAs were observed throughout the study using 10x42 Nikon Monarch and Oculus binoculars. We were able to identify the hawks as the same individuals by identifying missing wing and rectrix feathers. These birds were assumed to be a bonded male-female pair because they were territorial, chasing off conspecifics that entered the hunting zone during 25% (n = 4) of all sampling durations.

To determine correlates of hawk hunting success, hunting attempts and success (= # captures / # attempts) were each correlated with several parameters, including: date (cumulative experience), temperature (°C), cloud cover (clear = 1, partial = 2, overcast = 3), wind speed (MPH) and direction, hawk arrival time, relative darkness during hawk arrival and departure, bat emergence and exit (absence) time and maximum bat height during flight (m). We used an Apple iPhone 5S clock to record date and all arrival/departure times, temperature (using the weather application), wind speed and direction (using the Weather Underground application) and relative darkness (using the Light Meter application). Flight height of birds and bats was estimated by comparing with proximal buildings and extrapolating height per/floor.

## RESULTS

### Bat activity in emergence zone

Bats began emerging from the bridge between 19:41-20:35 hrs (mean = 20:08, N = 14) and were absent from the emergence zone by 19:46-20:58 hrs (mean = 20:33, N = 13). The total time of activity in the emergence zone averaged 26 min (range = 5-48 min, N = 13). Maximum flight height averaged 89 m (range = 22-350 m, N = 13).

### Hawk hunting behavior

Hawks arrived on site to commence hunting between 19:39-20:20 hrs (mean = 20:02, N = 10) with a mean relative darkness index of 274 (range = 43-706, N = 14), ceasing hunting when the mean relative darkness index was 40 (range = 1-204, N = 14).

Aerial hunting behavior could be divided into three general patterns: diving (recorded during 93% of all sampling sessions, n = 13), in-flight pursuit (71%, n = 10) and circling (50%, n = 7). Diving, the most predominant behavior, involved a straight-line dive of 30-50 m (N= 10), invariably gaining higher speed than the bats were flying. On one occasion a hawk began to dive from ~100 m.

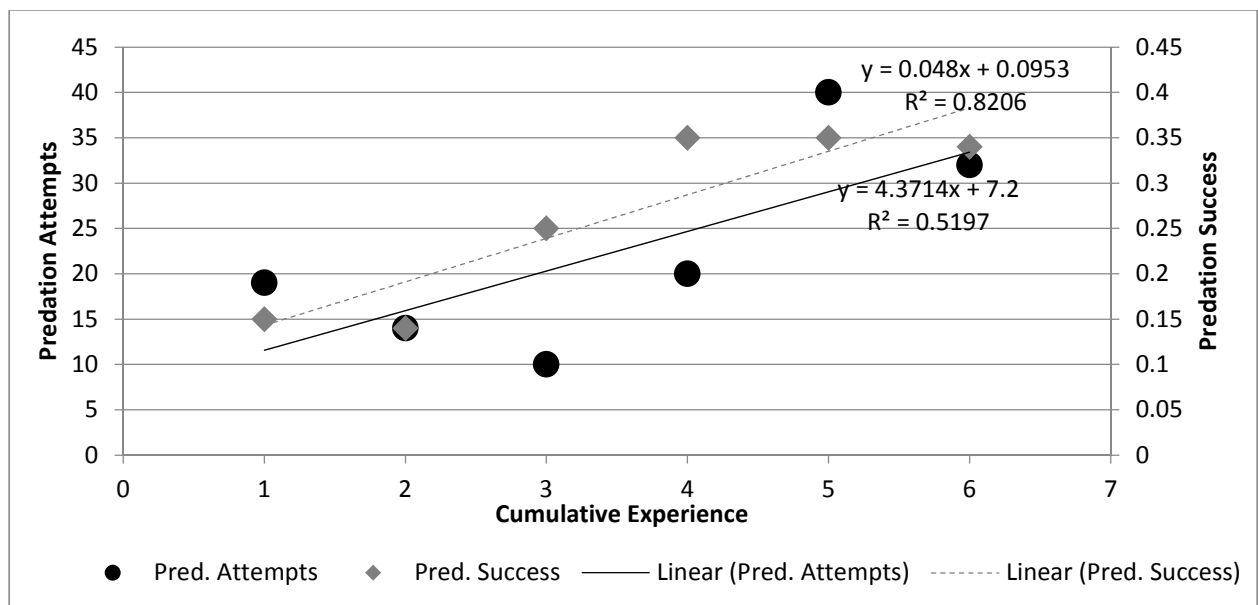


Figure 1 – The effect of cumulative experience on predation attempts and success (2015), both of which were positively correlated.

Predation attempts per sampling session ranged from 0-51 (mean = 21, N = 14), with hunting success ranging from 0-35% (mean = 17%, N = 14). Bats were consumed both in-flight on the wing (43%, n = 6) and while perched in a tree after catching (50%, n = 7). Five (83%, N = 6) of the observations of in-flight consumption took place during 2015, suggesting this behavior was favored during that year.

### Correlates of hawk hunting success

Hawk hunting attempts significantly correlated with date (cumulative experience) during 2015 ( $r = 0.83$ ,  $P = 0.04$ ,  $N = 6$ ; Fig. 1) but not 2014, as well as temperature ( $r = 0.54$ ,  $P = 0.02$ ,  $N = 14$ ; Fig. 2) and relative darkness during hawk arrival ( $r = 0.47$ ,  $P = 0.05$ ,  $N = 14$ ; Fig. 2). Non-significant correlations were found for cloud cover, arrival or emergence/absence time for hawks and bats respectively, relative darkness during hawk departure and maximum bat flight height. While wind speed and direction did not have enough samples to run correlations ( $N = 4$  each), it appeared that these two parameters had little influence on hunting attempts.

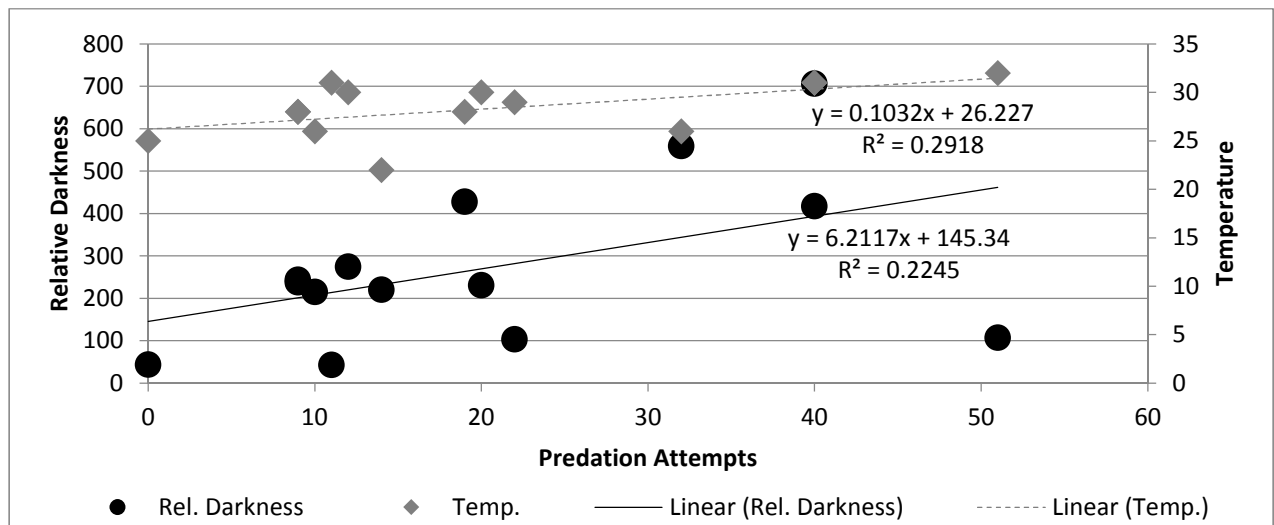


Figure 2 – The relationship between relative darkness and temperature on predation attempts, both of which were significantly correlated.

Hunting success was only significantly correlated with date (cumulative experience) during 2015 ( $r = 0.86$ ,  $P = 0.03$ ,  $N = 6$ ; Fig. 1), but not for any other parameters.

## DISCUSSION

Previous studies have found other species of raptors to display sustained predation on *Tadarida*, as we did with SWHAs. Martinez and Lee (2013) found Merlin made fewer predation attempts on bats than the SWHAs in our study, but had higher catching success rates (about a 50% rate of success catching at least 1 bat/attempt). This suggests that SWHAs may be less efficient at hunting bats than falcons such as Merlin. This essentially corroborated by Baker (1962) who described *Buteo* hawks to be no more than half as efficient at catching bats as Accipiters.

Some of the hunting and post-catching techniques that were utilized by the SWHAs in our study have also been documented in previous research. Baker (1962) recorded in-flight pursuit as a specific manner of attack used by SWHAs on *Tadarida*; we observed this technique in 71% of predation attempts. Our observation of SWHAs immediately transferring the captured prey to their bill and ingesting it whole in flight has been noted by Jaramillo (1993) and Sarasola and Negro (2005). However, they observed the hawk's prey consisting of insects instead of bats (Jaramillo 1993, Sarasola and Negro 2005). This suggests that some predatory behaviors of SWHAs may be applied to a variety of prey.

We predicted to find relative darkness to be correlated with hunting attempts given the diurnal nature of SWHAs and their requirement for suitable light conditions to hunt (Baker 1962). Contra to our results, Sarasola and Negro (2005) found the striking rate of SWHAs in their study to be negatively correlated with air temperature. Although the Sarasola and Negro (2005) study looked at a population of wintering SWHAs preying insects in Argentina, we would have expected to see similar results in our study. The positive correlation to temperature in our study may have been a consequence of more favorable weather conditions overall.

Although we gathered data on wind speed and direction in this study, we did not collect enough samples to run correlations. Yet, it appeared that these two parameters had little influence on the hawks' hunting attempts or successes. Lack of wind speed on aerial hawk strike rates has been documented in previous research (Sarasola and Negro 2005). In contrast, Baker (1962) described an anecdotal account of a gusty evening in which a SWHA missed a high percentage of strikes on *Tadarida*, with higher hunting success rates on two evenings with only slight breezes. These conflicting results indicate that further research should be conducted to determine the impact of wind speed and direction on predation attempts and successes of hawks.

Evidence of aerial predator-prey encounters between hawks and bats in an urban landscape might help to explain the mechanisms of novel prey selection by hawks in an unusual habitat. In addition, the large availability of bats in this urban setting could permit hawks to develop new prey-searching strategies to exploit a unique food source on their breeding grounds with a low energetic cost.

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