High Incidence of Hypopigmented Marks in the Endangered Florida Bonneted Bat

Lisa M. Smith,* Jeffery A. Gore, Elizabeth C. Braun de Torrez, Elysia Webb, Frank Ridgley, Brett Tornwall

L.M. Smith, E.C. Braun de Torrez, B. Tornwall
Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, Gainesville, Florida 32601

J.A. Gore
Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, Panama City, Florida 32409

E.C. Braun de Torrez, E. Webb
Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, Florida 32611

F. Ridgley
Conservation and Research Department, Zoo Miami, Miami, Florida 33177

Abstract

Aberrant patches of white skin or fur known as hypopigmented marks have been observed in many mammal species worldwide, but they are typically limited to only a few individuals in a population. Hypopigmented marks were documented in only two museum specimens of the federally endangered Florida bonneted bat (Eumops floridanus) as early as 1950, but recent observations suggest that these marks may be more common in this species than previously believed. To better understand the occurrence and persistence of hypopigmented marks in Florida bonneted bats, we evaluated the variation in frequency, compared effects on survival, and assessed spatial and temporal differences of specimens at an intensively studied site and across the species range. From 2014 through 2017, we regularly captured Florida bonneted bats for demographic studies at Babcock–Webb Wildlife Management Area in Charlotte County and we observed hypopigmented marks on 172 (80.8%) of 213 individuals, the highest incidence known for bats. The proportion of hypopigmented marks did not differ with sex, age at first capture, or reproductive status, and importantly, we documented the persistence of hypopigmented marks in individuals over multiple months. We also found no difference in survival or capture probability between hypopigmented and solid-colored individuals. Using data from concurrent mist-net studies, we assessed the proportion of Florida bonneted bats with hypopigmented marks across the species range and found a higher proportion of individuals with hypopigmented marks in the two northern counties (80.8% in Charlotte County and 61.5% in Polk County) compared with the two southern counties (21.1% in Miami–Dade County and 16.7% in Collier County). Additionally, we compared the proportion of hypopigmented individuals in Miami–Dade County between recently captured/collected bats (post-2004) and historically (pre-1965) collected museum specimens and found more hypopigmented marks in recently captured bats. The persistence of hypopigmented marks over time, the presence of marks on bats from different locations, and our finding of no effect of age on the presence of marks all strongly suggest that the hypopigmented marks in Florida bonneted bats are the result of genetic rather than environmental factors. Further study is required to understand the mechanism underlying the high incidence of hypopigmented marks and to determine whether the prevalence of hypopigmented marks indicates low genetic diversity that could threaten Florida bonneted bats.

Keywords: chromatic disorders; Eumops floridanus; Florida bonneted bat; hypopigmentation

Received: January 29, 2019; Accepted: July 25, 2019; Published Online Early: August 2019; Published: Month 2019

Citation: Smith LM, Gore JA, Braun de Torrez EC, Webb E, Ridgley F, Tornwall B. 2019. High incidence of hypopigmented marks in the endangered Florida bonneted bat. Journal of Fish and Wildlife Management 10(2):410–418; e1944-687X. https://doi.org/10.3996/112018-JFWM-110

Copyright: All material appearing in the Journal of Fish and Wildlife Management is in the public domain and may be reproduced or copied without permission unless specifically noted with the copyright symbol ©. Citation of the source, as given above, is requested.
Introduction

Chromatic disorders are pigmentation anomalies of the skin, fur, or iris caused by either a lack or an excess of melanin. Although chromatic disorders have been documented across many mammal species worldwide, they typically are rare within a species or a population (Caro 2005; Lucati and López-Baucells 2016). This is especially evident among bats, where aberrant coloration has been reported in 115 species and 10 families, but despite extensive sampling, only 609 individuals with pigmentation anomalies have been reported (Lucati and López-Baucells 2016). In addition, because most observations have been made from encounters with individual bats and not through extensive sampling, the frequency of chromatic disorders in a population has seldom been documented (Glass 1954; Herreid and Davis 1960; Geiger and Pacheco 2006).

Chromatic disorders can be classified into several categories on the basis of the extent to which the distribution of melanin varies from normal (Lucati and López-Baucells 2016). One common disorder results in an animal having patches of white skin or fur known as hypopigmented marks. These irregular white marks are the most common chromatic disorder reported in bats, accounting for 269 (44%) of the records of aberrantly colored individuals (Lucati and López-Baucells 2016). Hypopigmented marks may have an environmental or genetic origin. Possible environmental causes of hypopigmentation include age, stress (Herreid and Davis 1960; Caro 2005), injury (Davis 1968; Faure et al. 2009), and interaction with chemicals (Møller and Mousseau 2001).

Hypopigmented marks of genetic origin, often called piebald marks, are caused by a mutation of one of several genes that affect development or function of melanocytes, resulting in a localized absence of melanin and, therefore, patches of white skin or fur (Davis 2007; Dessinioti et al. 2009; Lamoreux et al. 2010; Abreu et al. 2013). An increase in the occurrence of these hypopigmented marks is believed to be caused by inbreeding, low genetic diversity, or genetic drift after a colonization or other isolating event (Walley 1974; Parsons and Bondrup-Neilson 1995; Laikre et al. 1996; Bensch et al. 2000; Clark et al. 2011). Hypopigmented marks have been documented in small, isolated populations of several species, including captive brown bears (Ursus arctos, Laikre et al. 1996) and meadow voles (Microtus pennsylvanicus, Parsons and Bondrup-Neilson 1995). Regardless of whether genetic or environmental factors are the cause of hypopigmentedated marks, the proportion of individuals with hypopigmented marks in any sample or population is usually low (< 10%; Herreid and Davis 1960; Parsons and Bondrup-Neilson 1995; Møller and Mousseau 2001).

The Florida bonneted bat (Eumops floridanus, family Molossidae) is a species endemic to south Florida (Belwood 1992; Timm and Genoways 2004). It is listed as a federally endangered species (USFWS 2013) under the U.S. Endangered Species Act (ESA 1973, as amended) with a census estimate of fewer than 1,000 individuals (FWC 2013). It is unclear if the species constitutes one continuous interbreeding population; however, occurrence data suggest that the distribution of Florida bonneted bats is patchy (Bailey et al. 2017). The Florida bonneted bat is typically solid brown and hypopigmented marks have been documented previously from only two museum specimens (Timm and Genoways 2004). However, since 2014 we have observed numerous individuals with hypopigmented marks. These recent observations led us to question whether the prevalence of hypopigmented marks in Florida bonneted bats varied spatially and temporally, whether hypopigmented marks varied in appearance, and whether they affected survival.

To better understand the occurrence of hypopigmentation in Florida bonneted bats, we examined specimens from across South Florida, including a study site where bats are regularly captured for demographic studies. Our objectives were to 1) evaluate variation in the frequency of hypopigmented marks among sex, age, and reproductive classes; 2) compare survival probability between hypopigmented and solid-colored individuals; 3) assess variation in the proportion of hypopigmented individuals in local populations across the species range; and 4) compare the proportion of hypopigmented individuals in recent captures and collections with that among older museum specimens.

Study site

The primary study area was in the Babcock–Webb Wildlife Management Area (BWWMA, 26°52′ N, 81°51′ W), in Charlotte County in southwest Florida (Figure 1). This area comprises a mesic flatwoods community, a mosaic of dry prairies, pine flatwoods, hammocks (hardwood forest), and freshwater marshes (FWC 2003). The pinelands are dominated by slash pine (Pinus elliottii), with an open canopy maintained by an aggressive regime of prescribed fire (FWC 2003). Water levels fluctuate seasonally, with approximately 40% of the study area flooded during the summer wet season (FWC 2003). In BWWMA, Florida bonneted bats roost in cavities in pine trees and in bat houses mounted on poles across the property (FWC 2003; Ober et al. 2017).

To assess the occurrence of hypopigmented marks in Florida bonneted bats outside BWWMA, we used data...
Figure 1. Counties in South Florida in which Florida bonneted bats *Eumops floridanus* were captured from 2014 to 2017 and location of primary study area in Babcock–Webb Wildlife Management Area (BWWMA), Charlotte County, Florida.
from individuals captured or collected in other sites within the species range during concurrent studies (see Braun de Torrez et al. 2017; Webb 2018). These sites included Florida Panther National Wildlife Refuge and Fakahatchee Strand Preserve State Park in Collier County, Avon Park Air Force Range in Polk County, and the urban area near Coral Gables in Miami–Dade County. The three conservation areas contained a mix of mesic and hydric slash pine and longleaf pine (Pinus palustris) flatwoods, cypress (Taxodium ascendens and Taxodium distichum) communities, freshwater prairies, ponds, and hardwood hammocks. The urban area consisted of small, disjunct green spaces, such as golf courses and parks, in a matrix of single-family and multifamily residences and commercial areas.

Methods

Field methods

In BWWMA, we identified 13 roosts of Florida bonneted bats, 10 in wooden bat houses and 3 in cavities in pine trees. We used mist nets (Avinet Inc., Dryden, NY) to capture bats at each occupied roost for 1 night every 4 mo from April 2014 through April 2017. We erected two or three triple-high mist-net arrays, that is, three tiers of nets on 7.3-m poles (Bat Conservation and Management Inc., Carlisle, PA), around each roost and captured bats as they emerged after sunset. We monitored mist nets until all bats had emerged or for a maximum of 3 h. We removed captured bats from the net immediately and recorded standard measurements including mass, forearm length, sex, reproductive status, and age. We marked each bat with a unique passive integrated transponder (12 mm, 0.1 g, 134.2 kHz ISO FDX-B PIT-Tags; Biomark Inc., Boise, ID) tag for identification and estimates of survival.

We examined the pelage of each bat and considered as a hypopigmented mark any single white patch ≥ 2 mm across. We noted the location of each mark in two ways. First, for each white mark (some individuals have multiple white marks) we noted whether it was on the bat’s ventral or dorsal side. Second, we noted each mark’s predominant lateral orientation as left side, right side, center, or extending across the body. For 25 bats selected at random in April 2017, we also measured the length (left to right) and width (cranial to caudal) of ventral white marks. Areas of unconsolidated flecks of white hairs were not considered as hypopigmented marks.

Outside BWWMA where there were no known roost locations, we captured free-flying Florida bonneted bats using paired triple-high mist-net arrays placed in locations where the species had previously been detected (for details on sample design see Braun de Torrez et al. 2017; Webb 2018). We sampled bats in Collier County (Florida Panther National Wildlife Refuge and Fakahatchee Preserve State Park) on 13 nights from March through May 2016, and in Polk County (Avon Park Air Force Range) and Miami–Dade County on 41 nights from May through July 2017. We set nets in relatively open areas (pine flatwoods, freshwater prairies, large quarry ponds, golf courses) and used an acoustic lure (BatLure™, Apodemus Field Equipment, Mheer, the Netherlands), which broadcasts Florida bonneted bat social calls recorded around known roosts, to increase the chances of capture (Braun de Torrez et al. 2017). Sample sizes were much lower in sites using this method because we were unable to capture bats emerging from roosts and capture rates were very low (less than one bat per night). We also examined eight Florida bonneted bats found dead or injured in Miami–Dade County and transferred to Zoo Miami between 2004 and 2017. To evaluate the historical occurrence of hypopigmented coloring in Florida bonneted bats, we examined museum specimens from the Florida Museum of Natural History, the University of Kansas Biodiversity Institute, and the American Museum of Natural History.

Data analysis

We used 2 × 2 contingency tables analyzed with Fisher’s exact test to determine whether the proportion of hypopigmented bats differed as a function of sex (male, female), age at first capture (adult, subadult), and reproductive status (reproductive, not reproductive). Because of differences in sample size and capture methods, we did not statistically test among capture locations and historical periods (1950–1965 vs. 2004–2017). We analyzed data in R 3.4.2 (R Core Team 2017). We used the marked R package (Laake et al. 2013; R Core Team 2017) to test whether the apparent survival and capture probability of passive integrated transponder-tagged Florida bonneted bats at BWWMA differed between hypopigmented and solid-colored individuals. We fit a Cormack–Jolly–Seber model that allowed capture probability (p) and apparent survival (ϕ) to vary as a function of the presence of hypopigmented marks. Cormack–Jolly–Seber models allow for individual variability in survival and capture probabilities, thereby reducing bias in parameter estimates (Pledger et al. 2003). We used a hessian function to compute associated error values and confidence intervals of model parameters.

Results

We captured 213 individual Florida bonneted bats at BWWMA at known roosts from 2014 through 2017. Of these, we found hypopigmented marks on 172 (80.8%) of the bats (Figure 2; Table S1, Supplemental Material). We found no evidence that hypopigmented markings were temporary or had developed spontaneously. For example, all 122 hypopigmented individuals recaptured ≥ 4 mo after first capture still had hypopigmented marks, and none of the 30 solid-colored individuals had developed hypopigmented marks when recaptured after ≥ 4 mo. The proportion of hypopigmented individuals did not differ significantly between males (68/85; 80.0%) and females (104/128; 81.25%; Fisher’s exact test: P =
Subadults accounted for 44.2% of the hypopigmented bats in BWWMA, and there was no significant difference in the proportion of hypopigmented individuals between bats first captured as subadults (76/195; 80.0%) and bats first captured as adults (96/118; 81.4%; Fisher’s exact test: $P = 0.86$, odds ratio $= 0.92$). The proportion of hypopigmented individuals (119/150; 79.3%) and solid-colored individuals (53/63; 84.1%) that were reproductively active also did not differ significantly (Fisher’s exact test: $P = 0.45$, odds ratio $= 0.73$).

Most (75.0%) of the hypopigmented bats had only a single white mark; the others had two or three marks (Table 1). The majority (91.9%) of bats had white marks exclusively on the ventral side, and in all but 1 of those 158 bats the ventral marks were located posterior to the sternum (Table 1). Dorsal marks were more variable in location and were located from near the tail to the back of the head. Hypopigmented marks occurred in a variety of lateral orientations, but the greatest proportion of marks occurred in the center of the ventral side (Table 2). Fifteen individuals had small areas on the dorsal side with multiple scattered hairs that appeared as flecks of white, but we did not classify these unconsolidated flecks as hypopigmented marks. The shape of the hypopigmented marks varied from small circles or lines to large angled bands or chevrons (Figure 2). The size of marks measured on 25 individuals was highly variable, with a mean $\pm$ SD length of 10.57 $\pm$ 10.66 mm (range: 2–54) and a width of 12.24 $\pm$ 10.17 mm (range: 2–35.3; Table S2, Supplemental Material). Dorsal marks were noted as being smaller than ventral marks, and none extended laterally across the entire back, although few dorsal marks were measured because of their rarity and the small number of bats examined.

We found no significant differences in apparent survival ($\phi$) or capture probability ($p$) between hypopigmented and solid-colored bats in BWWMA (Table 3; Table S3, Supplemental Material). Bats were captured 1–12 times, and 152 (71.4%) were recaptured at least once. We captured fewer solid-colored bats than hypopigmented bats, which accounted for the increased error associated with parameters describing solid-colored bats (Table 3).

We also captured 18 free-flying Florida bonneted bats in Collier County (Florida Panther National Wildlife Refuge and Fakahatchee Strand Preserve State Park), 19 in Miami–Dade County, and 13 in Polk County (Avon Park

Table 1. Number of individual white marks and dorsal and ventral location of marks on 172 hypopigmented Florida bonneted bats Eumops floridanus captured at Babcock–Webb Wildlife Management Area, Charlotte County, Florida, 2014–2017.

| Number | $n$ (%) | Location   | $n$ (%) |
|--------|---------|------------|---------|
| 1      | 129 (75.0) | Ventral    | 158 (91.9) |
| 2      | 33 (19.2)  | Dorsal     | 4 (2.3)  |
| 3      | 10 (5.8)   | Both       | 10 (5.8) |

Table 2. Lateral orientation (across entire body, left, center, or right) of 198 hypopigmented marks relative to the dorsal or ventral side of 172 hypopigmented Florida bonneted bats Eumops floridanus captured at Babcock–Webb Wildlife Management Area, Charlotte County, Florida, 2014–2017. White marks with no lateral orientation recorded are not included.

| Lateral orientation | Ventral, $n$ (%) | Dorsal, $n$ (%) |
|---------------------|------------------|-----------------|
| Across              | 25 (13.3)        | 0 (0.0)         |
| Left                | 41 (21.8)        | 1 (0.0)         |
| Center              | 63 (33.5)        | 6 (30.0)        |
| Right               | 59 (31.4)        | 3 (30.0)        |
Table 3. Survival (ψ; logit scale) and capture probability (p) of hypopigmented and solid-colored Florida bonneted bats Eumops floridanus captured at Babcock–Webb Wildlife Management Area, Charlotte County, Florida, 2014–2017.

| Beta              | Estimate | SE     | Lower 95% CI | Upper 95% CI |
|-------------------|----------|--------|--------------|--------------|
| ψ Solid-colored   | 2.11     | 0.37   | 1.38         | 2.84         |
| ψ Hypopigmented   | 2.10     | 0.15   | 1.80         | 2.40         |
| p Solid-colored   | 0.46     | 0.24   | 0.01         | 0.93         |
| p Hypopigmented   | 0.77     | 0.11   | 0.55         | 1.00         |

Air Force Range). We found Florida bonneted bats with hypopigmented marks in all four counties where we captured bats (post-2004), but the proportion of hypopigmented individuals varied by county. Counties in the northern portion of the range had the highest rates of hypopigmentation, with 80.8% hypopigmented individuals in Charlotte County (n = 172) and 61.5% in Polk County (n = 8; Table 4). The proportion of hypopigmented bats was lower in the two southern counties, with 21.1% in Miami–Dade County (n = 4) and 16.7% in Collier County (n = 3).

Of 41 museum specimens, the majority (n = 38) was collected in Miami–Dade County, and all but one of those were collected between 1950 and 1965; the other three museum specimens were collected in Charlotte County (Table S4, Supplemental Material). None of the Charlotte County specimens were hypopigmented, but three (8.1%) of the Miami–Dade County specimens were hypopigmented. Two of these hypopigmented museum specimens were reported by Timm and Genoways (2004); one we identified through our examination. The proportion of hypopigmented bats among the 37 historical (pre-1965) museum specimens from Miami–Dade County and among the 19 bats captured since 2004 in Miami–Dade County increased from 8.1% to 21.1%.

### Discussion

Our study is one of the few to have documented multiple cases of hypopigmentation in bats or any wild mammal, and we found the greatest incidence (> 80%) of hypopigmented markings known from a bat species. Further, all hypopigmented marks persisted over time in recaptured individuals (2014–2017) and the proportion of hypopigmented marks remained high over multiple recaptures, with no indication of an effect on survival. Even in the small sample of Florida bonneted bats that we examined from the southern part of the range, > 15% of individuals were hypopigmented. Hypopigmented marks have been documented in several other Molossid species, but typically only on a single individual (Gundlach 1877; Mitchell 1963; Caire and Thies 1988; Barquez et al. 2003; Geiger and Pacheco 2006; Romano et al. 2015). Three studies that recorded the proportion of hypopigmented individuals in a Molossid population all reported rates of < 10%. Herreid and Davis (1960) examined 47,409 Brazilian free-tailed bats Tadarida brasiliensis from four caves in Texas and documented white marks on 149 individuals (0.31%). Glass (1954) surveyed Brazilian free-tailed bats in two caves in Oklahoma and found “chin-whiskers” patterning in 58 of the 97 bats surveyed, but only 6 (6.2%) individuals had large, solid white marks that would typically be considered hypopigmented coloration. A study of broad-eared bats Nyctinomops laticaudatus in Brazil found approximately 40 individuals with hypopigmented markings in a roost of 2,300 (Geiger and Pacheco 2006).

Although the prevalence of the hypopigmented marks that we observed on Florida bonneted bats suggests that they are characteristic of the species as a whole, they varied too much in size, location, and presence to be considered a consistent or characteristic feature. Hypopigmented marks are defined as white and variable in size and distribution on the body (Davis 2007; Abreu et al. 2013). The white marks that we observed on Florida bonneted bats varied in size, shape, and location, although they occurred predominantly as a spot or band on the central abdomen. It remains unclear how much the hypopigmented markings have varied temporally and spatially within the species. A review of Florida bonneted bat biology by Timm and Genoways (2004) found only two records of hypopigmented bats, both from museum specimens, and no other studies or species accounts mention records of hypopigmented marks in Florida bonneted bats (Barbour and Davis 1969; Owre 1978; Belwood 1981, 1992; Marks and Marks 2006; Bartlett et al. 2013; but see Best et al. 1997). Interestingly, Gundlach (1877) reported a white belly band on a single individual of the closely related Eumops ferox in Cuba. The near absence of earlier reports of hypopigmented marks on Florida bonneted bats in the literature and in museum specimens suggests that the frequent occurrence of hypopigmented marks may be a recent development, but could also be due to underreporting in the literature. In Miami–Dade County, the proportion of hypopigmented individuals was higher in wild-caught bats captured or collected post-2004 than in specimens collected pre-1965; however, the uneven sample size and different collection methods did not allow us to statistically confirm an overall increase in the prevalence of markings. We were not able to evaluate the change in proportion of hypopigmented individuals for other areas of their range because of a lack of museum specimens or other records.

Hypopigmented marks can have environmental or genetic causes (Bensch et al. 2000; Møller and Mousseau 2001; Faure et al. 2009; Clark et al. 2011), but we saw no indication that environmental factors caused hypopig-

Table 4. Differences in the number of hypopigmented and solid-colored Florida bonneted bats Eumops floridanus captured in Charlotte, Collier, Miami–Dade, and Polk counties, Florida, 2004–2017.

| Total bats, n | Hypopigmented, n (%) | Solid-colored, n (%) |
|---------------|-----------------------|----------------------|
| Charlotte     | 213 172 (80.8)        | 41 (19.2)            |
| Collier       | 18 3 (16.7)           | 15 (83.3)            |
| Miami–Dade    | 19 4 (21.1)           | 15 (78.9)            |
| Polk          | 13 8 (61.5)           | 5 (38.5)             |
mented marks on Florida bonneted bats at BWWMA. We did not recapture any bats that had lost or gained hypopigmented marks, which would have been expected if injury or chemicals had affected fur color (Caro 2005; Faure et al. 2009). The large number of hypopigmented bats that we observed makes it highly unlikely that injury was the primary cause of hypopigmentation in Florida bonneted bats, and because nearly half of the hypopigmented bats were subadults, aging also does not explain the hypopigmented marks. We did record alopecia (hair loss) and scattered gray hairs in 32 bats at BWWMA, but these conditions were seen in both hypopigmented (n = 23) and solid-colored (n = 9) individuals. Furthermore, the alopecia and gray hairs typically affected large areas of the body, most commonly on the dorsal side where hypopigmented marks were less common. Finally, if environmental factors caused the hypopigmented marks in Florida bonneted bats, we likely would have seen the marks only in affected populations or a portion of the species range rather than throughout all areas sampled. The persistence of these marks over time and our finding of no effect of age on the prevalence of marks suggests that there may be an underlying genetic cause rather than environmental and therefore these hypopigmented marks may be classified as piebald markings.

Chromatic disorders with a genetic origin are typically associated with small, isolated populations and are thought to be a consequence of inbreeding, low genetic diversity, or genetic drift after colonization or other events that result in a small effective population size (Walley 1974; Parsons and Bondrup-Nielsen 1995; Laikre et al. 1996; Bensch et al. 2000; Clark et al. 2011). Because the Florida bonneted bat population may comprise <1,000 individuals (FWC 2013), it is likely susceptible to reduced genetic diversity and a loss, shift, or fixation of allele frequencies (Frankham et al. 2002). Unknown barriers to gene flow may result in cryptic genetic structuring that maintains lower effective population sizes and genetic diversity in some areas. Genetic bottlenecks after hurricanes or other extreme environmental events also may decrease genetic diversity (FWC 2013). The relationship between genetic diversity and the prevalence of hypopigmented marks across the range of the Florida bonneted bat remains unknown.

The presence of white marks on an animal could increase its visibility to predators, resulting in the quick removal of marked individuals from the population (Caro 2005; Lucati and López-Bauccells 2016; Rose et al. 2017). However, this may be of little impact to bats because they are active primarily at night and rely on dark roosts during the day (Lucati and López-Bauccells 2016). Furthermore, several species such as the spotted bat Euderma maculatum, the harlequin bat Scotomanes ornatus, and the pied bat Niumbaha superba have characteristic bold white marks. In our study, we found no apparent difference in survival between hypopigmented individuals and solid-colored individuals. Aberrantly colored bats may be treated differently by conspecifics, although there is no evidence of this (Uieda 2001; Geiger and Pacheco 2006; Rose et al. 2017) and aberrantly colored bats have been accepted socially by conspecifics, reproduced successfully, and survived for many years (Uieda 2001; Talerico et al. 2008; Treitler et al. 2013; Lucati and López-Bauccells 2016). At BWWMA, we recorded no difference in reproductive status between hypopigmented and solid-colored bats, and most roosts supported colonies with both hypopigmented and solid-colored individuals.

Although we did not observe any adverse effects associated with hypopigmented marks, it may be prudent to continue monitoring to confirm that these marks are not associated with reduced survival or reproductive success in this endangered species. Even if hypopigmented marks have little negative impact on individuals, the high incidence of hypopigmented marks may be an indication of reduced effective population size leading to the random increase in this trait. Additional research into the genetic structure of Florida bonneted bat populations could help identify the mechanisms underlying the high incidence of hypopigmented marks, confirm the chromatic disorder as piebald, and identify potential risks to the conservation of the species.

Supplemental Material

Please note: The Journal of Fish and Wildlife Management is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

Table S1. Data on all individual Florida bonneted bats Eumops floridanus captured or collected in Florida. Variables include county of capture, bat ID, sex, age at first capture, reproductive status, hypopigmented or solid-colored, number of spots, orientation, and dorsal or ventral location of marks.

Table S2. Data on measurements of white marks from 25 Florida bonneted bats Eumops floridanus captured at Babcock–Webb Wildlife Management Area, Charlotte County, Florida, 2014–2017. Variables include bat ID, width (mm), and height (mm) of hypopigmented marks.

Table S3. Data on capture history of all Florida bonneted bats Eumops floridanus captured at Babcock–Webb Wildlife Management Area, Charlotte County, Florida, 2014–2017. Variables include roost bat was captured at, date, and bat ID.

Table S4. Data on all museum specimens of Florida bonneted bats Eumops floridanus examined for hypopigmented marks.
pigmented marks. Variables include specimen ID, date, county, latitude, and longitude of specimen collection, sex, and pelage color description.

Found at DOI: https://doi.org/10.3996/112018-JFWM-110.S1 (45 KB PDF); also available at https://doi.org/10.5061/dryad.p7k5610.

Acknowledgments

We thank the numerous individuals who assisted us in the field, particularly Ralph Arwood, Amanda Bailey, Josh Birchfield, Terry Doonan, Emily Evans, Wade Gurley, Kristy Mobley, Jennifer Myers, Holly Ober, Cason Pope, Kathleen Smith, Seth Soferin, and Megan Wallrichs. We also thank Verity Mathis of the Florida Museum of Natural History, Robert Timm and Maria Eifler of the Kansas University Biodiversity Institute and Natural History Museum, and Neil Duncan of the American Museum of Natural History for their assistance in accessing and examining museum specimens. We also thank the Associate Editor and reviewers for their insightful comments that helped strengthen this manuscript. This study was funded by the Florida Fish and Wildlife Conservation Commission and the U.S. Fish and Wildlife Service.

Any use of trade, product, website, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

References

Abreu MSL, Machado R, Barbeiri F, Freitas NS, Oliveira LR. 2013. Anomalous colour in Neotropical mammals: a review with new records for Didelphis sp. (Didelphidae, Didelphimorphia) and Arctocephalus australis (Otariidae, Carnivora). Brazilian Journal of Biology 73:185–194.

Bailey AM, Ober HK, Sovie AR, McCleery RA. 2017. Impact of land use and climate on the distribution of the endangered Florida bonneted bat. Journal of Mammalogy 98:1586–1593.

Barbour RW, Davis WH. 1969. Bats of America. Lexington: University Press of Kentucky.

Barquez RM, Carrizo LV, Ferro LI, Flores DA, Mollerach M, Sánchez MS, García López AP. 2003. Primer caso de albinismo total para Nyctinomops laticaudatus (E. Geoffroy, 1805) (Chiroptera: Molossidae) no sul do Brasil. Chiroptera Neotropical 9:166–194.

Bartlett SN, McDonough MM, Ammerman LK. 2013. Molecular systematics of bonneted bats (Molossidae: Eumops) based on mitochondrial and nuclear DNA sequences. Journal of Mammalogy 94:867–880.

Belwood JJ. 1992. Florida Mastiff Bat Eumops glaucinus floridanus. Pages 216–223 in Humphrey SR, editor. Rare and endangered biota of Florida. Gainesville: University Press of Florida.

Bensch D, Hansson B, Hasselquist D, Nielson B. 2000. Partial albinism in a semi-isolated population of great reed warblers. Hereditas 133:167–170.

Best TL, Kiser WM, Rainey JC. 1997. Eumops glaucinus. Mammalian Species 551:1–6.

Braun de Torrez EC, Samoray ST, Silas KA, Wallrichs MA, Gumbert MW, Ober HK, McCleery RA. 2017. Acoustic lure allows for capture of a high-flying, endangered bat. Wildlife Society Bulletin 41:322–328.

Caire W, Thies M. 1988. Notes on the occurrence of morphological and color aberrations in bats from Oklahoma, Missouri, and Mexico. Proceedings of the Oklahoma Academy of Science 68:75–76.

Caro T. 2005. The adaptive significance of coloration in mammals. Bioscience 55:125–136.

Clark RW, Marchand MN, Clifford BJ, Stechert R, Stephens S. 2011. Decline of an isolated timber rattlesnake (Crotalus horridus) population: interactions between climate change, disease, and loss of genetic diversity. Biological Conservation 144:886–891.

Davis JN. 2007. Color abnormalities in birds: a proposed nomenclature for birders. Birding 39:36–46.

Davis R. 1968. Wing defects in a population of pallid bats. American Midland Naturalist. 79:388–395.

Dessinioti C, Stratigos AJ, Rigopoulos D, Katsambas AD. 2009. A review of genetic disorders of hypopigmentation: lessons learned from the biology of melanocytes. Experimental Dermatology 18:741–749.

Faure PA, Re DE, Clare L. 2009. Wound healing in the flight membranes of big brown bats. Journal of Mammalogy 90:1148–1156.

FWC Florida Fish and Wildlife Conservation Commission. 2003. A conceptual management plan for Fred C. Babcock–Cecil M. Webb Wildlife Management Area. Tallahassee, Florida. Available: http://chnep.wateratlas.usf.edu/upload/documents/CMP_Babcock_2003_2008.pdf (July 2019). Archived by WebCite at: http://www.webcitation.org/77vg8dywB

FWC Florida Fish and Wildlife Conservation Commission. 2013. A species action plan for the Florida bonneted bat Eumops floridanus. Tallahassee, Florida. Available: https://wildlife florida.org/wp-content/uploads/2018/05/Florida-Bonneted-Bat-Species-Action-Plan-Final-Draft.pdf (July 2019). Archived by WebCite at: http://www.webcitation.org/77vg85qge

Frankham R, Briscoe DA, Ballou JD. 2002. Introduction to conservation genetics. Cambridge, UK: Cambridge University Press.

Geiger D, Pacheco SM. 2006. Registro de albinismo parcial em Nyctinomops laticaudatus (E. Geoffroy, 1805) (Chiroptera: Molossidae) no sul do Brasil. Chiroptera Neotropical 12:250–254.

Glass BP. 1954. Aberrant coloration in Tadarida mexicana. American Midland Naturalist 52:400–402.

Gundlach J. 1877. Contribución a la Mamalogía Cubana. Havana, Cuba: G. Montiel y Comp.
Herreid CF, Davis RB. 1960. Frequency and placement of white fur on free-tailed bats. Journal of Mammalogy 41:117–119.

Laake JL, Johnson DS, Conn PB. 2013. marked: an R package for maximum-likelihood and MCMC analysis of capture–recapture data. Methods in Ecology and Evolution 4:885–890.

Laikre L, Andre R, Larsson H, Ryman N. 1996. Inbreeding depression in brown bear Ursus arctos. Biological Conservation 76:69–72.

Lamoreux ML, Delmas V, Larue L, Bennett DC. 2010. The colors of mice. A model genetic network. Bryan, Texas: Wiley-Blackwell.

Lucati F, López-Baucells A. 2016. Chromatic disorders in bats: a review of pigmentation anomalies and the misuse of terms to describe them. Mammal Review 2016:1–12.

Marks CS, Marks GE. 2006. Bats of Florida. Gainesville: University Press of Florida.

Mitchell HA. 1963. Aberrant white fur in the pocketed free-tailed bat. Journal of Mammalogy. 44:422.

Møller AP, Mousseau TA. 2001. Albinism and phenotype of barn swallows (Hirundo rustica) from Chernobyl. Evolution 55:2097–2104.

Ober HK, Braun de Torrez E, McCleery RA, Bailey AM, Gore JA. 2017. Sexual dimorphism in the endangered Florida bonneted bat, Eumops floridanus (Chiroptera: Molossidae). Florida Scientist 80:38–48.

Owre OT. 1978. The Florida mastiff bat, Eumops glaucinus floridanus. Pp. 43–44 in Layne JN, editor. Rare and endangered biota of Florida. Volume 1. Mammals. Gainesville: University Presses of Florida.

Parsons GJ, Bondrup-Nielsen SB. 1995. Partial albinism in an island population of meadow voles, Microtus pennsylvanicus, from Nova Scotia. Canadian Field Naturalist 109:263–264.

Pledger S, Pollock KH, Norris JL. 2003. Open capture–recapture models with heterogeneity: I. Cormack–Jolly–Seber model. Biometrics 59:786–794.

[ESA] U.S. Endangered Species Act of 1973, as amended, Pub. L. No. 93-205, 87 Stat. 884 (Dec. 28, 1973). Available: https://www.fws.gov/endangered/esalibrary/pdf/ESAAll.pdf (July 2019).

[USSFWS] U.S. Fish and Wildlife Service. 2013. Endangered and threatened wildlife and plants; endangered species status for the Florida bonneted bat; final rule. Federal Register:61003–61043. Available at: https://www.govinfo.gov/content/pkg/FR-2013-10-02/pdf/2013-23401.pdf (July 2019).

Webb E. 2018. Foraging ecology of the Florida bonneted bat, Eumops floridanus. Master’s thesis. Gainesville: University of Florida.