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First documentation of acorn consumption by eastern screech owl (*Megascops asio*)

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ABSTRACT

We present evidence for the first documentation of consumption of a water oak (*Quercus nigra*) acorn by an eastern screech owl (*Megascops asio*). A screech owl diet typically consists of small mammals, small birds, and arthropods. In our study, we had a 1-m x 1-m sand pad under observation from a game camera that was set on a 1-min time-lapse delay. On this sand pad, we placed five water oak acorns. In a series of six images over six minutes, we observed an eastern screech owl land near the sand pad, walk to an acorn, and appear to consume the acorn. Although there could be other plausible explanations and events that transpired between 1-min image intervals, we believe this acorn was consumed by the eastern screech owl. The importance of this addition of food type to the diet of a raptor is largely unexplored and undocumented.

1. Introduction

Screech owls (*Megascops asio*) are carnivorous, primarily feeding on protein-rich food items such as birds, small mammals, and arthropods. According to Artuso (2010), invertebrates (insects, earthworms, crustaceans, arachnids, gastropods) make up the majority (66%) of the diet of eastern screech owls, with beetles being the most consumed prey. Additionally, eastern screech owls consume other birds (15% of prey captures, mainly passerines), mammals (15%, primarily meadow voles, *Microtus pennsylvanicus*), and a small portion of amphibians/fishes (<1%; Artuso, 2010). As meat-eating specialists, their digestive system is specifically designed to process protein-rich foods such as animal tissue. However, as is common in nature, there exist a multitude of exceptions to the rule and documented cases where animals consume food items outside of their dietary norms are frequent. For example, Fitzsimons and Leighton (2021) observed piscivorous and insectivorous black kites (*Milvus migrans*) and carnivorious whistling kites (*Haliastur sphenurus*) consuming avocado (*Persea americana*) in Australia. Further, black kites have been known to consume nuts from oil palm (*Elaeis guineensis* (Cramp, 1982). Pacific bazas (*Aviceda subcristata*), a species of Australian hawk, and the oriental honey-buzzard (*Pernis ptilorhynchus*), known to specialize in consuming bees and wasps, were documented consuming fruit (Fitzsimons and Leighton, 2021). Previous literature reviews by Brown and Amadon (1968), Ferguson-Lees and Christie (2001), and Fitzsimons and Leighton (2021) synthesizes 13, 18, and 29 species of fruit-eating raptors, respectively. Recently, Barbary macaques (*Macaca sylvanus*) were observed hunting and consuming rabbits, chicks, and eggs, despite Barbary macaques having never previously been known to eat vertebrates (Young et al., 2012). Perhaps more common than previously believed, white-tailed deer (*Odocoileus virginianus*) have been reported in several instances to consume both nestlings and eggs of birds as well as several fish species (Pietz and Granfors, 2000; Ellis-Felege et al., 2008). Herbivorous rabbits have been reported to consume animal carcasses, and sometimes prefer them over their typically preferred plant-based items (Clauss et al., 2016). Greenhawk (2015) observed *Anolis cristatellus*, a primarily frugivorous and insectivorous anole reptile, consume marshmallow residue on a stick. These examples are all described as opportunistic foraging, where these animals are taking advantage of an available source of nutrients, despite that source not being a regular part of their diet. However, dietary deviations such as these may be necessary to supply additional nutrients to diminish deficiencies, improving survival and reproduction. Here, we describe the first documentation of an eastern screech owl consuming an acorn.

2. Material and methods

During 2017–2019, as part of a separate study investigating the consumption of hard mast by wildlife, we gathered and analyzed roughly 7.3 million images from camera trap sites that were baited with

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acorns. It is worth noting that this observation was made opportunistically within the context of the aforementioned study, which had a different primary objective.

Our study area was in Macon County, Alabama on 3406 ha of privately-owned land. The area, managed for wildlife (northern bobwhite [*Colinus virginianus*], and white-tailed deer), was primarily comprised of upland pine (*Pinus taeda*) intermixed with hardwood drainages (*Quercus* spp., *Liquidambar styraciflua*). Primary oak species

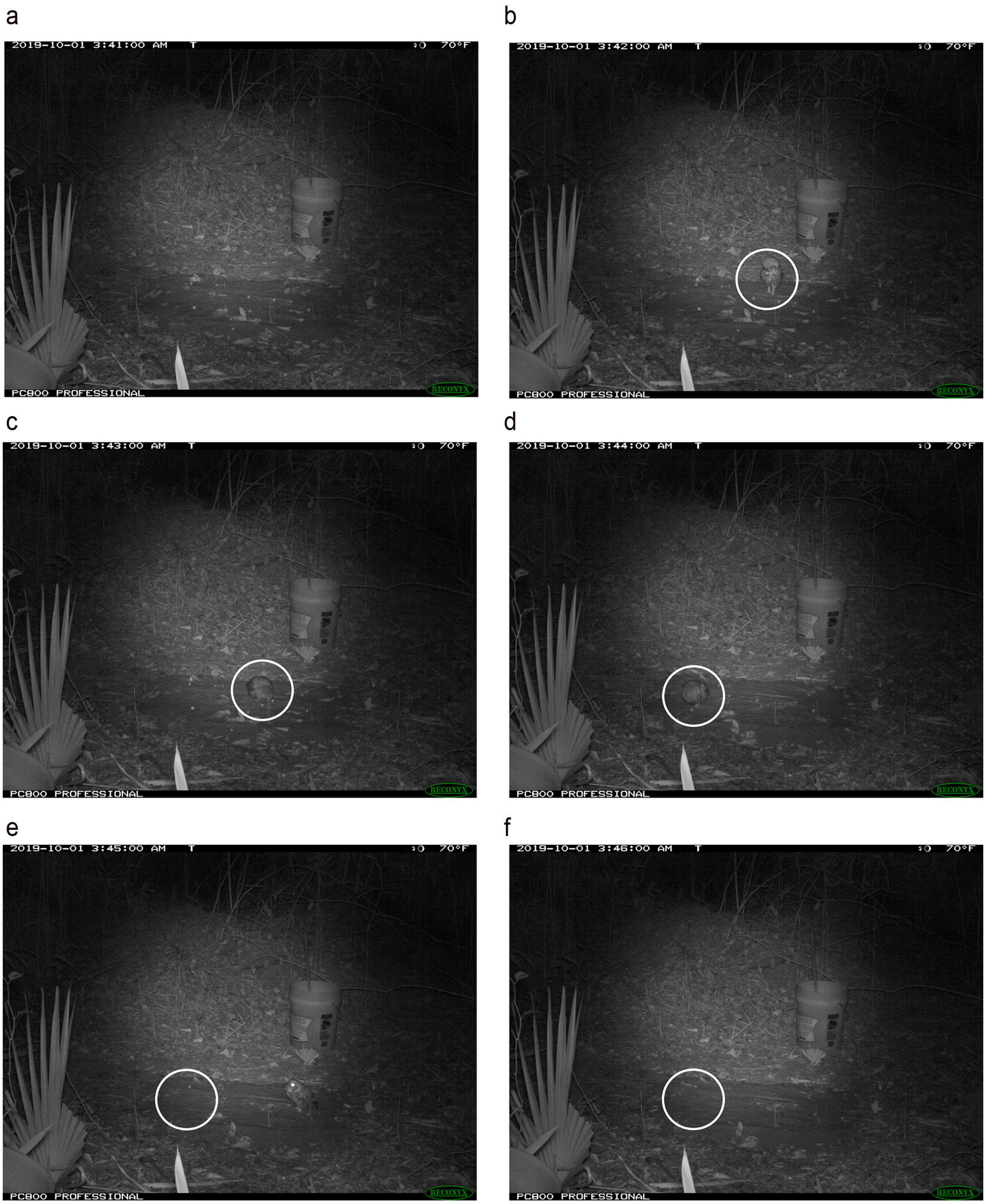

Fig. 1. **a**. Game camera view of sand pad containing five placed acorns in Macon Co., AL.
b. Game camera view of sand pad containing five placed acorns and an eastern screen owl *(Megascops asio)* in Macon Co., AL.
c. Game camera view of sand pad containing five placed acorns and an eastern screen owl *(Megascops asio)* in Macon Co., AL.
d Game camera view of sand pad containing five placed acorns and an eastern screen owl *(Megascops asio)* overlooking an acorn in Macon Co., AL.
e Game camera view of sand pad containing four placed acorns and an eastern screech owl *(Megascops asio)* who appears to have consumed an acorn from the sand pad in Macon Co., AL.
f Game camera view of sand pad containing four placed acorns after an eastern screech owl *(Megascops asio)* has consumed an acorn in Macon Co., AL.

included water oak (*Quercus nigra*), white oak (*Quercus alba*), southern red oak (*Quercus falcata*), and turkey oak (*Quercus laevis*) within mixed forest, deciduous forest, evergreen forest, and woody wetlands.

We established 40 camera trap sites at which we observed acorn fate (wildlife consumption or other means of acorn disappearance). At each camera trap site, we established a light-colored, 1-m x 1-m sand pad to create a contrasting background from the forest floor enabling us to observe acorns more easily. Each sand pad was placed with the center of the pad 2.5 m from the base of an acorn-producing oak tree from which we gathered acorns to place on the sand pad. We then positioned 5 acorns in a quincunx arrangement on the sand pad with the outer acorns at least 5 cm from the edge of the pad. We used the species of acorns (*Quercus nigra, Quercus alba, Quercus laevis*) corresponding to the tree beneath which the camera trap was established; however, in some instances when acorns could not be found, we used acorns from a nearby tree which may not have been of the same species. We used a game camera (PC800 HyperFire Professional IR, Reconyx) equipped to operate 24 h a day for a 14-day period with a 1-min time-lapsed delay between each image to monitor the fate of acorns on the sand pad. Additionally, cameras were set to automatically provide a time and date stamp on each image. Each camera was installed on the oak tree with a tree-mounted stand 1 m above the ground and 2.5 m from the sand pad. We then aimed the camera at the sand pad using a laser pointer to ensure the field of view encompassed the entire sand pad and adjacent areas. We monitored acorns on the sand pads for 14 consecutive days each month (September–February) during 2018–2019 and 2019–2020.

When analyzing the images, we used Timelapse2 Image Analyser software (University of Calgary, Calgary, Alberta, Canada) and identified any image when an acorn disappeared. The five images (i.e., 5 min) before and after an acorn disappearance were used to classify the fate of the acorn and identify the cause of its disappearance.

3. Results

We analyzed 7.3 million images collected over two years and 10 total sampling periods (140 days) to determine acorn fate and estimate consumption by wildlife. Seventeen wildlife species were observed on camera consuming acorns over the two-year study. In an image series collected on 1 October 2019, we observed an eastern screech owl appear in camera view on the sand pad at 3:42 AM, standing directly over and looking at an acorn (Fig. 1b). A minute later at 3:43 AM the owl leaned down and put its bill in the proximity of the acorn (Fig. 1c) and then the following minute moved to another acorn on the sand pad, also leaning over with its bill near or touching the acorn (Fig. 1d). In the next minute (3:44 AM), the second acorn disappeared, and the owl is then pictured on the sand pad with its head tilted upward (3:45 AM; Fig. 1e). The next image at 3:46 AM shows the screech owl had left the sand pad and camera view and the acorn is no longer visible (Fig. 1f).

4. Discussion

Based on the series of images portraying the owl on the sand pad, we believe the owl consumed the acorn. Despite their normal foraging habits, owls possess the physical and behavioral attributes to effectively consume and digest acorns, particularly water oak acorns that are smaller than other documented prey items (Artuso, 2010). Because raptors do not have teeth, they consume their food items whole or torn into pieces to be swallowed. To do this, many times the bird will tilt its head back to elongate and widen the esophagus for ease in consuming whole items. This behavior seen in our images is consistent with typical raptor feeding behavior. The digestive anatomy of a screech owl is like many other small raptor species. Food items are consumed whole and swallowed, passing through an extensible esophagus, through the crop and proventriculus to the gizzard, where the mechanical breakdown of food occurs. The muscles in the gizzard contract to grind and crush tougher objects. The proventriculus produces gastric juice with a low pH (highly acidic) which allows for further chemical breakdown of food. Screech owls have a particularly large, round, single-chambered gizzard (Hristov, 2020). Here, an acorn can be crushed by the muscles of the gizzard and broken into small pieces. After food items are crushed, indigestible components are retained in the gizzard and compacted into a pellet which is egested, thereby allowing only digestible food to pass through the rest of the digestive system. From there, broken down food travels to the small intestine, which functions as the main source of chemical digestion and nutrient absorption (Murray, 2014). Screech owls and other carnivorous birds have a short small intestine to increase passage rate and reduce body weight, thereby improving flight and hunting ability. To compensate, increased villi (fingerlike projections on the inner intestinal lining) create more surface area and maximize nutrient absorption in a shorter timeframe. The small intestine is where the majority of lipid and starch breakdown occurs. Enzymes (i.e., amylase) secreted in the owl small intestine convert starch into simple sugars, allowing energy absorption by the body (Leprince et al., 1979). After nutrient breakdown and absorption, the food passes through the glandular ceca (assists with water balance) to the rectum and is excreted (Murray, 2014).

Although raptor digestive systems are typical of carnivores and specialized to process protein, and to a lesser extent lipids, they may also be able to break down other compounds such as carbohydrates. For example, screech owls were found to be able to digest chitin (a difficult-to-digest carbohydrate found in arthropod exoskeletons) at a rate up to 30.4% (Akaki and Duke, 1998). In comparison to the digestibility of granivorous bird species that regularly consume hard mast and insects, owls were found to have high levels of chitinase (2618 μg AGh $^{-1}$ ml^{-1}), an enzyme that breaks down chitin, and greater ability to digest chitin. For instance, the northern bobwhite has a lesser ability to digest chitin (6.7%) even though insects (containing high levels of chitin) comprise a large portion of their diet (Weiser et al., 1997; Akaki and Duke, 1999). Eastern screech owls have the capability to not only consume but also digest these complex carbohydrates.

We postulate that the owl in our study opportunistically consumed the acorn due to its high energy content (lipids and carbohydrates). Similar strategies have been shown in other carnivorous taxa that consume lipid-plant-based items that have similar chemical structures as their typical animal food items (MacHado and Pizo, 2000; Pizo and Oliveira, 2001). For example, harvestmen (*Neosadocus variabilis*, a predatory spider) consumed several fruiting plant species due to their high lipid levels (MacHado and Pizo, 2000). In this way, a carnivore acted as a frugivore opportunistically due to necessary nutritional benefits derived from plant material. Although raptors are classified as such based on their carnivorous eating habits, there have been documented cases of other food types consumed outside of carnivory. Crested caracaras (*Caracara plancus*) were recorded to consume fruit and seeds of the "bacuri" palm (*Arralea phalerata*) in Brazil (Galetti and Guimarães, 2004). Likewise, the American swallow-tailed kite (*Elanoides forficatus*) has been documented in several instances to consume seeds and fruits (Lempke, 1979; Gerhardt et al., 2004; Meyer et al., 2004). Additionally, over 13 species in the families Cathartidae, Accipitridae, and Falconidae were recorded consuming fruits and other seeds (Galetti and Guimarães, 2004).

A wide diversity of native wildlife species consume acorns as a necessary, but ephemeral, food source. This hard mast provides nutritional benefits and is a major source of energy that many species rely on for survival and successful reproduction, particularly through the winter months when other food is not as available for consumption (Eiler et al., 1989); Kirkpatrick and Pekins (2002) coined acorns "the staff of life" for many wildlife species. Over 90 North American wildlife species have been shown to use acorns as a food source, ranging from Ursidae (bears) to Cervidae (deer) to Passerines (songbirds), and many more (Goodrum et al., 1971; Greenberg, 2000). The acorn nutritional value is mainly expressed in terms of the high energy levels because protein levels are limited (<4%; Saffarzadeh et al., 1999). Energy comes in two main forms, carbohydrates and lipids. Carbohydrates account for over half of the available energy in an acorn and are available as starch and sugars, both non-structural carbohydrates (Saffarzadeh et al., 1999). Starch is a valuable nutrient as it is easily broken down to glucose, and therein readily absorbed, thus enabling wildlife to meet high energy demands (Mccusker et al., 2011). Approximately 58% of the acorn kernel is starch, a non-structural carbohydrate (Saffarzadeh et al., 1999). To be able to process starch into a usable nutrient (sugar/glucose), the enzyme amylase is required, which is present in humans and many other wildlife species. Numerous owl species have been reported to produce amylase, indicating their ability to digest starch (Leprince et al., 1979; Marti et al., 1986; Al-Saffar and Al-samawy, 2014; Szabo et al., 2014; Montolio et al., 2018). These non-structural carbohydrates are more easily digestible than structural carbohydrates (cellulose, hemicellulose, etc.) that are typically consumed by herbivores. Most (40–80%) non-acorn forage available for wildlife is primarily comprised of hemicellulose and cellulose, creating a digestive challenge for many wildlife species (Schroeder, 2004).

Lipids account for 9% of the energy in acorns, a relatively high amount in comparison to other herbivorous forage options (León-Camacho et al., 2004; Charef et al., 2008). Crude fat is more than twice as high in acorns (7.7%) compared to domestic grains specifically planted for wildlife benefits such as corn (3.80%), sorghum (2.90%), barley (1.80%), wheat (2.50%), rye (1.50%), and oats (4.20%; (Saffarzadeh et al., 1999). Crude fat increases the digestibility of metabolizable energy (ME), a highly desired aspect for wild animals where energy is often a limiting factor (Just, 1982). Moreover, crude fat levels can reach 6.34 g/kg of dry matter in acorns, a high percentage compared to other native forages that are heavily comprised of cellulose and hemicellulose (structural carbohydrates) and are difficult to digest (Weimer, 1996). Dehulled acorns contain a high concentration of unsaturated fatty acids relative to other available and preferred forage types (Saffarzadeh et al., 1999), which have benefits for digestion and cardiovascular health (Buochuama, 2018). Acorns contain high levels of oleic acid (66.06%) and linoleic acid (14.67%), fatty acids that are essential for wildlife as they must be ingested and cannot be created within the body (Rey et al., 1997; Saffarzadeh et al., 1999; Rey and López-Bote, 2001). On accounts of these energy benefits, acorns provide necessary nutritional elements to many wildlife species.

Many wildlife species rely on acorns as part of their seasonal diet. For example, white-tailed deer rely on acorns as a nutritional base of their diet, making up 50% of their overall diet during parts of the year, or as high as 76–90% when readily available (Harlow et al., 1975; McShea and Schwede, 1993). According to Johnson et al. (1995), acorns are the most important item for white-tailed deer throughout the fall months in southern Appalachian forests. Similarly, squirrels (*Sciurus* spp.) rely heavily on acorns as a food source during fall but also caching this hard mast for use later in the year (Havera and Smith, 1979; Fox, 1982). Likewise, Rogers (1976) reported that American black bears (*Ursus americanus*) prefer acorns during fall due to their high energy content and ability to help build fat reserves prior to hibernation. In times of hard mast failure, black bears have been shown to have reduced survival and reproduction. For example, Rogers (1976) found in years of hard mast failure only 33% of females reproduced compared to 59% in years of hard mast presence; moreover, female weights were decreased substantially during hard mast failures. Not only do acorns allow for fat deposition to be used during hibernation but enable females to maintain body condition into the spring when lactation is important. Avian species like ruffed grouse (*Bonasa umbellus*) also consume acorns due to their many nutritional benefits. In years with poor mast availability, metabolic energy (ME) in the grouse diet may be 20% less than during years when acorns are available (Servello and Kirkpatrick, 1988). Dietary ME is positively associated with clutch size, egg weight, and hatchability (Beckerton and Middleton, 1982). Another avian species that utilize the high nutrition of acorns are wild turkeys (*Meleagris gallapavo*). Dalke et al. (1942) reported the importance of this food item in wild turkey diets in Missouri, noting the behavioral implications of this hard mast. Specifically, in high mast years, turkeys will remain in acorn-rich areas; however, in poor mast years, they will semi-permanently leave these areas in search of other food items. Turkeys' dramatic change in behavior is due mainly to the presence of high-nutrition acorns.

Although we believe the most plausible explanation for the acorn disappearance was due to owl consumption, it is possible the acorn could have been removed from the sand pad by means other than owl consumption. Firstly, the owl could have pushed it out of camera view without consuming it (e.g., kick, shove, cover). However, we never saw the acorn appear on camera throughout the remainder of the study period. Secondly, another animal could have come within the one-minute camera delay and removed the acorn and exited camera view prior to the next image capture. However, we find this scenario unlikely because the owl was shown on camera on the sand pad for several minutes before and after the acorn disappearance, appearing to never have left the sand pad. We did not see evidence of another animal on the sand pad or surrounding areas within this timeframe.

5. Conclusions

Our discovery marks the first known and documented consumption of an acorn by an eastern screech owl. Although there are reports of other raptors consuming vegetative material, we have not been able to locate in the literature any records of acorn consumption by an eastern screech owl, or any other owl species. We find it a valuable addition to natural history records for both predator and prey species. Marking the record of an eastern screech owl straying from its typical forage taxon is a useful phenomenon to understand the food habits of the species more thoroughly. Additionally, this record shows yet another species that use the nutritional benefits of hard mast. Hard mast consumption by owls and other raptors may be a more common behavior than originally believed, which would have many ecological and management implications.

Declaration of Competing Interest

None.

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