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Distribution and Habitat Suitability for Small Mammals in Need of Conservation from Louisiana

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Abstract

Managing species with small population sizes is challenging without current knowledge of where they occur and where suitable habitat is located. A literature and museum database search for distributional records of eight species of small mammals that are imperiled in Louisiana was conducted. Using that data, we generated habitat suitability models for each species. The most contemporary distribution for each of these species in the state is provided and two critical regions in Louisiana where suitable habitat for multiple species overlaps is identified.

Key words: *Bassariscus astutus*, *Chaetodipus hispidus*, *Eptesicus fuscus*, habitat suitability, *Lasionycteris noctivagans*, Louisiana, *Myotis septentrionalis*, *Sorex longirostris*, *Spilogale putorius*

Introduction

One of the challenges for conserving species with small population sizes is identifying areas of suitable habitat (Vidal-Garcia and Serio-Silva 2011; Zhang and Vincent 2018). Recent advances in predictive modeling have allowed researchers to use information on species occurrence to predict areas throughout the landscape that contain high quality habitat. This is advantageous to wildlife managers because it allows them to identify where quality habitat exists and focus their resources toward those areas (McCune 2016; Zhang et al. 2018).

In Louisiana, there are eight species of small mammals that possess critically small population sizes (< 20 known extant populations) and are listed as a species of greatest conservation need by the Louisiana Department of Wildlife and Fisheries (Louisiana Department of Wildlife and Fisheries 2015). Each of these species possess a priority ranking of either S1 (species is critically imperiled in Louisiana because of extreme rarity; 5 or fewer known extant populations), S2 (species is imperiled in Louisiana because of rarity; 6 to 20 known extant populations), SU (species is possibly in peril in Louisiana, but status uncertain), or SZ (transient species in which no specific consistent area of occurrence is identifiable). These species include the Eastern Spotted Skunk (*Spilogale putorius*, S1), Northern Long-eared Bat (*Myotis septentrionalis*, S1), Ringtail (*Bassariscus astutus*, S1), Hispid Pocket Mouse (*Chaetodipus hispidus*, S2), Southeastern Shrew (*Sorex longirostris*, S2), Big Brown Bat (*Eptesicus fuscus*, S2), Northern Pygmy Mouse (*Baiomys taylori*, SU), and Silver-haired Bat (*Lasionycteris noctivagans*,

SZ). The objectives of this research were to 1) update the distributions of each target species, 2) use a common predictive habitat model to predict habitat suitability throughout Louisiana, and 3) determine which environmental variable is most important when predicting areas of suitable habitat.

METHODS

Distributional data were collected for the eight species of small mammals by obtaining records from VertNet (www.vertnet.org), additional museum holdings, the Louisiana Natural Heritage Program, and published accounts (see species accounts below). Museums from which data were collected include the Louisiana State Museum of Natural Science (LSUMZ), Louisiana State University at Shreveport (LSUS), McNeese State University (MSC), Field Museum of Natural History (FMNH), University of Louisiana at Monroe (NLU), National Museum of Natural History (NMNH), Northwestern State University (NSU), University of Louisiana at Lafayette (SLU), Museum of Texas Tech University (TTU), Natural History Museum of Los Angeles (LACM), and Museum of Southwestern Biology (MSB).

Distribution maps for each species were generated using the compiled data. Occurrence points were separated into one of two categories: 1) those reported in Lowery's (1974) *Mammals of Louisiana and Adjacent Waters*, or 2) those found as a result of the data search. This allows for discussion on how recent sampling efforts have updated the distribution of each species in Louisiana. Species accounts include a list of specimens examined which are organized by the source from which the data were obtained. Records of unvouchered specimens taken from published sources also were noted in the specimens examined. If geographic coordinates were not provided in the original voucher record, the exact locality was converted using Google Earth.

Predictions of habitat suitability were performed for all species except *L. noctivagans* and *B. taylori*, because records of *L. noctivagans* appear to be the result of migrating individuals (not permanent populations) and only one specimen of *B. taylori* has been collected in the state. A set of climate and land cover variables were obtained to predict suitable habitat for each species. Land cover (Land) data were obtained from a global land cover data set with a 1 km spatial resolution (Hansen et al. 2000). The map of land cover was derived from 1992–1993 data collected from the Advanced Very High Resolution Radiometer (AVHRR) and consists of 12 land cover classifications. Climate variables for North America were extracted from the 1 km spatial resolution WorldClim database (WorldClim version 2.0, Fick and Hijmans 2017). All 19 bioclimatic layers (11 temperature and 8 precipitation) were used in the analysis and consisted of annual mean temperature (Mean_t), mean diurnal range (Mean_dr), isothermality (Iso), temperature seasonality (Temp_sea), maximum temperature of warmest month (Max_t), minimum temperature of coldest month (Min_t), temperature annual range (Temp_rng), mean temperature of wettest quarter (Meant_wetqr), mean temperature of driest quarter (Meant_dryqr), mean temperature of warmest quarter (Meant_warmqr), mean temperature of coldest quarter (Meant_coldqr), annual precipitation (Mean_p), precipitation of wettest month (P_wet), precipitation of driest month (P_dry), precipitation seasonality (Precip_sea), precipitation of wettest quarter (P_wetqr), precipitation of driest quarter (P_dryqr), precipitation of warmest quarter (P_warmqr), and precipitation of coldest quarter (P_coldqr). These environmental data were extracted to each presence locality (the geographic location where an individual was noted as present) of all species.

The Maximum entropy model (Maxent 3.4.1; Phillips et al. 2019) was used to predict habitat suitability for each species. The Maxent algorithm operates on a set of constraints that describes what is known from the sample of the target distribution. Maxent does not require information on where a species does not occur (absence localities); rather it characterizes the background environment with a sample of background points from the study region. Species occurrence at these background points is unknown (Phillips et al. 2006). Maxent predicts the probability distribution across the study area and employs maximum entropy principles and regularization parameters to prevent over-fitting (Phillips et al. 2006; Phillips and Dudík

2008). Maxent has become a popular method that performs well when compared to other presence-only and presence-absence models (Hoffman et al. 2010). Habitat suitability maps were produced using the default settings including removing duplicate species records. Predictions were produced with the logistic output in Maxent where the probability of occurrence ranged from 0 to 1. Characterization of the background environment was done by randomly generating 10,000 background points throughout Louisiana. Maxent was prompted to generate response curves for each environmental variable, which show how the logistic prediction changes over a range of environmental values. Variable importance was determined by the highest percent contribution of a variable to the Maxent model. Percent contribution of a given variable is estimated by adding the increase in regularized gain to the contribution of the corresponding variable, or subtracting from it if the change to the absolute value of lambda is negative. Only the variable with the largest percent contribution value is reported.

The accuracy of the Maxent habitat suitability predictions were evaluated by calculating area under the receiver operating characteristic curve (AUC) values. The AUC curve is a plot of the sensitivity vs. 1-specificity at all possible threshold probabilities for a positive prediction, with sensitivity representing how well the data correctly predicts presence, and specificity provides a measure of correctly predicted absences (Fielding and Bell 1997). An AUC value of 0.5 indicates that the performance of the model is no better than random. A higher AUC value equals a better fit, with a 1.0 AUC indicating a perfect fit. Models with AUC values greater than 0.8 are considered good predictors of a species distribution (Fielding and Bell 1997).

RESULTS

Based on museum database and literature searches, new parish records are reported for *L. noctivagans*, *E. fuscus*, *M. septentrionalis*, *S. putorius*, *B. taylori*, and *B. astutus*. Predictions of habitat suitability are the first for these species in Louisiana and identify critical areas throughout the state which should have high management priority. The distribution and habitat suitability for each species is described in detail within the species accounts below.

ORDER CHIROPTERA
Family Vespertilionidae
***Lasionycteris noctivagans* (LeConte, 1831)**
Silver-haired Bat

Lasionycteris noctivagans is a wide-ranging species occurring from southeastern Alaska, the southern half of Canada, most of the United States, and into northern Mexico (Hall 1981). This species primarily roosts in trees as individuals or in small groups throughout its range and is typically associated with old growth forest and grassland habitats (Kunz 1982).

In Louisiana, only four records of *L. noctivagans* have been recorded (Fig. 1). The first specimen captured in the state was from Winn Parish on 22 March 1958 (Lowery 1974). The second specimen was captured on 05 November 1974 in Lincoln Parish (Louisiana Natural Heritage database). Both the Winn and Lincoln parish specimens were captured in mixed hardwood forests. The third record came from a specimen collected 9 mi (14.5 km) south of Cameron, Lousisiana, in the Gulf of Mexico on 24 October 1975. Little information exists for this specimen, but the person who prepared it, Gary Graham, recalled that it was collected on an oil platform and then passed along to the LSUMZ. The final specimen was documented by Lance and Rogowski (1999) on 03 February 1997 from Vernon Parish in a stand of longleaf pine.

Currently this species is listed as "Least Concern" by the International Union for the Conservation of Nature (IUCN; Solari 2019). In Louisiana, it has a SZ ranking, meaning it is a transient species with no consistent area of occurrence in the state. This ranking is supported by the sporadic occurrence of *L. noctivagans* and suggests that permanent populations have not been established in the state. This bat is known to migrate south during the fall and then back north in early spring (Kunz 1982). Populations in Texas follow a similar pattern (Schmidly and Bradley 2016) so it seems logical that the specimens from Louisiana were the result of either a southward or northward migrator. One of the specimens reported here most likely came from an

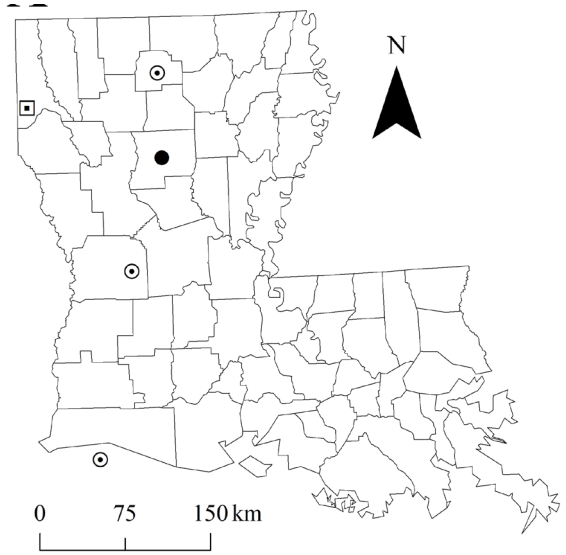

Figure 1. Specimen records of the Silver-haired Bat (*Lasionycteris noctivagans*) and Northern Pygmy Mouse (*Baiomys taylori*) in Louisiana. The solid circle represents an individual of *L. noctivagans* reported in Lowery (1974), whereas enclosed circles represent new records found through database and literature searches during this study. The enclosed square represents the location of *B. taylori* as reported by Stevens (2015).

oil platform in the Gulf of Mexico. Oil platforms are one of the few stationary structures in ocean habitats, thus it's possible migrating bats would utilize these platforms as temporary rest sites during their migration. Finally, all specimens noted in this account were captured in either the fall (October and November) or early spring (February and March), which coincides with their known migratory timing (Kunz 1982).

Specimens reported by Lowery (1974) (1)—Winn Parish: 3 mi W of Tullos (31.9476 N, -92.6385 W), 1 LSUMZ.

Additional specimens reported by Lance and Rogowski (1999) (1)—Vernon Parish: 4.7 km N of Fullerton (31.0927 N, -92.9672 W).

Additional specimens examined (1)—Cameron Parish: Gulf of Mexico, 9 mi S of Cameron (29.6647 N, -93.3196), 1 LSUMZ.

Additional specimens, Louisiana Natural Heritage Program (1)—Lincoln Parish.

***Eptesicus fuscus* (Palisot de Beauvois, 1796)**
Big Brown Bat

Eptesicus fuscus occurs throughout North and Central America and southward into northwestern South America. This species is locally found in some parts of the Bahama Islands and Greater Antilles including Cuba, Hispaniola, Jamaica, and Puerto Rico (Hall 1981). *Eptesicus fuscus* occurs in a variety of forested habitats and will readily occupy man-made buildings (Barbour and Davis 1969).

Lowery (1974) noted that *E. fuscus* is not especially widespread in Louisiana, and only occurred in west-central, northeastern, and southeastern portions of the state. Since then, 14 unique locations for *E. fuscus* have been noted. Most recently, Stevens et al. (2017) conducted an extensive survey of road culverts for bats throughout Louisiana, which documented new records for nine parishes. During a biotic survey of Winn Ranger District in the Kisatchie National Forest, Crnkovic (2003) captured four individuals across a seasonal stream in Winn Parish. Also within the Winn Ranger District, Ferrara and Leberg (2005) conducted a bridge survey for roosting bats which included portions of Winn, Natchitoches, and Grant parishes. They identified 97 individuals of *E. fuscus* throughout the study area, however, precise locations were not given. Finally, data from Louisiana Natural Heritage Program add new records of *E. fuscus* for three parishes. Combined, these new data extend the known range of *E. fuscus* into the central and northwestern portions of the state (Fig. 2A).

Predictions of habitat suitability (AUC = 0.883) show that most suitable habitat exists in northern Louisiana (Fig. 2B). This includes a band of highly suitable habitat that runs northeast from the Sabine River in DeSoto and Sabine parishes into Jackson and Winn parishes and then eastward towards the Mississippi River in Tensas Parish. The environmental variable that possessed the highest percent contribution to the model was Land (Table 1). Among the 12 different land cover classifications found within this variable, the category "Urban and Built" was the most important, which likely explains why many towns and cities are identified as highly suitable habitat (Fig. 2). This is not surprising given that *E. fuscus* is readily found in man-made structures (Barbour and Davis 1969) and

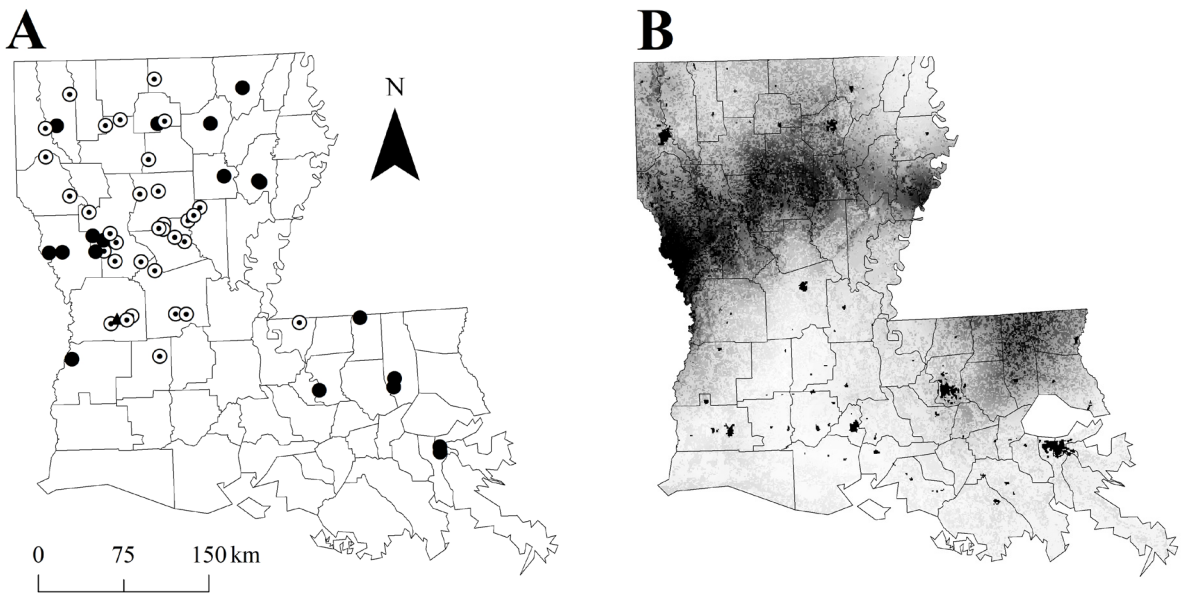

Figure 2. Specimen records and predicted suitable habitat for the Big Brown Bat (*Eptesicus fuscus*) in Louisiana. A) Known records of *E. fuscus*; solid circles represent individuals reported in Lowery (1974), whereas triangles represent confirmed unvouchered specimens, and enclosed circles represent new records found through database and literature searches during this study. B) Predicted distribution of *E. fuscus* based on models generated in this study. Darker colors represent higher suitability of habitat.

Table 1. Variables that contributed the most to predicting suitable habitat for each species. Contribution values (%) represent that variable's percent contribution compared to all other measured variables.

Species	Variable	Contribution (%)
Eptesicus fuscus	Land	56.8
Myotis septentrionalis	Land	75.7
Spilogale putorius	Precipitation seasonality	32.4
Bassariscus astutus	Precipitation of the warmest month	50.6
Chaetodipus hispidus	Precipitation of the driest month	47.0
Sorex longirostris	Annual precipitation	80.0

many of the specimens examined were captured within an urban area.

Currently, *E. fuscus* is listed as a species of "Least Concern" by the IUCN (Miller et al. 2016), but its state ranking is categorized as S2, meaning it is imperiled within Louisiana due to rarity (6–20 known populations). Stevens et al. (2017) showed that this species can be found throughout the northern part of the state, and suggested that a reconsideration of its conservation status may be warranted. Despite these recent efforts, *E. fuscus* continues to be absent from the southern portion of Louisiana, even though seemingly suitable habitat (i.e. towns, cities) exist in this area. Further investigation is needed to determine its biogeographic limits.

Specimens reported by Lowery (1974) (32)—Beauregard Parish: Merryville (30.75 N, -93.54 W) 3 LSUMZ. Caldwell Parish: Columbia, (32.10 N, -92.00 W) 1 FMNH. East Baton Rouge Parish: Baton Rouge

(30.44 N, -91.18 W) 2 LSUMZ. Franklin Parish: 1.5 mi NW Gilbert (32.06 N, -91.67 W) 2 NLU; Gilbert (32.04 N, -91.65 W) 1 NLU. Lincoln Parish: Ruston (32.52 N, -92.63 W) 4 LSUMZ. Morehouse Parish: Mer Rouge (32.77 N, -91.79 W) 1 NMNH. Natchitoches Parish: Provencal (31.56 N, -93.28 W) 2 LSUMZ; Robeline (31.69 N, -93.30 W) 5 NSU; Vowells Mill (31.65 N, -93.20 W) 1 LSUMZ. Orleans Parish: New Orleans (29.92 N, -90.07 W) 1 NMNH. Ouachita Parish: Monroe (32.50 N, -92.11 W) 1 LSUMZ. Sabine Parish: 7 mi W of Many (31.56 N, -93.60 W) 1 LSUMZ; 15 mi W of Many (31.56 N, -93.73 W) 1 LSUMZ. Saint Helena Parish: 5 mi NNE of Chipola (30.98 N, -90.75 W) 1 LSUMZ. Tangipahoa Parish: Hammond (30.50 N, -90.46 W) 4 (3 LSUMZ, 1 SLU); 2 mi W Ponchatoula (30.42 N, -90.47 W) 1 SLU.

Additional specimens reported by Stevens et al. (2017) (9)—Bienville Parish: I-20 (32.5621 N, -93.0059W) TTU. DeSoto Parish: I-49 (32.2963 N, -93.7463 W) TTU. Grant Parish: US-165 (31.6215 N, -92.4197 W) TTU. LaSalle Parish: US-165 (31.8742 N, -92.2579 W) TTU. Lincoln Parish: I-20 (32.5396 N, -92.5687 W) TTU. Rapides Parish: I-49 (31.4083 N, -92.7158 W) TTU. West Feliciana Parish: US-61 (30.9671 N, -91.3451 W) TTU. Union Parish: US-167 (32.8609 N, -92.6572 W) TTU. Winn Parish: US-167 (32.0118 N, -92.6560 W) TTU.

Additional specimens examined (7)—Bienville Parish: 0.9 mi W, 1.5 mi S of Ada (32.5234 N, -93.1506 W) 1 LSUS. Caddo Parish: Shreveport (32.5132 N, -93.7426 W) 1 LSUS. Natchitoches Parish: 6 mi S of Provencal (31.56 N, -93.20 W) 1 LACM. Winn Parish: 1.5 mi S, 4.25 mi E of Goldonna (31.9948 N, -92.8367 W), 4 LSUS.

Additional specimens, Louisiana Natural Heritage Program (18)—Allen Parish: (30.756 N, -92.697 W). De Soto Parish: (31.994 N, -93.521 W). Grant Parish: (31.779 N, -92.376 W); (31.565 N, -92.511 W); (31.722 N, -92.592 W); (31.758 N, -92.615 W). Le Salle Parish: (31.817 N, -92.320 W). Natchitoches Parish: (31.479 N, -92.847 W); (31.491 N, -93.099 W); (31.632 N, -93.082 W); (31.702 N, -93.137 W); (31.867 N, -93.337 W). Rapides Parish: (31.074 N, -92.531 W); (31.068 N, -92.427 W). Vernon Parish: (31.069 N, -92.954 W), (31.041 N, -93.002 W). Winn Parish: (31.722 N, -92.621 W), (31.728 N, -92.662 W).

***Myotis septentrionalis* (Trouessart, 1897)**
Northern Long-Eared Bat

Myotis septentrionalis occurs throughout most of the eastern United States and Canada, reaching its southern limit in the southeastern United States and its western limits along the eastern side of the Rocky Mountains (Hall 1981). This species typically roosts in a variety of hardwood tree species, but also is known to roost in man-made structures (Barbour and Davis 1969; Sasse and Perkins 1996).

Myotis septentrionalis was only recently discovered in Louisiana (Crnkovic 2003) when three specimens were captured in the Winn Ranger District in the Kisatchie National Forest, Winn Parish (Fig. 3A). They were netted over a seasonal stream surrounded by mixed hardwood and pine forest. Stevens et al. (2017) added three new locations in Jackson, West Feliciana, and Grant parishes. Ferrara and Leberg (2005) identified seven individuals of *M. septentrionalis* during their survey of bridges in the Winn Ranger District, however no specific locations were given.

Predictions of suitable habitat (AUC = 0.897) for *M. septentrionalis* indicate that highly suitable habitat exists in west-central and north-central Louisiana (Fig. 3B), although some suitable habitat also is found in the southeastern portion of the state. The variable which contributed most to the model was Land (Table 1) with the category "Evergreen Needle Forest" being most important. Thus, it is not surprising that the habitat suitability map for *M. septentrionalis* closely resembles the distribution of pine forest in Louisiana. All captures discussed above occurred in either pine or mixed hardwood/pine forest habitat.

Myotis septentrionalis is of conservation concern both in North America and in Louisiana. Currently this species is listed as "Threatened" under the Endangered Species Act (USFWS 2016), and "Near Threatened" by the IUCN (Solari 2018). The primary threat to *M. septentrionalis* is the fungus, *Psuedogymnoascus destructans*, which causes White Nose Syndrome (WNS). This disease has resulted in large population declines, specifically in the northeastern U.S (Frick et al. 2010; Langwig et al. 2012). In Louisiana, *M. septentrionalis* has been assigned a state ranking of S1, meaning it is critically imperiled in the state due to extreme rarity.

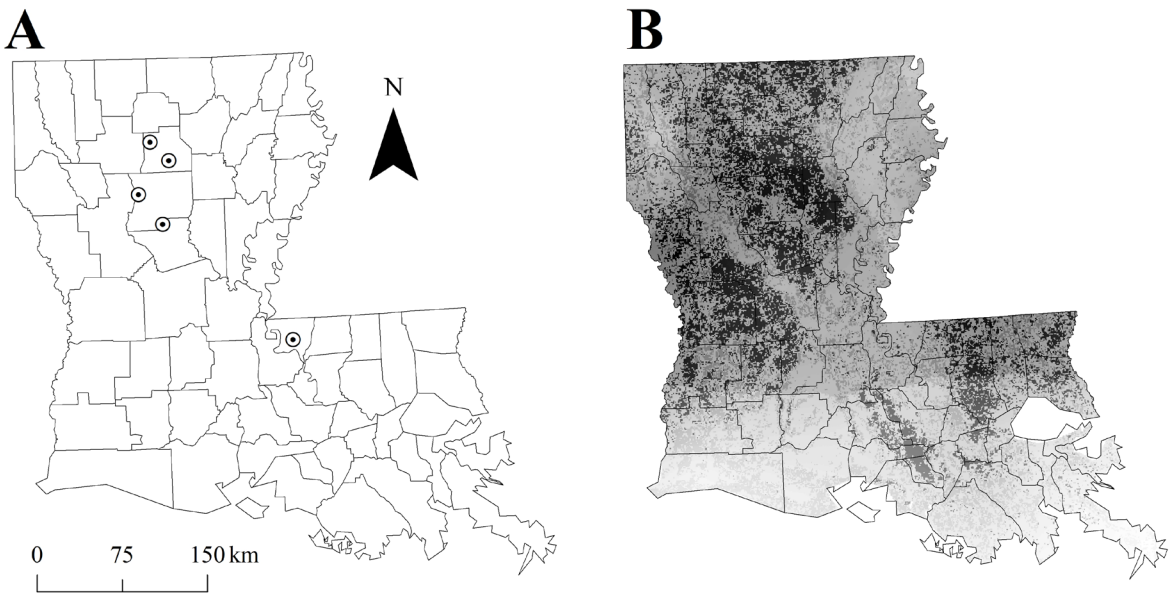

Figure 3. Distribution and predicted suitable habitat for the Northern Long-Eared Bat (*Myotis septentrionalis*) in Louisiana. A) Known records of *M. septentrionalis*; enclosed circles represent new records since Lowery (1974) found through database and literature searches during this study. B) Predicted distribution of *M. septentrionalis* based on models generated in this study. Darker colors represent higher suitability of habitat.

Although population declines have been detected in the eastern portion of this species' range, it appears to be expanding to the west and south. In addition to the southward expansion into Louisiana, extralimital records of *M. septentrionalis* have been noted in Texas (Schmidly and Bradley 2016), Kansas (Sparks and Choate 2000), Nebraska (Benedict 2004; Johnson and Geluso 2017), and Canada (Caceres and Prybus 1997). Given its susceptibility to WNS and its current range expansion west and south, the population status of *M. septentrionalis* should be monitored closely in Louisiana.

Specimens examined (3)—Winn Parish: 1.5 mi S, 4.25 mi E of Goldonna (31.9948 N, -92.8367 W), 3 LSUS.

Specimens reported by Stevens et al. (2017) (3)]—Grant Parish, USFS Road 556 (31.7569 N, -92.6123 W) 1 TTU. Jackson Parish, US-167 (32.24 N, -92.53 W) 1 TTU. West Feliciana Parish, US-61 (30.84 N, -91.40 W) 1 TTU.

Additional specimens, Louisiana Natural Heritage Program (1)—Jackson Parish (32.384 N, -92.707 W).

ORDER CARNIVORA
Family Mephitidae
***Spilogale putorius* (Linnaeus, 1758)**
Eastern Spotted Skunk

Spilogale putorius occurs throughout much of the southeastern United States, extending its range westward to central Texas and then north through the Great Plains. It reaches its northern limits in two distinct areas: southern Ontario and southern Pennsylvania (Kinlaw 1995). *Spilogale putorius* prefers upland wooded habitats that contain brushy and rocky features (Nowak 1999) and avoids any wetland or semi-aquatic habitat (Ehrhart 1974).

A total of 28 specimen records were examined from Louisiana, most of which are concentrated in the southeastern and southwestern parts of the state (Fig. 4A). This species is known to be locally rare throughout its geographic range and is rarely found in high abundance. The distribution of *S. putorius* in Louisiana is enigmatic in that it has not been found in the northern part of the state even though records exist in neighboring states (Lowery 1974). Further, the locations where *S. putorius* has been found appear

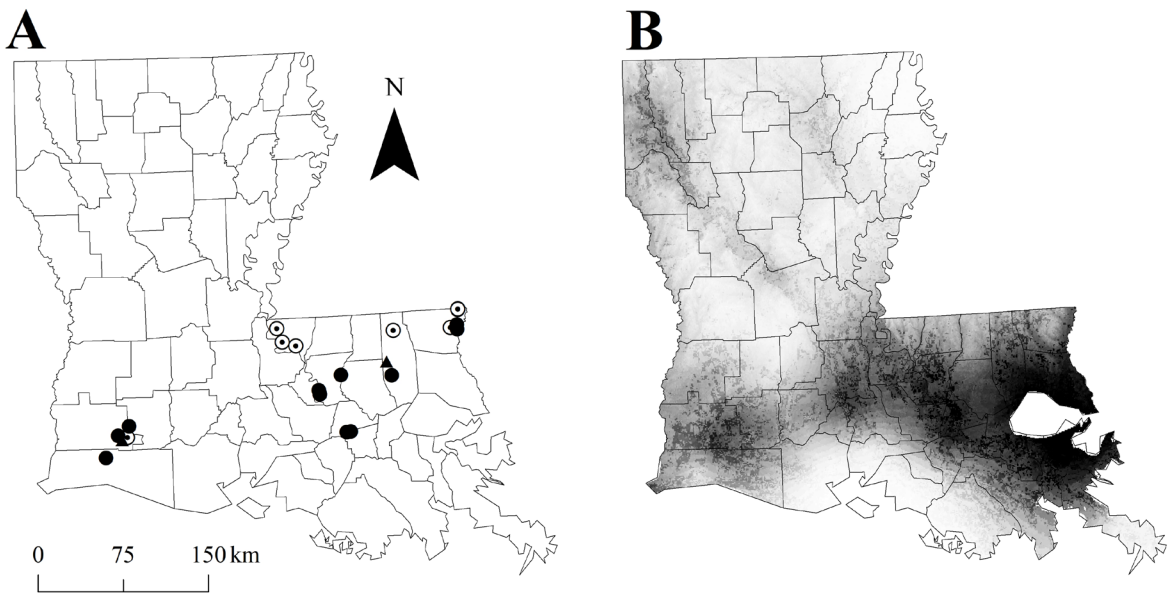

Figure 4. Distribution and predicted suitable habitat for the Eastern Spotted Skunk (*Spilogale putorius*) in Louisiana. A) Known records of *S. putorius*; solid circles represent individuals reported in Lowery (1974), whereas triangles represent unvouchered specimens confirmed by Lowery. Enclosed circles represent new records found through database and literature searches during this study. B) Predicted distribution of *S. putorius* based on models generated in this study. Darker colors represent higher suitability of habitat.

to be disjunct, with no records found in south-central Louisiana and no new parish records have been reported since Lowery (1974). A severe decline in population numbers (see discussion below) may explain why this species is absent from many parts Louisiana.

Predictions of habitat suitability (AUC = 0.914) show three main areas that possess suitable habitat for *S. putorius* (Fig. 4B). The area with the most suitable habitat is in southeastern Louisiana and includes all areas surrounding Lake Pontchartrain and extens westward to the Mississippi River. The second area is in southwestern Louisiana and includes parts of Calcasieu, Cameron, and Jefferson Davis parishes. Finally, suitable habitat is predicted to exist in extreme northwestern Louisiana in Caddo and Bossier parishes. The environmental variable that contributed the most to the model was precipitation seasonality, which is a measure of the variation in monthly precipitation totals over the course of the year (Table 1). Predictions of this variable indicate that as variation in monthly precipitation increase, probability of occurrence for *S. putorius* decreases.

Spilogale putorius is listed as "Vulnerable" by the IUCN, and the plains subspecies *S. p. interrupta* is under consideration for listing under the U. S. Endangered Species Act (Gompper and Jachowski 2016). In Louisiana, this species holds an S1 conservation ranking indicating it is critically imperiled in Louisiana due to extreme rarity. Gompper and Hackett (2005) concluded that *S. putorius* has experienced range-wide declines since the 1940's to less than one percent of their historic populations. They attributed this decline to habitat loss, pesticide use, overharvest, and disease. The declining populations of *S. putorius* may be a factor in explaining its absence from northern Louisiana.

Specimens reported by Lowery (1974) (21)—Ascension Parish: 7 mi SW of Sorrento: (30.14 N, -90.94 W) 1 LSUMZ; 2 mi SE of Burnside (30.17 N, -90.90 W) 1 LSUMZ. Calcasieu Parish: 7.5 mi SE Lake Charles (30.11 N, -93.25 W) 1 LSUMZ; Iowa (30.23 N, -93.01 W) 4 NMNH; Holmwood (30.1241 N, -93.0804 W), unvouchered specimen. Cameron Parish: 16 mi S, 1.5 mi W Lake Charles (30.16 N, -93.11 W) 1 MSC. East Baton Rouge Parish: Baton Rouge (30.45N, -91.18W)

2 LSUMZ; University (30.41 N, -91.17 W) 3 LSUMZ. Livingston Parish: 16 mi NE University (30.55 N, -90.96 W) 1 LSUMZ. Tangipahoa Parish: 2 mi W of Independence along I-55 (30.6335 N, -90.5237 W), unvouchered specimen. Washington Parish: 2 mi N of Angie (30.95 N, -89.80 W) 1 LSUMZ, 3 mi S Varnado (30.84 N, -89.83 W) 1 SLU; 0.75 mi S Varnado (30.88 N, -89.82 W) 1 SLU.

Additional specimens examined (7)—Calcasieu Parish: 6 mi S of Iowa (30.14 N, -93.02 W) 1 LSUMZ. Washington Parish: 7 mi S, 5 mi W of Angie (30.86 N, -89.89 W) 1 TTU; 2.5 mi N of Angie (31.00 N, -89.80 W) 2 TTU. West Feliciana Parish: 4 km S of Bains (30.79 N, -91.38 W) 1 LSUMZ; Tunica Island (30.82 N, -91.51 W) 1 LSUMZ; 2 mi E of Angola (30.92 N, -91.56 W) 1 FMNH.

Additional specimens, Louisiana Natural Heritage Program (1)—Tangipahoa Parish (30.869 N, -90.443 W).

Family Procyonidae

***Bassariscus astutus* (Lichtenstein, 1830)**

Ringtail

Bassariscus astutus is found throughout Mexico, and its distribution extends north into the Great Plains of Kansas and westward past the Rocky Mountains into Utah, Nevada and California. To the east, *B. astutus* has been reported in southern Arkansas and northern Louisiana (Poglayen-Neuwall and Toweill 1988). *Bassariscus astutus* can be found in a variety of habitats throughout their range including semi-arid habitats with rock outcroppings, riparian areas, coniferous forests, and dry tropical habitats (Lacy 1983; Schmidly and Bradley 2016).

Five records of *B. astutus* in Louisiana were examined; four of which were reported in Lowery (1974) (Fig. 5A). Two specimens exist as museum vouchers, two were confirmed by Lowery (1974) but no vouchers were taken, and the final record was confirmed through

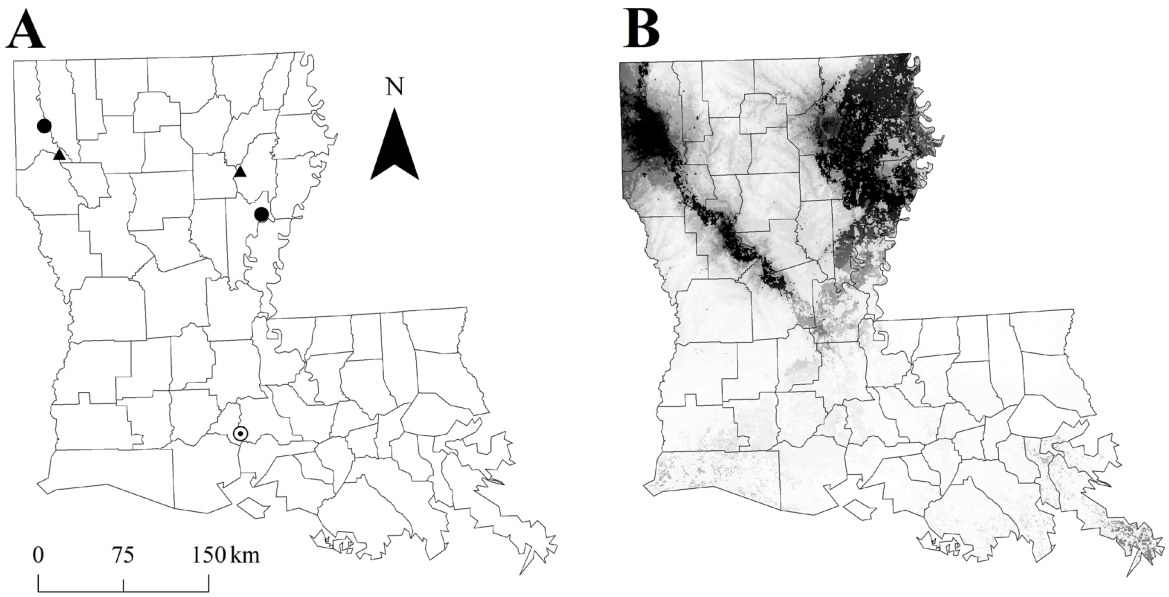

Figure 5. Distribution and predicted suitable habitat for the Ringtail (*Bassariscus astutus*) in Louisiana. A) Known records of *B. astutus*; solid circles represent individuals reported in Lowery (1974), whereas triangles represent unvouchered specimens confirmed by Lowery. Enclosed circles represent new records found through database and literature searches during this study. B) Predicted distribution of *B. astutus* based on models generated in this study. Darker colors represent higher suitability of habitat.

the Louisiana Natural Heritage Program. These specimens represent the eastern most records of *B. astutus* throughout its range. Lowery (1974) mentions that many reports existed of this species from the Sabine River basin, which runs along the Texas-Louisiana border. This seems plausible given that some records exist in extreme eastern Texas (Schmidly and Bradley 2016) in addition to those from western Louisiana. However, the last confirmed sighting of *B. astutus* in Louisiana was 1977 (Lafayette Parish), so it appears unlikely that permanent populations currently exist in the state.

The habitat suitability model (AUC = 0.973) for *B. astutus* shows that the highest quality habitat is generally associated with the Red River basin beginning in northwestern Louisiana and moving southeast until eventually connecting to the Atchafalaya River (Fig. 5B). There also is highly suitable habitat in the northeastern corner of the state. This habitat also coincides with an extensive system of rivers and bayous including the Mississippi, Tensas, and Ouachita rivers. The environmental variable that contributed the most to the model of habitat suitability was precipitation of the warmest month (Table 1). Predictions of this variable indicate that as precipitation in the warmest month increases, probability of occurrence for *B. astutus* decreases, which aligns with its overall preference for direr habitats (Lacy 1983).

Overall the conservation status of *B. astutus* is listed as "Least Concern" by IUCN (Reid et al. 2016). However, in Louisiana, it has a state ranking of S1 meaning that it is critically imperiled because of extreme rarity. Given that a confirmed record of *B. astutus* has not appeared in Louisiana in more than 40 years, it is possible that this species is extirpated from the state. If *B. astutus* still occurs in Louisiana, the most likely area would be the northwestern corner and along the Red River. Both of these regions possess highly suitable habitat and are closer to established populations of *B. astutus* in Texas.

Specimens reported by Lowery (1974) (4)—Caddo Parish: Shreveport (30.52 N, -93.75 W) 1 LSUMZ; extreme southeastern corner of parish (32.3112 N, -93.6098 W) unvouchered specimen. Catahoula Parish: 3 mi S Sicily Island, Buck Bayou Lake (31.69 N, -91.88 W) 1 LSUMZ. Franklin Parish: Liddieville (32.1343 N, -91.8456 W) unvouchered specimen.

Additional specimens, Louisiana Natural Heritage Program (1)—Lafayette Parish (30.141 N, -91.953 W).

ORDER RODENTIA
Family Heteromyidae
***Chaetodipus hispidus* (Baird, 1858)**
Hispid Pocket Mouse

Chaetodipus hispidus can be found throughout the Great Plains from North Dakota south into central Mexico. It is found on the front range of New Mexico, Colorado and Wyoming, and reaches its western most distribution in southeastern Arizona. The eastern most extent of its range can be found in west-central Louisiana. Habitat preferences include a wide variety of grasslands including shortgrass prairie (Kaufman and Fleharty 1974), mid- and tallgrass prairie (Findley et al. 1975), and agricultural areas (Fleharty and Navo 1983).

Eighteen specimens of *C. hispidus* in Louisiana were examined. Eleven of these were not found in Lowery (1974), although none of them represent new parish records. All specimens were found in west-central Louisiana, several of which were in Vernon Parish (Fig. 6A). Although the distribution of *C. hispidus* is limited in Louisiana, it can be found in high abundance where it occurs. This is especially true on the Fort Polk military base (Sarah Pearce, pers. comm.)

Predictions of highly suitable habitat (AUC = 0.968) for *C. hispidus* are found in west-central Louisiana, primarily in the parishes of Allen, Evangeline, Natchitoches, Rapides, Sabine, and Vernon. Some suitable habitat is predicted throughout north-central Louisiana but separated by the Red River basin (Fig. 6B) suggesting the river could act as a barrier to dispersal. Suitable habitat for *C. hispidus* in Louisiana appears to coincide with areas in the historical distribution of longleaf pine savannah habitat. This forest ecosystem is characterized by dry sandy soils dominated by wiregrass and bluestem grasses and an open pine canopy (Harrington and Miller 2013). This resembles the preferred habitat for *C. hispidus* in other parts of

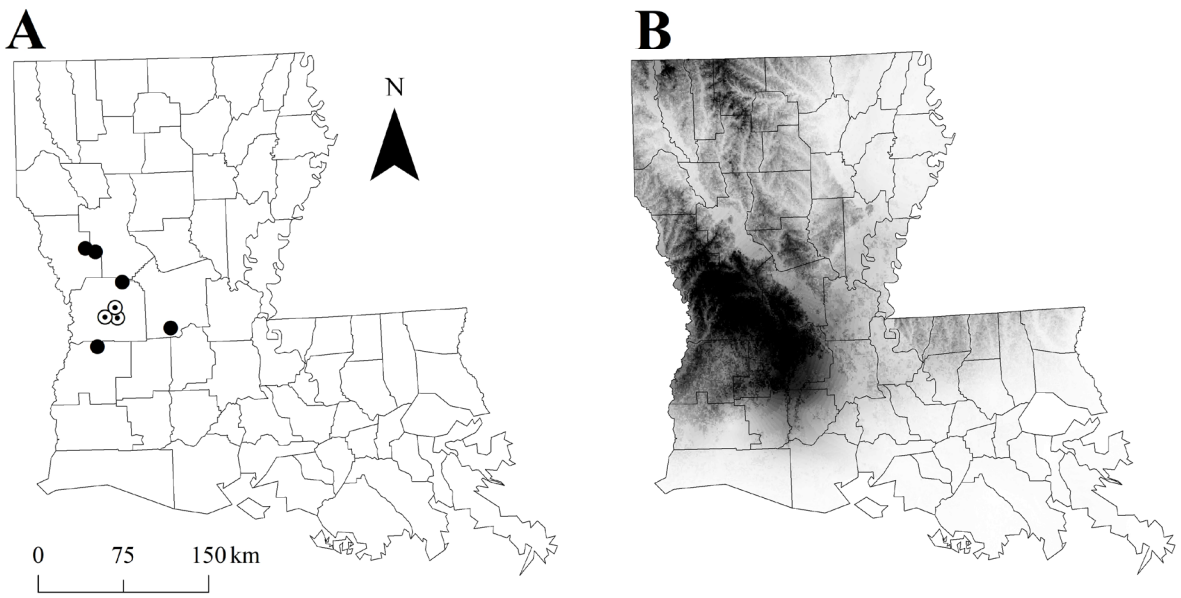

Figure 6. Distribution and predicted suitable habitat for the Hispid Pocket Mouse (Chaetodipus hispidus) in Louisiana. A) Known records of C. hispidus; solid circles represent individuals reported in Lowery (1974), whereas enclosed circles represent new records found through database and literature searches during this study. B) Predicted distribution of C. hispidus based on models generated in this study. Darker colors represent higher suitability of habitat.

its geographic range which generally is described as dry grasslands (Maxwell and Brown 1968; Kaufman and Fleharty 1974; Paulson 1988). The environmental variable that contributed most to the model of suitable habitat was the precipitation of the driest month (Table 1). Predictions of this variable indicate that the probability of occurrence for *C. hispidus* increases when precipitation in the driest month is 100–120 mm, and that probability of occurrence decreases in areas with higher amounts of precipitation.

Chaetodipus hispidus is listed as "Least Concern" by the IUCN (Linzey et al. 2016). In Louisiana, it possesses a state rank of S2, meaning that it is of conservation concern due to rarity in the state. Although there are areas where this species is caught in abundance (i.e. Fort Polk), the apparent ties to the dry, longleaf pine savannah habitat should generate a high level of conservation concern. Longleaf pine savannah is one of the most endangered ecosystems in North America, having lost approximately 97% of its historic range (Harrington and Miller 2013).

Specimens examined by Lowery (1974) (7)—Beauregard Parish: DeRidder (30.84 N, -93.28 W) 1 LSUMZ. Natchitoches Parish: Vowells Mill (31.56 N, -93.28 W) 3 LSUMZ. Sabine Parish: 2 mi SE of Fort Jessup (31.59 N, -93.37 W) 1 LSUMZ. Rapides Parish: Glenmora (30.97 N, -92.58 W) 1 NMNH. Vernon Parish: Hutton (31.33 N, -93.03 W) 1 LSUMZ.

Additional specimens examined (11)—Vernon Parish: 1.5 km N, 11 km E Fort Polk (31.06 N, -93.09 W) 4 LSUMZ; Fort Polk (31.07 N, -93.21 W) 6 NMNH; 4 mi E of Hornbeck: (31.14 N, -93.11 W) 1 FMNH.

Family Cricetidae

***Baiomys taylori* (Thomas, 1887)**

Northern Pygmy Mouse

Baiomys taylori reaches the southern limits of its distribution in central Mexico. From there its distribution stretches northward in two distinct projections (Eshelman and Cameron 1987). The first projection follows the eastern coast of Mexico and reaches its

northern limit in southern Oklahoma (Roehrs et al. 2008). The second projection follows the western coast of the Mexican mainland, excluding the Baja Peninsula, and reaches its northern limits in southern Arizona and New Mexico (Geluso et al. 2017). This species has a range of habitat preferences from coastal (Schmidly 1983), mid-grass (Stickel and Stickel 1949), and short-grass prairies (Raun and Wilks 1964), to various oak forests (Schmidly 1983; Grant et al. 1985).

Only one specimen of *B. taylori* has been collected in Louisiana (Stevens 2015). An adult male was captured in Caddo Parish (Fig. 1) along Highway 169 in a roadside right-of-way. Recent evidence suggests that this species is expanding its range northward in New Mexico (Geluso 2017), Texas (Green and Wilkins 2010), and Oklahoma (Roehrs et al. 2008). It is likely this specimen is a result of this recent range expansion and not a lack of sampling effort. For instance, Stevens (2015) captured several Fulvous Harvest Mice (*Reithrodontomys fulvescens*) at the same location and Lowery (1974) shows several specimens of *R. fulvescens*, along with other small rodent species (i.e. Cotton Mouse, *Peromyscus gossypinus*, and Cotton Rat, *Sigmodon hispidus*) historically were collected in this area.

The conservation status for *B. taylori* is "Least Concern" according to the IUCN (Timm et al. 2016). In Louisiana, this species has a ranking of SU meaning that it is possibly imperiled but the status is uncertain due to a lack of information. Although only one record exists from northwestern Louisiana, it is likely that other populations occur in the state. Stevens (2015) noted the closest known occurrence of *B. taylori* was 47 km to the northwest in Texas. Given the close proximity of known populations to Louisiana and the current evidence that *B. taylori* is expanding its geographic range, continued surveys for this species should be conducted.

Specimens reported by Stevens (2015) (1)—Caddo Parish: 4.5 km north of Spring Ridge (32.352 N, -93.942 W) 1 TTU.

ORDER SORICOMORPHA
Family Soricidae
***Sorex longirostris* (Bachman, 1837)**
Southeastern Shrew

Sorex longirostris occurs throughout the southeastern United States and ranges as far north as Maryland, West Virginia, and Indiana and then westward to Missouri and Arkansas (French 1980). This species has a range of habitat preferences, from wet areas found on the edges of marshlands and rivers (Mumford and Rippy 1962; Layne 1978), agricultural fields (Rose 1980), dry upland forests (Foreman 1956; Negus and Dundee 1965), and sandy areas (Goodpaster and Hoffmeister 1952). French (1980) noted that, no matter what habitat *S. longirostris* was captured in, nearly all contained heavy ground cover consisting of either grasses or various woody shrubs.

Twelve specimens of *S. longirostris* were examined. Three of these were not reported by Lowery (1974), none of which represent a new parish record (Fig. 7A). This species is found only in the pine forest habitat within the southeastern panhandle of Louisiana and does not occur west or south of the Mississippi River. Lowery (1974) discussed his extensive and mostly futile trapping effort for *S. longirostris*, which suggests that nowhere in the state does this species exist in high abundance.

Suitable habitat for *S. longirostris* generally reflects the restricted distribution within the state. The highest amount of suitable habitat (AUC = 0.975) can be found in the northern panhandle of southeastern Louisiana where all records of *S. longirostris* are known (Fig. 7B). There are other areas of suitable habitat to the west in Allen and Evangeline parishes, and to the south in Lafourche, St. James, and St. John the Baptist parishes. These regions of suitable habitat are separated from occupied suitable habitat by the Mississippi River, suggesting that the river could be a barrier to dispersal. The environmental variable that contributed most to the model was annual precipitation (Table 1). Predictions of this variable indicate that as annual precipitation increase, so does the probability of occurrence for *S. longirostris*.

The overall conservation status for *S. longirostris* is "Least Concern" according to the IUCN (Cassola 2016). In Louisiana, this species has a ranking of S2 meaning that it is imperiled in the state due to rarity. There is evidence that this species has permanent, reproductive populations in Louisiana (Lowery 1974; Lucas and Hoffman 2015), although there is no place where it is caught in abundance. For comparison, *C. hispidus* also is ranked as an S2 with a similar sized

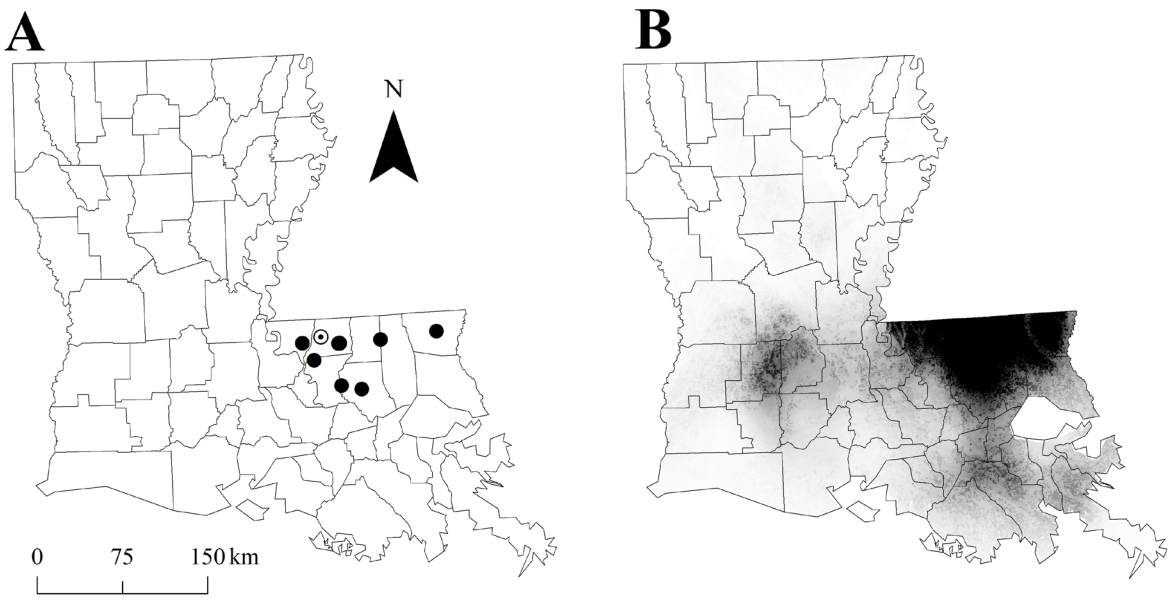

Figure 7. Distribution and predicted suitable habitat for the Southeastern Shrew (*Sorex longirostris*) in Louisiana. A) Known records of *S. longirostris*; solid circles represent individuals reported in Lowery (1974), whereas enclosed circles represent new records found through database and literature searches during this study. B) Predicted distribution of *S. longirostris* based on models generated in this study. Darker colors represent higher suitability of habitat.

range in Louisiana, however, there are locations where *C. hispidus* is commonly captured. The same cannot be said for *S. longirostris*, which may justify a reexamination of this species' conservation status.

Specimens reported by Lowery (1974) (9)— East Baton Rouge Parish: Plains (30.69 N, -91.20 W) 1 LSUMZ. East Feliciana Parish: 1 mi SE of Clinton (30.45N, -90.76W) 1 LSUMZ; 5 mi SE of Clinton (30.80 N, -90.96 W) 1 LSUMZ. Livingston Parish: 5 mi SE of Walker (30.48 N, -90.95 W) 1 LSUMZ; 3 mi NNE of Denham Springs (30.486 N, -90.956 W) 1 LSUMZ. Tangipahoa Parish: 3 mi W of Fluker (30.82 N, -90.56 W) 1 LSUMZ. Washington Parish: 10 mi E of Franklinton (30.85 N, -90.09 W) 1 LSUMZ. West Feliciana Parish: 5 mi NE of Saint Francisville (30.82 N, -91.31 W) 2 LSUMZ.

Additional specimens examined (3)—East Feliciana Parish: Idlewild Experimental Station (30.80 N, -90.95 W) 2 MSB. West Feliciana Parish: 7 mi W Clinton (30.865 N, -91.132 W) 1 LSUMZ.

CONCLUSIONS

Updates on the distribution and predictions of habitat suitability are provided for eight species of small mammals that are imperiled in Louisiana. The overall distribution of three species (*C. hispidus*, *S. longirostris*, and *B. astutus*) has not markedly changed since they were first described by Lowery (1974), new parish records are reported for three species (*L. noctivagans*, *E. fuscus*, and *S. putorius*), and two species (*M. septentrionalis* and *B. taylori*) are new additions to Louisiana's mammalian fauna since Lowery (1974). In some cases, these changes in distribution could be the result of incomplete historical sampling. For instance, it is likely that *E. fuscus* has always occurred in the central and northwesterm portions of Louisiana and is only now being documented because of recent biological surveys. Alternatively, some of these new

records may be the result of species expanding their geographic range due to climate change and/or changes in habitat. For instance, *M. septentrionalis* has been expanding its range westward and southward throughout North America (Sparks and Choate 1996; Caceres and Pybus 1997; Benedict 2004). The recent discovery of this species in Louisiana is most likely the result of that range expansion. Similarly, *B. taylori* was only recently captured in Louisiana (Stevens 2015) and has been expanding its geographic distribution northward in the United States (Roehrs et al. 2008; Geluso et al. 2017).

The maps of predicted habitat suitability provide valuable information for the conservation and management of these species. Knowing where suitable habitat exists will provide guidance for future surveys and highlight critical areas of Louisiana that need preservation. Based on the maps provided, there are at least two critical parts of Louisiana where suitable habitat overlaps for multiple species and these areas should be given high management priority. The first area is along the western border of Louisiana, primarily in the parishes of Vernon, Sabine, and DeSoto, where highly suitable habitat overlaps for *E. fuscus*, *C. hispidus*, and *M. septentrionalis*. This zone falls within the Upper West and West Gulf Coastal Plain ecoregions that historically were inhabited by longleaf and shortleaf pine woodlands but have mostly been replaced with planted pine plantations (Louisiana Department of Wildlife and Fisheries 2015). The second area is the northern portion of the eastern panhandle, specifically east and north of the Mississippi River, where highly suitable habitat overlaps for *S. longirostris*, *M. septentrionalis*, *E. fuscus*, and *S. putorius*. This region predominately falls within the East and Upper East Gulf Coastal Plain ecoregions and these regions are of special concern because they are located in parts of Louisiana that have experienced some of the highest human population growth (Louisiana Department of Wildlife and Fisheries 2015).

Finally, based on information presented here and in other sources, a reevaluation of the conservation status of certain species in Louisiana may be warranted. Stevens et al. (2017) suggested that the status of *E. fuscus* be reconsidered based on its relative commonness in the state. Data presented in this report supports Stevens et al. (2017) in that this species is widespread throughout the state and an elevation in state ranking could be appropriate. Conversely, *S. longirostris* currently has a state ranking of S2, yet few new records have been added since Lowery (1974). Also, it does not appear to be caught in high abundance at any of its capture localities. Based on this information, *S. longirostris* may deserve a state ranking of S1.

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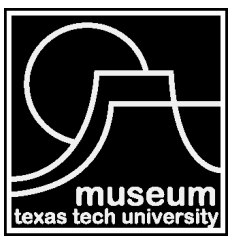

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