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CHARACTERIZING THE ECOLOGY OF PLAINS (SPILOGALE INTERRUPTA) AND EASTERN (SPILOGALE PUTORIUS) SPOTTED SKUNKS: A SYSTEMATIC LITERATURE REVIEW AND POPULATION ASSESSMENT IN KANSAS

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An Abstract of the Thesis by
Jenell de la Peña

The plains spotted skunk (*Spilogale interrupta*) has recently been recognized as a distinct species from the eastern spotted skunk (*Spilogale putorius*). While once abundant across the central and eastern United States, both species have experienced population declines, resulting in their review for listing under the Endangered Species Act (1973). In Kansas, the plains spotted skunk has suffered a particularly dramatic decline, the last detection in the state having occurred in 2020. Additionally, due to the recent taxonomic split, many past studies reporting on *S. putorius* ecology actually describe findings of two species, potentially complicating our understanding of both species' habitat needs. We have paired a systematic literature review with a large-scale camera trap survey to determine the ecology and presence of the plains spotted skunk in Kansas. We collected data from 170 papers published on either species and found the majority of the literature focuses on the ecology of *S. interrupta* and subsequently infers the results apply to both species despite limited evidence to support this extrapolation of interspecies comparison. We also ascertained that the majority of studies conducted for both species are concentrated in just four states within their respective ranges. In the second part of this thesis, we describe a large-scale camera study conducted between February 2022 and June 2023. We surveyed 602 locations across 18 counties in Kansas and we did not detect a spotted skunk. The limited data on the ecology of plains spotted skunk in the literature,

compounded with the rapid decline of the species' population, necessitates immediate conservation action.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

CHARACTERIZATION OF THE ECOLOGY OF THE PLAINS (*SPILOGALE INTERRUPTA*) AND EASTERN (*SPILOGALE PUTORIOUS*) SPOTTED SKUNKS: A SYSTEMATIC LITERATURE REVIEW

ABSTRACT

The plains spotted skunk (*Spilogale interrupta*) and eastern spotted skunk (*Spilogale putorius*) were recently recognized as distinct species. While once abundant across the central and eastern United States, respectively, both species have experienced severe population declines. Many previous studies reporting on the eastern spotted skunk actually describe findings of the two newly separated species, complicating our understanding of both species' habitat needs. We conducted a systematic literature review for both the eastern and plains spotted skunk to differentiate these species' trends in research over time. Among 170 publications, 39% were listed as describing the eastern spotted skunk even though those populations are now recognized as the plains spotted skunk. Over the past two decades, spotted skunk research interest and ensuing publications have surged, resulting in a diverse and multifaceted approach of methodological preferences within the field. Even so, many geographic regions lack modern and comprehensive research efforts, highlighting the need for further

investigations in the understudied areas to fill these knowledge gaps. The distribution of research topics and varied attention to population dynamics highlight the importance of implementing long-term studies where spotted skunks are known to persist, and especially in areas where they are rare. For contemporary spotted skunk research, we also suggest working towards standardizing methodology, including reporting detection rate, as this would aid in comparing knowledge and trends across population subsets and states. Accurately classifying the ecology of these now separate species is vital to evaluating both present and future research needs for the effective conservation of the plains and eastern spotted skunks.

INTRODUCTION

Spotted skunks (*Spilogale spp.*) are mesocarnivores with geographic ranges that encompass a wide array of habitat types extending across much of North and Central America. Historically, spotted skunks were considered an important furbearer species throughout the central and eastern United States (USA). Yet by the 1950s, the annual trapper harvest dramatically declined in the central and southern Great plains (Choate et al. 1973, Gompper & Hackett 2005, Landholt & Genoways 2000, Sasse & Gompper 2006). Following the precipitous decline, concerns about the plains spotted skunk (*Spilogale interrupta*; formerly *Spilogale putorius interrupta*) were highlighted with the species' first proposed petitioning for listing under the ESA in 1994 (USFWS 1994); thereafter, a decision was released that determined there was not enough information to warrant the official federal listing of the species. However, prior to the petition, numerous states had already listed the spotted skunk as either threatened or endangered locally (Eastern Spotted Skunk Cooperative Study Group 2020). Subsequently, a second federal

petition was submitted to the ESA in 2012 (US Fish and Wildlife Service 2012), but it was determined to be unwarranted for federal listing (US Fish and Wildlife Service 2023).

Formerly known as a subspecies of the eastern spotted skunk, the plains spotted skunk is now recognized as a distinct species (McDonough et al. 2022). While the 2012 proposed listing included the plains spotted skunk as a subspecies of the eastern spotted skunk (*Spilogale putorius*), multiple studies have indicated that there was a distinct population decline in the Great Plains region (Gompper & Hackett 2005). The plains spotted skunk's historic range spans the Great Plains, from the Mississippi River west to the continental divide, as far north as North Dakota, and South into Mexico (McDonough et al. 2022). Conversely, the eastern spotted skunk's range spans east of the Mississippi River, south to Florida, and follows the southern Appalachian Mountains north to southern Pennsylvania (McDonough et al. 2022). Plains and eastern spotted skunk populations are located across vastly different ecoregions, with current populations varying in size and spread across their range in disconnected subpopulations (Perry et al. 2021). Furthermore, both species appear to be habitat generalists, and utilize multiple cover types across their range (Harris et al. 2020, Lesmeister et al. 2009, Lombardi et al. 2017, Perkins et al. 2022, Thorne & Ford 2021).

The recent separation of *S. putorius* and *S. interrupta*, compounded with a history of both taxonomic and common name changes, complicates our understanding of the ecology and population status of the two species. While both species have been the focus of research since the late 1890s, some articles published prior to the taxonomic split that occurred in 2022 (McDonough et al. 2022) describe the ecology of the plains spotted

skunk when the skunk species in the publication is referred to as the eastern spotted skunk. Both of these species are of conservation concern due to the paucity of contemporary research concerning both local and range wide population status'.

This limited comprehension, coupled with an insufficient understanding of the species' habitat requirements complicates conservation efforts. Herein, we present a comprehensive systematic literature review comparing and contrasting the cumulative knowledge of the eastern spotted skunk and plains spotted skunk. We utilized the recent taxonomic revision as a guideline to analyze various aspects, including: temporal trends, publication patterns, geographical variations, methodological shifts, taxonomic considerations, and topic trends. Additionally, we addressed research gaps for both species in order to contribute insights for guiding future research and management efforts.

METHODS

We conducted a systematic review of published literature following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Page et. al 2020) with the goal of distinguishing ecological trends based on the recent taxonomic revision of eastern and plains spotted skunk (McDonough et al. 2022). We used multiple data collection efforts to survey all published literature on either species. First, we ran a search with the ISI Web of Science (WoS) Core Collection to produce the majority of primary peer-reviewed literature to include in our study. We supplemented the WoS search with a Google Scholar (GS) search to investigate gray literature (e.g., trapping journals, state reports, notes) in order to systematically include all relevant

literature and reduce commercial publication bias (Haddaway et al. 2015). Finally, we also included articles from our personal collection of literature that was not indexed.

We conducted both our initial WoS and GS searches on 26 September 2022. For the WoS search, we selected a variety of single keywords and a combination of keywords, coupled with Boolean operators: "* spotted skunk*" OR Spilogale OR "Spilogale interrupta" OR "Spilogale putorius" OR “Spilogale interrupta putorius", OR "Spilogale i. putorius" OR "S. putorius" OR "S. interrupta" OR S. i. putorius. The initial WoS search yielded 272 unique articles. For our GS, we attempted to incorporate the common and scientific names of the two focal species in a single search including the following terms: “Spotted skunk spilogale interrupta putorius”. The GS search yielded 217 articles; we read all records between 1–10 web pages. Beyond this point, results became noticeably less relevant. Due to the recent high volume of published articles after the taxonomic revision in 2022 (McDonough et al. 2022), we ran a secondary WoS search on 30 March 2023 using the same code as the first run. The GS search yielded so few unique articles from the first WoS search (i.e., 12 unique publications not included in the initial WoS search); thus, we did not feel it was necessary to run an additional GS search.

We combined search results from WoS and GS and removed all duplicate publications before conducting a preliminary review of the results for relevancy, based on the title and abstract. We followed this initial review with a thorough reading of each publication to assess inclusion. While our searches yielded numerous articles that appeared to align with our inclusion criteria, we subsequently excluded several for various reasons. We excluded published species descriptions (i.e., field guides), as our

focus was on primary literature that presented new data, specimen detections, or analyses on either species. We also excluded papers conducted outside of the continental United States and titles clearly pertaining to species other than our two focal species, such as the striped skunk (*Mephitis mephitis*) and the hog-nosed skunk (*Conepatus spp*). Publications that exclusively discussed the western spotted skunk (*Spilogale gracilis*) were omitted due to their lack of relevance. However, a few publications warranted inclusion when they reported data on either the plains or eastern spotted skunk along with the western spotted (n = 5) or striped skunk (n = 2). To mitigate the potential for duplicate data and bias in our analysis, we refrained from incorporating auxiliary literature reviews that did not contribute new insights regarding our two focal species. However, state and trapper reports were included as gray literature sources, as they provided important information regarding the trends and geographic ranges of these two species.

Once papers were deemed appropriate for inclusion, we cross-referenced their titles with our personal collection of literature and included any relevant publications that were not included from the WoS and GS searches. For each publication we retained, we used the method of reference-mining. This method entailed reading through each paper's reference list to further identify and subsequently add any relevant publications that were not included in any of the initial searches (Rodrigues Alves et al. 2018). We created a flow diagram based on the PRISMA guidelines to display the search process, selection, and exclusion of literature from our initial search to the total number of articles analyzed (Fig. 1.1, Page et al. 2021).

Following the collection and cataloging of all articles, we organized literature by publication year, scientific names used in the study, current taxonomy (eastern or plains

spotted skunk determined by study location using ranges proposed by McDonough et al. (2022), and the study's findings. We collected the following data for each publication: the year a study was published, sample size (i.e. number of skunk individuals sampled), study location by state, detection rate, sample method (Table 1.1), and topic studied (Table 1.2). We defined the category of sample size as the reported number of individual skunks used within a study, encompassing various sources such as museum specimens, roadkill, trapper harvest numbers, GPS/VHF-collared skunks, and the number of unique skunks detected on camera traps, etc. We considered a study location as the state in which each study was conducted, the state data was solicited from, or where used specimens or samples were collected (i.e., the state museum specimens originated from). In some cases, a single publication may have encompassed multiple studies, states, topics, or methods. We counted all instances for each publication.

As we concluded our analysis, we maintained a high level of confidence in the body of evidence presented for the plains and eastern spotted skunks. Our rigorous search process and collaborative efforts of four independent search methods enhanced the reliability of the trends outlined in this systematic review.

Table 1.1. Sampling method (n = 9) definitions used to categorize research methods used in each publication for plains and eastern spotted skunk research.

Sampling Method	Definition
GPS/VHF	Utilized Global Positioning Systems (GPS) or Very High-Frequency (VHF) radio transmitters on one or more individuals to track activities, such as movements and spatial behavior.
Camera Trap	Employed game cameras to capture images, videos, or time-lapse footage.
Live Trap	Utilized live traps (i.e. box traps, track plate, foot-hold traps, and drift fences) for capture.
Trapper Report	Utilized data gathered from trappers, which may include information on the harvest or capture of spotted skunks, as reported by individuals involved in trapping activities.
Specimens	Data obtained from verified visual sightings, public reports, deceased specimens, museum collections, vouchered records, non-vouchered photographic records, and images.
Survey	Data collected through systematic and or standardized surveys or questionnaires distributed to researchers, wildlife professionals, or the general public to compile information.
Scat	Utilized scat (feces) samples to extract information, excluding the use of scat samples to determine the number of individual skunks.
Spotlight	Utilized spotlights to detect focal species.
None	The research did not employ any specific sampling method (i.e. fossil samples).

Table 1.2. Topics and corresponding definitions used to categorize publication research topics in plains and eastern spotted skunk literature.

Topic	Definition
Ecology	The examination of the habitat, environment, or vegetation utilized by the study species, including daytime resting place interactions with the surrounding environment.
Phenology	Documenting timing, life cycle events, or reproductive behavior, including breeding periods, morphometrics, and seasonal activity patterns in individual skunks or specific population subsets.
Diet	Documenting the food consumed by the focal species, often involving the collection and analysis of scat (fecal) samples.
Distribution	The geographical occurrence and presence or absence of a species within a specific area.
Disease	Descriptions of abnormal health conditions observed in specific individuals or populations, including infections and parasitic research.
Behavior	Studying how individuals or populations interact with their environment, including movements, habitat use, bait/lure responses, nocturnal activity, or responses to weather conditions.
Taxonomy	Identifying and categorizing one or more species through genetics research or pelage analyses.
Anatomy/Physiology/Genetics	Examining the structure, functions, or genetic properties of the focal species (e.g., sperm, morphology, blood chemistry, bone aging, growth, development, and weight variations).
Population Dynamics	The investigation and analysis of factors influencing the fluctuations in population size over time, including trends (e.g., trapper reports), and examining population characteristics, such as the number of kits born per year, kit survival, survival rates, reproduction rates, and sex ratios.

RESULTS & DISCUSSION

Our final analysis encompassed 170 sources of spotted skunk literature (Fig. 1.1; Appendix I). The initial Web of Science search returned 272 records and our secondary WoS search produced 472 records. The Google Scholar search contributed an additional 217 records, resulting in a comprehensive initial search of 961 records (Fig. 1.1). After our first examination of article titles, we identified and removed 773 records that were duplicates or not applicable to our objectives. We read the abstracts of the resulting 188 papers; we were only unable to locate one article from all returned records after an extensive search. We read 135 papers beyond their abstracts and employed reference mining techniques to incorporate an additional 30 publications. Furthermore, we supplemented our dataset with 16 papers from our personal collection of literature that were not indexed in the aforementioned sources.

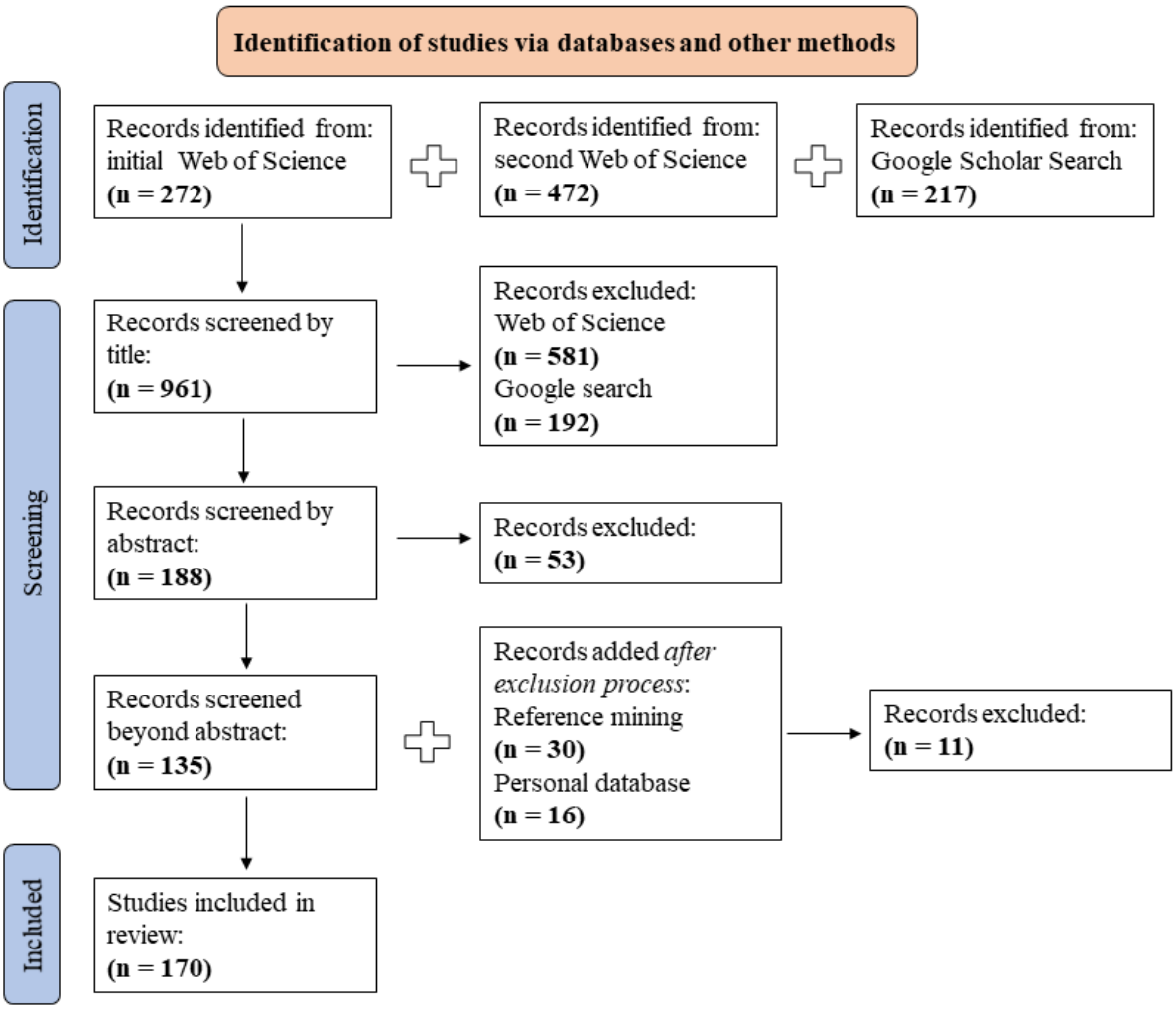

Figure 1.1. Literature review process of selected publications (based on PRISMA flow diagram for systematic literature reviews; Page et. al 2020).

Temporal Trends

Over the past century, the documentation of both the plains and eastern spotted skunk has progressed to encompass more comprehensive investigations of species that were initially relatively unknown and under-researched. Since the late 1890s, the two species have been the subject of only a few hundred publications, with a notable increase in research occurring within the last two decades. Initial research on both focal species between 1890–1939 yielded only one publication per year, on average (Fig. 1.2). These early publications primarily focused on plains spotted skunks, mainly providing records

and presence-absence data. Notably, only one paper contained occupancy data (Hibbard 1933), while a limited number explored topics including behavior, diet, and taxonomy (Appendix II).

The surge in publications on spotted skunks, spanning from the 1940s through the 1960s (Fig. 1.2), heralded a pivotal era of comprehensive research and seminal contributions that laid the groundwork for subsequent investigations and significant milestones in the field. Wilfred Crabb's (1941a, 1941b, 1944, 1948) comprehensive observations covered various aspects and topics of plains spotted skunks, and this period also saw the publication of Richard Van Gelder's (1959) influential taxonomic revision of the genus *Spilogale*. Both of these authors researched and documented novel interactions, behaviors, and ecological associations from a period preceding any significant population decline. These publications established the groundwork for research on spotted skunks, creating a path for subsequent studies on the species. In the late 1960s, Rodney Mead's (1967, 1968, 1970) influential research shifted towards anatomical and physiological aspects of spotted skunks. Disease topics gained attention during this decade as well, and we observed a continued focus on presence studies across all time periods (Appendix II).

From 1970 to 1999, the number of publications remained fairly consistent, with an ongoing emphasis on physiological studies and a growing interest in occupancy analysis and population dynamics. The early 2000s marked a shift towards research on furbearer harvest trends, with the landmark publication by Gompper and Hackett (2005), which identified the precipitous decline of the species with harvest records. Influential milestones during this period (1970s to early 2000s) ignited spotted skunk research.

These milestones included state listings in the 1980s (Hackett et al. 2007, Nilz & Finck 2008a), the separation of Mephitidae from Mustelidae in the late 1990s (Dragoo & Honeycutt 1997), and the first proposal for the plains spotted skunk to be listed under the ESA in 1994 (US Fish and Wildlife Service 1994). From 2000 onwards, the number of publications continued to increase and may have been influenced by further significant events, such as the second submission for the plains spotted skunk (when recognized as *S. putorious interrupta*) review for federal listing in 2012 (US Fish and Wildlife Service 2012). Funding and research time constraints may have delayed research output, yet from 2017 onward, the increasing trend in the number of publications continued. This publication trend continued into 2021, notably with *Southeastern Naturalist*'s special issue entitled "Ecology and Conservation of the Eastern Spotted Skunk".

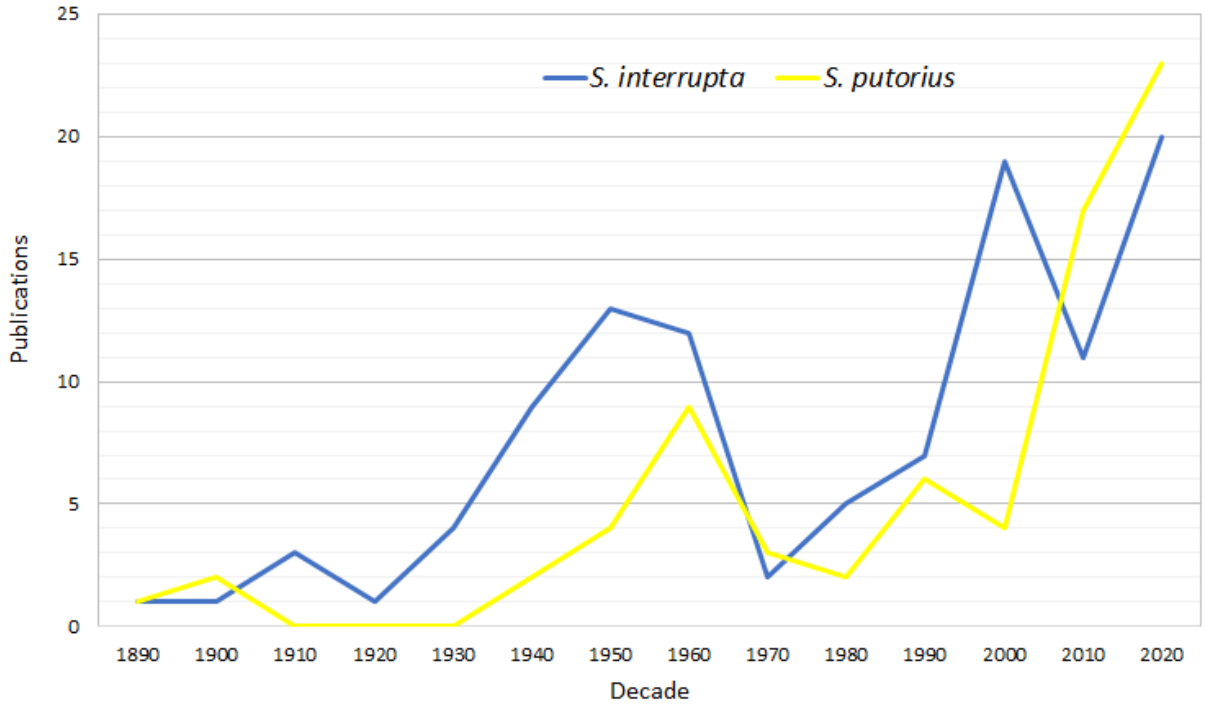

Figure 1.2. Temporal trends in spotted skunk publications, up to 30 March 2023.

Publications Trends

Articles on eastern and plains spotted skunks were published in a diverse range of 74 publishing sources, reflecting the wide array of sources that have contributed to our understanding of these species over the past century (Appendix III). Most publishing sources (70%) were represented by only one spotted skunk publication. Interestingly, the two most commonly utilized journals for our dataset were the *Southeastern Naturalist* and the *Journal of Mammalogy*, both of which compromised 28% of all publications. When considering the trends in journal selection, the majority of papers were published in naturalist-oriented journals, such as the *Southeastern Naturalist*, potentially due to that journal hosting a special issue on the species. Additionally, six other naturalist journals were selected for publication, alongside 26 local state journals. It appears this trend of publishing in regional naturalist journals may be due to the fact that since the species are

declining in many areas of its range, and several studies report small sample sizes, research may not be publishable in broader journals. Whether this pattern stems from the specialized nature of spotted skunk research or other factors, it may suggest that this valuable body of knowledge may not be as widely accessible or visible to the broader scientific community.

Geographical Trends

Understanding the geographical distribution of research on these two species is essential for gaining insights into the scope and focus of scientific investigations across their ranges. Our analysis encompassed research conducted across the 27 states within the historical range of both the eastern and plains spotted skunks, with 13 states falling within the plains range and 15 within the eastern range (McDonough et al. 2022) (Appendix IV). Only a few publications (2%) did not report where their data came from, and of those that did report, 13% described studies conducted in more than one state. The majority (59%) of the research has been concentrated within the range of the plains spotted skunk compared to the range of the eastern spotted skunk (Fig. 1.3). While both species ranges fall within Louisiana (McDonough et al. 2022), only one publication specifically reported verified detections of the eastern spotted skunk in the state; however, other studies incorporated it in their range-wide analyses. This distribution reflects varying levels of investigation across the two regions.

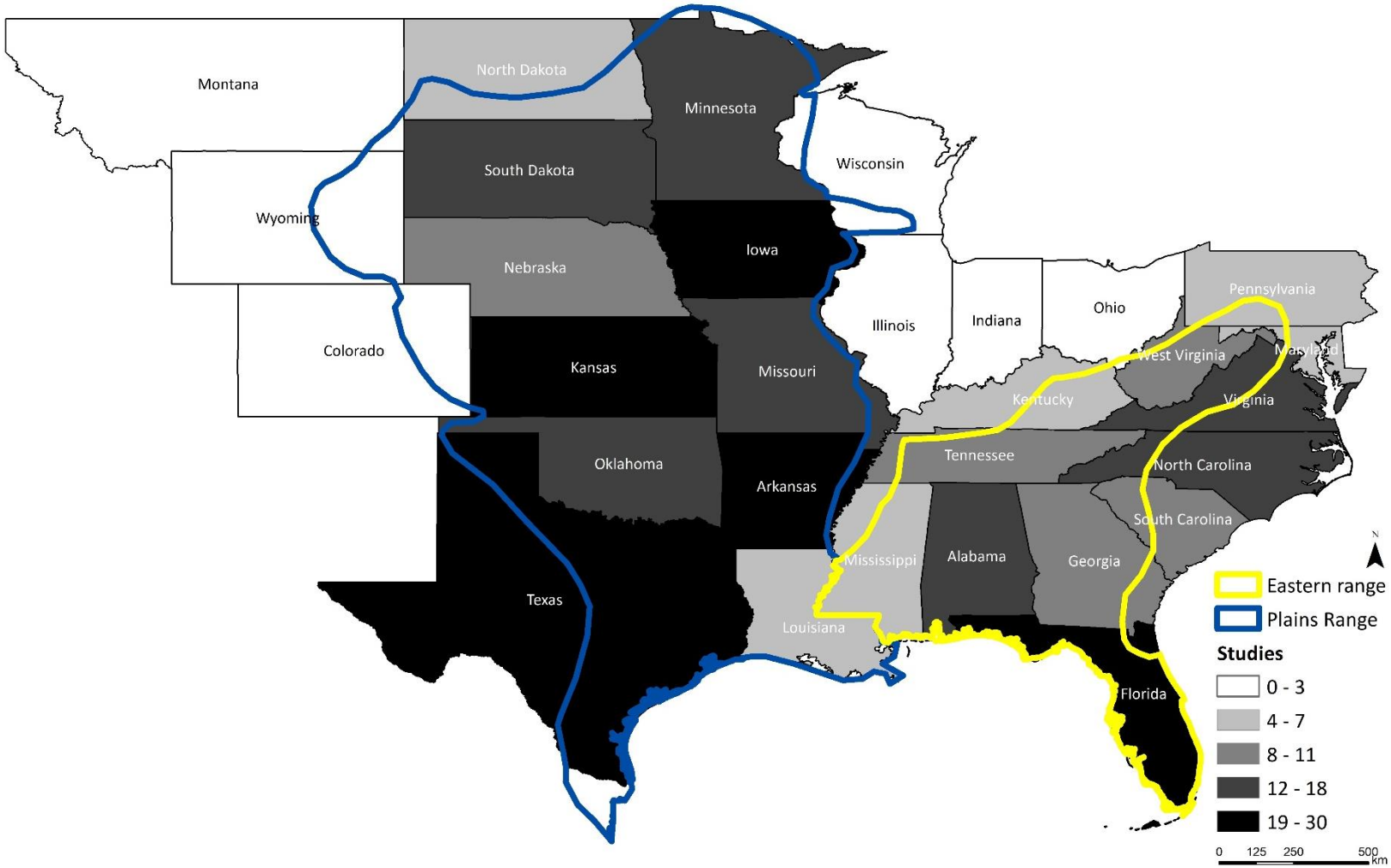

Figure 1.3. The number of studies conducted per state within the historic range of the plains and eastern spotted skunk (IUCN eastern spotted skunk range adaptation). If a publication encompassed multiple states, all were incorporated in the analysis.

Hotspots of plains spotted skunk studies primarily included Arkansas (contributing to approximately 9% of the total studies of both species), Iowa, and Texas (Appendix IV). Although Iowa has been a historically studied location, there have been no in-state publications since Fritzells' harvest report in 2002, and contemporary detections are scarce in range-wide studies (Perry et al. 2021). Missouri, Arkansas, and Texas have maintained a consistent presence in the realm of modern spotted skunk research. It is important to acknowledge that these states may be at the forefront of contemporary research because they had detectable populations of spotted skunks at the time (Hackett et al. 2007, Perkins et al. 2022, Perry et al. 2021). Missouri, Arkansas, and Texas have also been the focus of multiple investigations, addressing a wide array of ecological and behavioral aspects of spotted skunks. The understudied geographic areas for plains spotted skunks include South Dakota, North Dakota, Minnesota, and Nebraska (Fig 1.3). While these states have been studied by means of range-wide spotted skunk research, none of these states have been locations of local contemporary surveys as reported in the literature.

While eastern populations have been well-studied in a few states where detectable populations also exist, there is a critical gap in documentation for many other states. Within the eastern range, most studies have been located within Florida (9%), Alabama (4%), North Carolina (4%), and Virginia (5%) (Fig 1.3). The eastern spotted skunk population in Florida are known for the highest survival rate among all spotted skunk species (Harris et al. 2020, 2021, Kinlaw et al. 1995b). Spotted skunks have been suggested as a sentinel species, and may serve as a key indicator of ecosystem health in Florida due to their high densities and survival rates (Jachowski et al. 2023). However, a

few states also located on the periphery of the eastern spotted skunk range have received less or limited attention. For instance, Georgia has thus far never conducted an assessment study, and Pennsylvania and Louisiana are lacking in the contemporary literature, with the most recent publications coming from the late 1940s and 1960s, respectively (Crain & Packard 1966, Latham & Studholme 1947). Kentucky and Tennessee would also benefit from increased research attention across all relevant topics to enhance our understanding of spotted skunk ecology and distribution in these states. However, several states (e.g., North Carolina, West Virginia, South Carolina, and Alabama) have carried out comprehensive contemporary studies that have substantially advanced our understanding of the eastern species (Arts et al. 2022, Detweiler et al. 2022, Eng & Jachowski 2019, Hassler et al. 2021b, Marneweck et al. 2022). Historically, trapping rates for eastern spotted skunk populations are not as well-documented as those for the plains species, perhaps contributing to the overall smaller numbers of studies and topics researched in their range. The presence of disjunct populations throughout the eastern range further highlights the need for comprehensive research efforts (Perry et al. 2021).

While certain states within both the plains and eastern ranges have been extensively studied and contribute to the overall topic's trends, research gaps persist. Effective conservation will require expanding research and monitoring efforts to encompass all states and regions where spotted skunk populations may be present, particularly in areas where research has been scarce or absent (Perry et al. 2021). Emphasizing the importance of surveying range boundaries is vital for a thorough

understanding and targeted conservation efforts. This broader strategy is essential for gaining comprehensive insights into distribution and conservation needs.

Methodological Trends

Numerous publications reported researching more than one spotted skunk species; as a result, we categorized 185 studies based on reported sampling method, and if a study encompassed multiple sampling methods, all were incorporated in the analysis. The predominant sampling method overall, and for both species, was the use of specimens (47% of studies), followed closely by live trapping (40%) (Table 1.3). Conversely, spotlighting for skunks was the least utilized method; only a single study (0.4%) used spotlighting for skunks, as it proved ineffective at detecting skunks compared to scent-stations and tracks (Reed 2000).

An array of sampling methods were used, with 23% incorporating more than one sampling method. The most elaborate research articles integrated up to five distinct methods within their investigative frameworks (e.g., Nilz & Finck 2008b). Conversely, four studies abstained from any sampling methods and instead analyzed spotted skunks via mammal checklists, a status update, and a historical type locality article (Boppel & Long 1994, Hibbard 1933, 1944, Woodman & Ferguson 2021). The incorporation and scope of methods used across spotted skunk literature sheds light on the diversity of methodological preferences within the field of spotted skunk research.

Table 1.3. Sampling methods used in eastern and plains spotted skunk research from 184 studies. If a study reported more than one sampling method, all were counted. See Table 1.1 for method descriptions.

Sampling Method	**Total and Percent (%) of Studies Utilizing Method (n = 184)**	***S. putorius* Studies (n = 76)**	***S. interrupta* Studies (n = 108)**
Specimens	87 (47%)	28	59
Live Trap	74 (40%)	37	37
Camera Trap	40 (22%)	25	15
GPS/VHF	23 (13%)	18	5
Trapper Report	12 (7%)	1	11
Survey	10 (5%)	1	9
Scat	6 (3%)	1	5
None	4 (2%)	0	4
Spotlight	1 (0.5%)	1	0

We observed a broad range of sample sizes across spotted skunk studies, from zero to a maximum of 46,176 individuals (Sampson 1980) (mean = 417; median = 9). Most publications reported their sample size (84%). Notably, eight publications analyzed more than one species (i.e., combining plains and eastern individuals, and western and striped skunks), yet they combined all instances of "skunks" so it was impossible to distinguish sample size by species. Three publications exclusively presented archeozoological evidence, highlighting the prehistoric presence of spotted skunks in the states of Indiana, Illinois, and Missouri; these studies were not included in our analysis because we did not constitute fossil evidence as modern samples (Parmalee & Hoffmeister 1957, Richards 1984, Wolverton 2002). As a recommendation for future research, we suggest that studies involving multiple species clearly report and distinguish the number of individuals used for each species to enhance clarity and comparability across studies. We also encourage studies to promote transparency in reporting, to not

only specify the sample size but also provide detailed information on how the sample size was determined (e.g., distinguishing between the number of spotted skunk game camera detections and individual number of skunks detected on a game camera).

Among all publications, 75% explicitly reported their study duration. The reported ranges were substantial, from as brief as one month or less (n = 6) to a maximum of 207 years (Nilz & Finck 2008a), with a mean of 17.5 years and median of 2 years. Approximately 30% of publications that reported duration were conducted within a relatively short span of 0–12 months. Short duration studies (≤ 1 year) most often incorporated live trapping (53%), camera traps (37%), or GPS/VHF tracking (18%), potentially due to the intensity of such efforts not being conducive to long survey periods. None of the short duration studies included trapper reports. Moderate-duration studies (1–5 years) contributed to approximately 41% of the literature that reported study duration. Among these, studies that incorporated live trapping dominated (58% of moderate-duration studies), followed by camera traps (31%) and GPS/VHF tracking (30%). The more temporally extensive studies (≥ 5 years) constituted 29% of the studies that reported duration, and within this category, 22% were trapper reports, while a substantial portion (76%) of these longer-term studies that incorporated specimens. Furthermore, an evident trend emerges wherein shorter-duration studies tended to utilize active methods such as live trapping, while longer-term studies often relied upon previously collected data, particularly trapper reports and specimens. It is noteworthy that this trend highlights the importance of implementing more long-term studies employing active research methods. Additionally, it is important to highlight that 21% of the publications reported the number

of sampled individuals, but not the study duration, emphasizing the need for standardized reporting practices in future research endeavors in order to compare research efforts.

In the studies that reported trap nights (27%), we encountered a wide spectrum of trapping durations (mean = 91,389; median = 2,461), ranging from a minimum of zero to an astonishing maximum of 3,997,455 trap nights, as seen in a comprehensive study spanning five years that incorporated both trapper reports and surveys (Sasse 2018). This extreme variability highlights the substantial investments of time, resources, and effort required to effectively detect and study spotted skunks, particularly in areas where they are rare.

Detection rates are intrinsically tied to the number of trap nights, and are an essential aspect of fieldwork that can significantly influence the outcome of research efforts. Thirty-four (20%) publications reported detection rate, but 6% of these studies reported multiple detection rates within the one publication, yielding 42 unique detection rate values. We observed a wide spectrum of mean detection rates, spanning from 0–9% (Table 1.4). On average, eastern spotted skunks were detected at a greater rate compared to plains spotted skunks (2.5% vs. 1.1%, respectively) (Fig. 1.4). Among all the studies that reported detection rates, values ranged from 0% to just over 15% (Eng & Jachowski 2019). The majority of detection rates were reported by studies conducted since 2020 (88%). The definition and reporting of “detection rate” varied across studies, contributing to a lack of uniformity in reporting and making it challenging to compare research across populations. However, detection rate is typically determined by the number of spotted skunk detections per unit of effort, with effort measured as the number of trap nights.

Standardizing the definition and reporting of detection rate would aid researchers in approximating and comparing distribution dynamics across population subsets and states.

Table 1.4. Mean, standard deviation, and range of both eastern (*S. putorius*) and plains spotted skunk (*S. interrupta*) detection rates, as reported in the publication. Publications reported data spanning across 17 states located within the eastern and plains spotted skunk historic range. States are organized by mean detection rates across the two species' ranges. Note that one publication may report detection rates from more than one study (n = 34 publications; n = 42 reported detection rates).

Species	State	Mean Detection Rate (%)	Studies	Standard Deviation (%)	Range (%)
S. putorius	South Carolina	9.10	2	8.91	2.80–15.40
	Florida	8.99	4	13.34	0.50–28.80
	Alabama	2.02	2	2.80	0.40–4.0
	North Carolina	1.46	2	1.90	0.12–2.80
	Virginia	0.39	3	0.16	0.21–0.50
	Kentucky	0.39	2	0.45	0.07–0.70
	Maryland	0	1	--	--
	Mississippi	0	1	--	--
S. interrupta	Iowa	4	1	--	--
	Texas	1.66	9	3.39	0.15–10.67
	South Dakota	1	1	--	--
	Minnesota	0.83	1	--	--
	Arkansas	0.39	5	0.41	0.07–0.88
	Missouri	0.38	1	--	--
	Kansas	0.30	3	0.51	0–0.89
	Oklahoma	0.21	3	0.32	0–0.576
	Tennessee	0.07	1	--	--

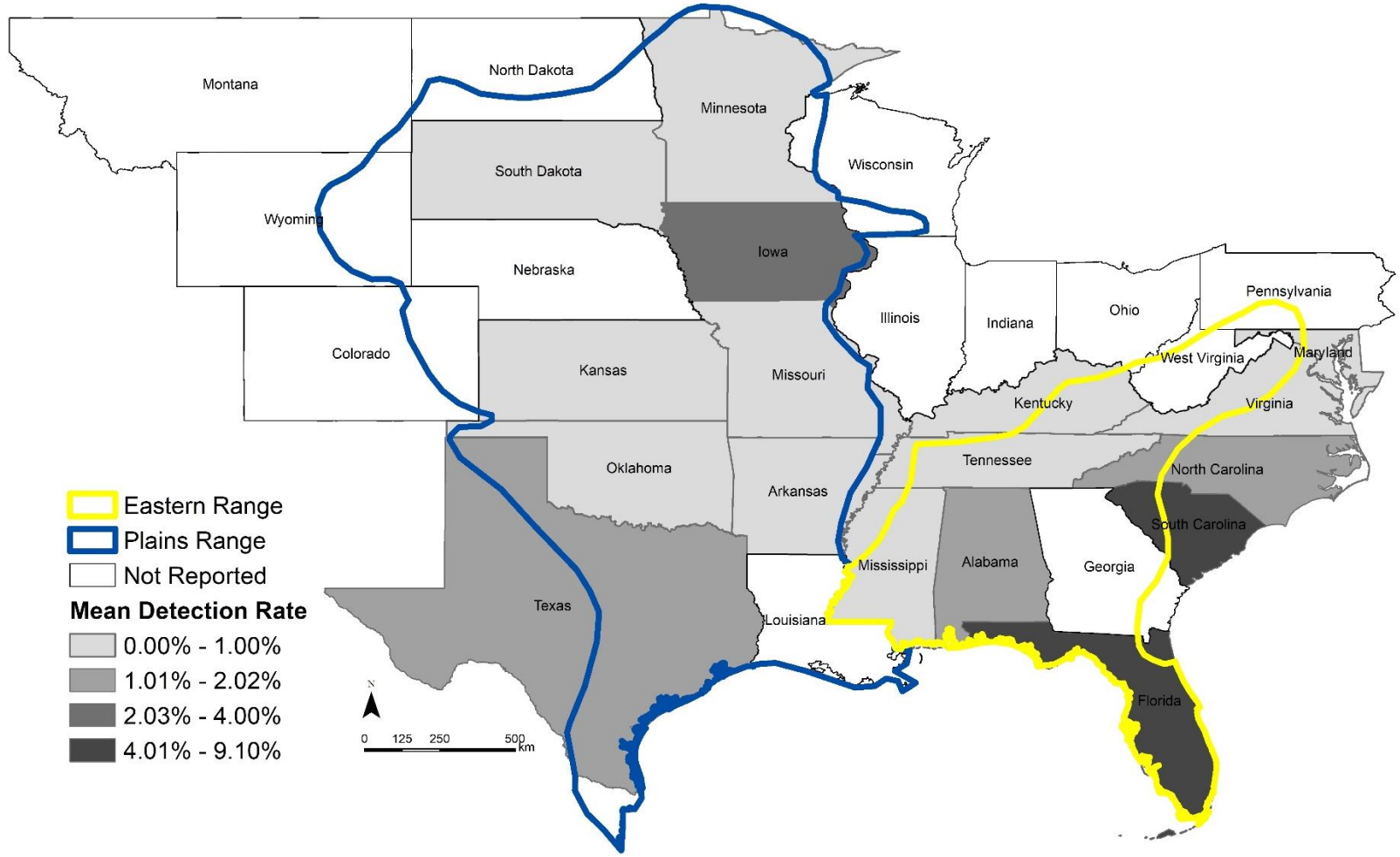

Figure 1.4. Mean reported detection rates of either the plains or eastern spotted skunk per state, with the historic range of both species (IUCN Eastern spotted skunk range adaptation). If a publication reported more than one detection rate for multiple states or sampling methods, all were incorporated in the analysis.

Among the 170 papers analyzed, only a minority (6%) estimated spotted skunk abundance with most of the analyses focusing on estimating occupancy of either the plains or eastern spotted skunk (Table 1.5). This limited focus on abundance analysis has contributed to the ongoing knowledge gap concerning the true abundance of the non-uniformly distributed populations of both species across their ranges. In contrast, a more substantial portion of the literature (31%) estimated occupancy, and 8% of the studies integrated both occupancy and abundance analyses within their research frameworks. However, it is essential to highlight that the majority of the papers (56%) did not incorporate any kind of abundance or occupancy estimation in their investigations. This distribution reflects the varying degrees of attention directed towards population dynamics in the context of spotted skunk research, with a significant proportion of studies not extensively delving into this important facet of the species' ecology. Given the multiple petitions for federal listing, it is crucial to continue effectively investigating both the plains and eastern spotted skunk current distribution and abundance. If this trend persists, these limitations in understanding population dynamics have substantial conservation implications, potentially impeding our ability to make well-informed management decisions and developing effective conservation strategies.

Table 1.5. Publications that analyzed spotted skunk (both *S. interrupta* and *S. putorius*) populations in terms of their abundance and/or occupancy (n = 170).

Population Analysis	**Articles**
Abundance	10 (5.9%)
Occupancy	52 (30.6%)
Abundance & Occupancy	13 (7.7%)
None	95 (55.9%)

Taxonomic & Topic Trends

Understanding the ecological and biological intricacies of the eastern and plains spotted skunks is crucial for their conservation and management. Following the taxonomic revision, there was initial uncertainty regarding which papers were focused on the plains spotted skunk or if these publications pertained to the eastern spotted skunk without delving into the study's methods to clarify. Among all publications, 5% did not report the taxonomic classification of their study individuals (i.e. used museum specimens). Some reported taxonomy without specifying the study location, making it impossible to determine the current taxonomy, and; thus, these studies were excluded from this analysis. Among the remaining publications with taxonomic information, 7% focused on two or more *Spilogale* species, signifying several subspecies. Of the publications that addressed their study species as *S. putorius*, 39% actually pertained to *S. interrupta* (Fig 1.5A). All papers designating the plains spotted skunk taxonomy as *S. putorius interrupta* or *S. interrupta* correctly referenced the now recognized species.

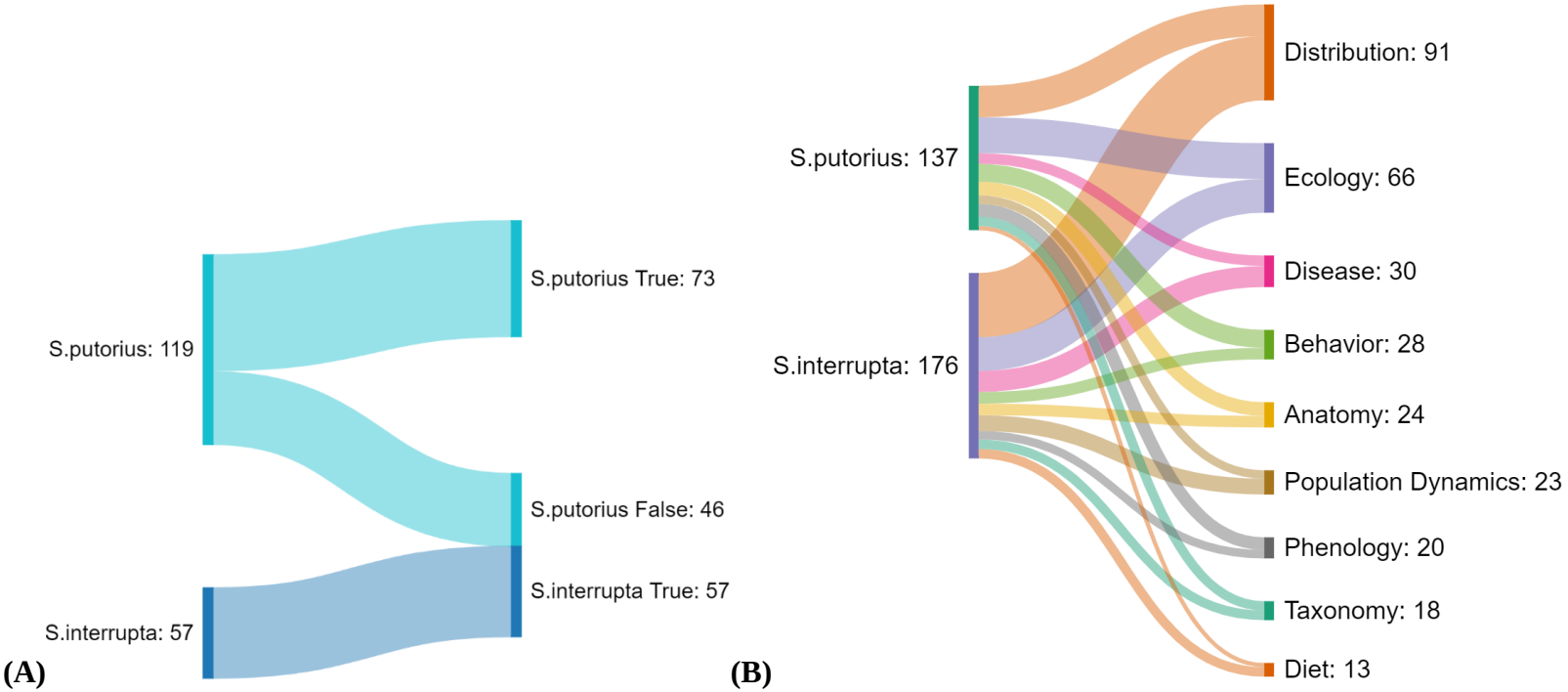

Figure 1.5. (A) Reported distribution of eastern (*Spilogale putorius*) and plains spotted skunk (*Spilogale interrupta*) studies (n = 176) before and after their taxonomic split (McDonough et al. 2022). (B) Topic distribution per study pertaining to the current taxonomy of both the eastern and plains spotted skunk. Note that one publication may encompass multiple studies or species across topic areas. Diagram created using SankeyMATIC (Bogart n.d.).

Research topic trends showed a clear emphasis on the topic of distribution and ecology across both species (52% and 38% of all spotted skunk studies, respectively; Fig 1.5B). This was particularly the case for the plains spotted skunk, where its distribution was the most extensively studied topic (35% of all plains spotted skunk studies), while phenology was the least studied topic for the species (5%). While eastern spotted skunk research also had a substantial focus on distribution, it received considerably less attention in comparison to plains. Dietary studies, taxonomy, and phenology were notably limited for both species.

Within the literature, both the eastern and plains spotted skunk have received seemingly equal representation across topics, with no single topic appearing to be excessively studied. Nevertheless, the plains has received relatively more focus in the topics of distribution, population dynamics, and disease (Fig. 1.5B). This emphasis could be partially attributed to historical research trends, particularly on specific states within the plains' range, which may have prompted subsequent research to continue in the same direction (Bailey 1915, Black 1936, Hibbard 1933, Johnson 1921, Pellett 1913, Selko 1937, Spurrell 1917). The conservation status and perceived threats to the plains spotted skunk might have also driven research efforts. The species' precipitous population decline was first highlighted with a focus in the Midwest (Gompper & Hackett 2005). It is possible that the plains spotted skunk may have been considered more at risk or had a lower population abundance in specific areas within its range, which may have led to the increased research dedicated to their distribution and population dynamics.

For the eastern spotted skunk, ecology was the most common topic (25%), with diet being the least explored (3%). Dietary needs and food habits are understudied, yet

critical areas of spotted skunk research, especially given the ongoing population decline. The specific cause for the decline remains unknown (Gompper & Hackett 2005), and it is essential to investigate whether dietary needs may have or continue to contribute to the decline in population status of the plains and eastern spotted skunk. To gain a more precise understanding of why differences in topic focus exist, further investigation and analysis of specific topic studies and research in the field is necessary.

Following the recent taxonomic revision (McDonough et al. 2022), there is a heightened demand for a stronger emphasis on taxonomy within the literature. The revision reaffirms the importance of reevaluating and enhancing our understanding of the species' classification, and paucity of literature on taxonomy may be attributed to several factors. Taxonomic research often requires specialized expertise, comprehensive surveys, and rigorous morphological or genetic analysis. These requirements may not have been available at the time, were considered resolved or less critical in comparison to alternative research topics. Further genetic studies could enhance our understanding of genetic and taxonomic variations among spotted skunk populations, particularly as they become increasingly isolated due to declining population sizes and environmental changes.

The understudied trend of the topic of phenology for both species is also unclear. This lack of comprehensive study could stem from various challenges in data collection, the relatively short lifespan of spotted skunks (Crabb 1944), or the difficulties associated with detecting and implementing long-term monitoring studies due to the elusive nature of the species. (Butler et al. 2021, Lesmeister et al. 2010). It is important that we continue to build upon the existing phenological literature (Arts et al. 2022, Benson et al. 2019,

Detweiler et al. 2022, Sprayberry & Edelman 2018). Monitoring spotted skunk phenology can serve as a crucial indicator for the biodiversity and the overall health of an ecosystem, as well as aid in the identification of environmental changes that may affect spotted skunk populations.

Knowledge Gaps and Future Directions

In the realm of scientific literature on mesocarnivores, research on the eastern and plains spotted skunk is notably limited in comparison to more abundant species. Over the course of more than a century, a mere 170 papers published on the two species emphasizes the limited attention received in the academic discourse. Furthermore, the recent taxonomic revision revealed that many topics previously attributed to the eastern spotted skunk were unknowingly misclassified predating the split. As we move forward, it is imperative to rectify this misclassification and address knowledge gaps within the literature for more accurate and meaningful representation for these two conservation priority species.

It is important to prioritize the investigation of under-sampled regions and states. Most studies have only been conducted in a few states within each species' range. For both the eastern and plains spotted skunk, the majority of studies have been conducted in only four states within each respective species range. These geographic gaps in research representation, particularly in states located at the periphery of the species' range, require attention due to their potential significance in furthering our understanding of spotted skunk ecology and critical aspects of their population dynamics. Given the evident and increasing interest in spotted skunk research, it is imperative that future research efforts

prioritize geographic regions and research topics that have been historically lacking in investigation, capitalizing on the current momentum in this field.

The inclusion of Colorado and Wyoming in the historical range of the plains spotted skunk and Ohio in the range of the eastern spotted skunk is perplexing due to the absence of both verified and unverified records in these states. The rationale behind incorporating these states in their historical ranges remains unclear. Our literature review yielded only one publication conducted solely in Wyoming; however, we excluded the publication as the species was not detailed nor could we confirm, based on its location, whether the spotted skunk studied was the plains or western species (Boulerice & Zinke 2017). To ensure accuracy, it is imperative to conclusively identify the species utilized in this or any spotted skunk study, either through genetic analysis or pelage. The USFWS's status assessment report included a geographic and temporal figure of current positive spotted skunk detections in Wyoming (US Fish and Wildlife Service 2022), inferring that these detected individuals were plains spotted skunks (*S. interrupta*), not western spotted skunks (*Spilogale gracilis*). This would suggest a range expansion for the plains species, a claim that requires substantiation through genetic analysis or the appropriate methodology to confirm its validity.

Implementing standardized reporting to ensure consistent data collection and reporting in spotted skunk studies would be beneficial. This standardization could encompass key metrics, such as detection rate, trap nights, species identification, and study duration. To achieve standardized practices, wildlife researchers can work towards adopting uniform guidelines and terminology to not only enhance our knowledge of spotted skunks within local populations, but also enable valuable comparisons with

neighboring states and across the entire species range. Ultimately, a consistent standardized reporting system would help contribute to broader regional and range-wide conservation efforts.

The need for long-term studies is crucial for monitoring population trends in regions spotted skunks are known to persist. Additionally, long-term studies in previously unexplored regions can serve as essential tools to confirm the true presence of spotted skunks, investigate the possibility of extirpation, or identify regions where the species may be exceptionally rare (Perkins et al. 2022). By combining systematic, long-term research efforts with a focus on under-sampled areas, biologists can bridge existing knowledge gaps and make informed decisions regarding the conservation of these two-declining species. As researchers delve into under-sampled regions to enhance our understanding of spotted skunk populations, a parallel emphasis on refining detection methodologies us also important for ensuring the accuracy and completeness of a population assessment. For example, a long-term study conducted in West Virginia confirmed the presence of a detectable population in the state, but did not report a detection rate (Hassler et al. 2021a). While the accuracy and comprehensiveness of this study is not in question, it is important for researchers to report their detection rates to provide a more complete and transparent understanding of the species' presence and distribution.

To enhance spotted skunk research, we suggest prioritizing additional efforts in estimating abundance, while following established standardized monitoring protocols to effectively assess trends in distribution and population parameters. Accurate estimates are essential, particularly for monitoring population declines and offering pertinent data for

potential state and EPA listing petitions. Within monitored regions, it is also advisable to re-evaluate assessments of habitat associations, considering ongoing landscape changes and potential urbanization impacts.

Since the release of the Eastern Spotted Skunk Cooperative Study Group's Conservation Plan (2020), there have been a few noteworthy developments in the priority research areas for both the eastern and plains spotted skunks. The taxonomic revision has reinforced the significance of understanding the distribution of both species, even though estimating their abundance remains challenging in some areas. Research should prioritize assessing trends in extant populations, the factors that are influencing those trends, and identifying the conservation implications of identified patterns. Working towards addressing the limitations of existing research, standardizing reporting practices, prioritizing under-sampled regions, and enhancing the precision of species identification are a few steps wildlife researchers can take towards advancing our knowledge of the eastern and plains spotted skunk.

CONCLUSIONS

In our comprehensive analysis of literature on both the plains and eastern spotted skunks, we described prominent trends and knowledge gaps. Over the past century, research on these species has evolved from rudimentary descriptions to in-depth multi-faceted investigations covering diverse topics ranging from diet to disease. Events like federal listing petitions have also influenced interest in spotted skunk research. The taxonomic revision necessitated reevaluating historical associations and research trends, to gain a more precise understanding of these two distinct species. Geographic distribution and population dynamics were popular research topics within both the plains

and eastern ranges. While certain states within both respective ranges have received more attention, others remain notably understudied, emphasizing the need for systematic research in previously under-represented areas to address local and range wide knowledge gaps. Methodological preferences varied within the literature, including differences in sampling method, study duration, and population analysis techniques. To enhance comparability and transparency within the field, more long-term investigations, active data collection efforts, and standardized reporting practices may be necessary. The current momentum in spotted skunk research offers an opportunity to bridge knowledge gaps, refine our understanding of spotted skunk ecology, and inform conservation strategies. Future research should prioritize under-sampled regions and adapt to evolving research needs.

CHAPTER II

POPULATION STATUS ASSESSMENT OF THE PLAINS SPOTTED SKUNK (*SPILOGALE INTERRUPTA*) IN KANSAS

ABSTRACT

While once abundant across the central United States, the plains spotted skunk (*Spilogale interrupta*) has experienced range-wide population declines, resulting in their Kansas listing as a Tier I Species of Greatest Conservation Need (SGCN). The species has suffered a particularly dramatic decline in Kansas, with the last confirmed sighting in the state in 2020. Our research objectives were to document plains spotted skunks in Kansas and describe their habitats to inform state conservation efforts. We conducted a statewide baited camera trap survey at 602 locations from February 2022–June 2023, targeting previously designated spotted skunk priority habitat and historic detection locations in 18 counties. Our intensive spatial and temporal sampling design, coupled with our efforts to resample former locations with positive detections, yielded no spotted skunks. The paucity of recent plains spotted skunk detections in state-designated priority habitat poses a challenge. If spotted skunk populations persist in the state, implementing conservation measures in Kansas may be required

INTRODUCTION

The plains spotted skunk (*Spilogale interrupta*) is a cryptic and conspicuous mesocarnivore, characterized by its unique pelage and odor. This squirrel-sized member of the *Mephitidae* family is easily recognized by its distinct pattern of black fur with broken white stripes from its head to its rump. While there are numerous species of spotted skunk within the genus of *Spilogale*, the plains spotted skunk is mainly distributed throughout the central United States. Historically, the plains spotted skunk was found from north-central United States into southern Texas, bounded by the Continental Divide in the west to the Mississippi River in the east (Kinlaw 1995a, McDonough et al. 2022). Beginning in the 1900s, the species began to experience severe population declines across a significant amount of its range. As a result, the plains spotted skunk has become a species of conservation concern (Gompper & Jachowski 2016). Although there has been an influx of contemporary interest in the species, more information on the species is warranted range wide.

In Kansas, the species was once widely distributed throughout the state, but its population has since experienced a dramatic decline. Notably, the historical significance of the plains spotted skunk became increasingly evident particularly due to its role as a fur-bearer species throughout the central United States. Within the state, harvest records from the 1930s totaled in the hundreds of thousands and remained high into the first half of the 1940s (Choate et al. 1973, Gompper & Hackett 2005, Roy 1997). By the 1950s, severe population declines were observed in Kansas and throughout their range (Cockrum 1952, Gompper & Hackett 2005, Sasse & Gompper 2006, Landholt & Genoways 2000). The decline of the species in Kansas continued into the 1970s,

prompting the permanent closure of the spotted skunk-trapping season in 1977 (Nilz & Finck 2008b). Verified and unverified sightings of the species have also dwindled in the state (Choate et al. 1973, Nilz & Finck 2008b), with the most recent sighting occurring in Gray County on a Kansas Department of Wildlife and Parks (KDWP) game camera in 2020 (Z. Cordes, KDWP, pers. comm. 2022). The precise causes of these steep population declines are still a subject of debate, with potential factors ranging from habitat loss, disease, and pesticide use to historical overharvest and low regional recruitment (Choate et al. 1973, Gompper & Hackett 2005, Lesmeister et al. 2010).

Habitat associations for the plains spotted skunk differ across its range and associated ecoregions west of the Mississippi River. For example, existing literature describes spotted skunk habitat in Kansas and Iowa as associated with mixed tallgrass prairie, overgrazed pastures, overgrazed riparian zones, weed-grass-shrub-bramble cover, and croplands (Choate et al. 1973, Crabb 1948, Polder 1968). In Texas, the species was found to be associated with woodlands and prairies (Schmidly & Bradley 2016) and shrub thickets (Jefferson 2021, Perkins 2022). Additionally, the species has been found in old oak-hickory stands with fallen logs and brush piles in the Missouri and Arkansas Ozarks (Hackett et al. 2007, LaRose et al. 2022, Lesmeister et al. 2009, 2013, McCullough 1984). LaRose (2022) specifically noted a negative relationship between the species and habitat disturbance in Missouri and Arkansas, contrasting its affinity for agriculture in more western regions of its range (e.g., Choate et al. 1973). Given the diverse habitats in Kansas, ranging from deciduous forests in the east to grasslands and row crop agriculture in the west, it remains unclear which specific habitat features the species depends upon in Kansas. Although critical habitats have been designated

throughout the state by the KDWP following Nilz & Finck's (2008a) recommendations (Fig. 2.1), more extensive data collection is needed to understand spotted skunk habitat associations in Kansas.

The precipitous population decline of the plains spotted skunk has prompted multiple petitions for the species to be listed under the Federal Endangered Species Act (ESA) (1973). The plains spotted skunk was first proposed for listing under the ESA in 1994 as a subspecies (formerly *S. putorius interrupta*; McDonough et al. 2022) of the eastern spotted skunk (*Spilogale putorius*). However, insufficient information at that time led to a decision against listing the species. From 2012–2023, the species was under review for federal listing (US Fish and Wildlife Service 2012). Recently, the US Fish and Wildlife Service announced that there were enough viable populations within the plains spotted skunk range to not warrant listing (US Fish and Wildlife Service 2023). Even so, the spotted skunk is currently recognized as a state-threatened species by the Kansas Nongame and Endangered Species Conservation Act (1982) (Nilz & Finck, 2008a, Rohweder 2022). Thus, an urgent need exists for increased data collection efforts to assess the presence and distribution of the plains spotted skunk across the state of Kansas.

The primary objective of this study was to document plains spotted skunks in Kansas using baited camera traps, focusing on areas of verified historical detections and critical habitat designated by the KDWP. If detected, our aim was to evaluate patterns in habitat and landscape features among the locations where they were found. The lack of systematic studies has resulted in an incomplete understanding of the spotted skunks' historical and contemporary distribution. This gap in knowledge, coupled with a dramatic population decline over time (Gompper & Hackett 2005, Cockrum 1952), highlights the

need for a population status assessment. The findings from this study were intended to update a species distribution map and offer insights regarding conservation actions to benefit this species in Kansas.

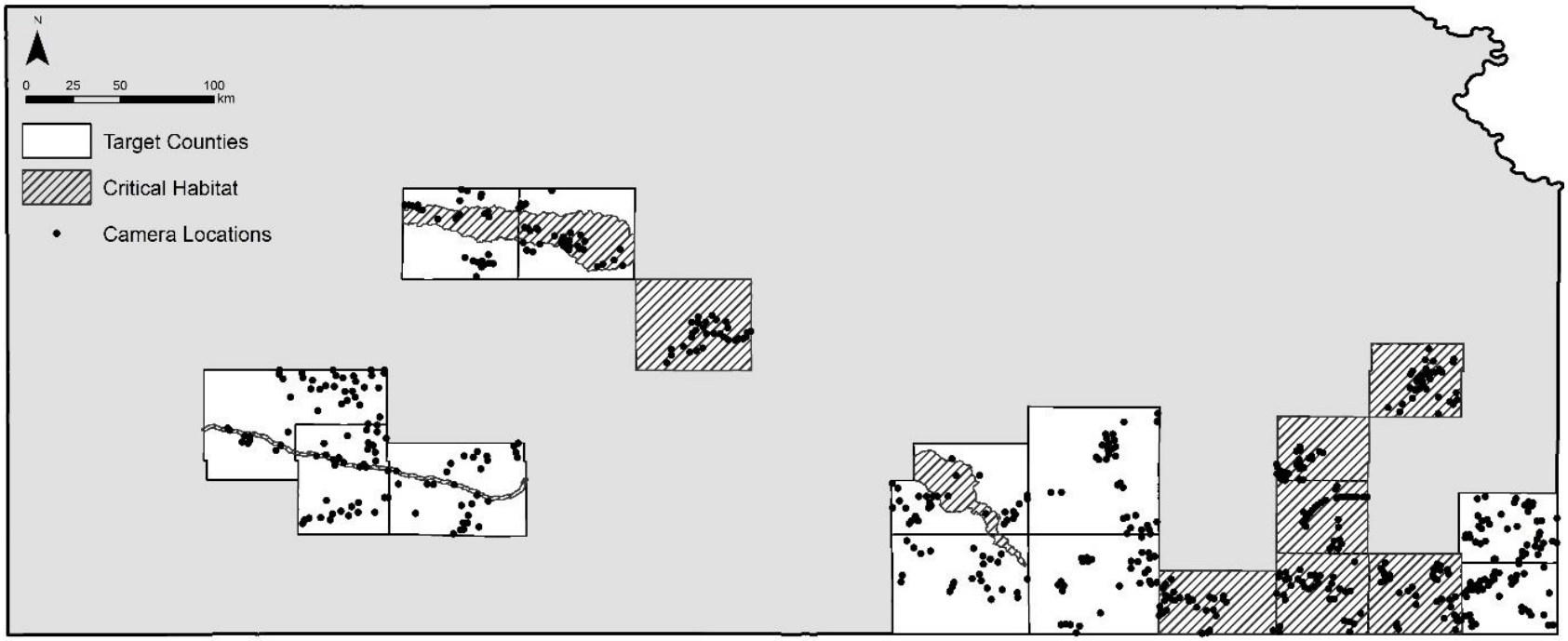

Figure 2.1. Sampling efforts for the plains spotted skunk spanned 18 counties throughout Kansas, targeting areas designated as spotted skunk critical habitat (Nilz & Finck 2008a). We surveyed 602 camera trap locations between February 2022 and July 2023.

METHODS

Study Area

We surveyed 18 counties across three regions in Kansas, each representing diverse habitats, KDWP-designated spotted skunk critical habitats (Nilz & Finck 2008a), historic spotted skunk locations, and recent sighting locations (Z. Cordes, KDWP, pers. comm., 2022). The three target areas each consist of unique physiographic regions: western, central, and southeast Kansas. The High Plains of western Kansas are dominated by vast flatlands and rolling expanses of pastureland that encompass the alluvial plain of the Arkansas River Lowlands (Aber & Aber 2009). We also sampled within central Kansas, which is comprised of the sediment-deposited Smoky Hills, specifically along the Smoky Hill River Corridor from western to north-central Kansas. The southeast region transitions to forested areas, spanning across the Chautauqua Hills, Osage Cuestas, Cherokee Lowlands, and Ozark Plateau (Aber & Aber 2009).

In western Kansas, we surveyed Trego, Ellis, Barton, Ford, Finney, and Gray counties. In central Kansas, we surveyed Sedgwick, Butler, Sumner, and Cowley counties. Lastly, in southeast Kansas, we surveyed Montgomery, Chautauqua, Woodson, Wilson, Anderson, Cherokee, Crawford, and Labette counties. We sampled sites that were reasonably accessed on both public and private land. Private landowner approval was obtained prior to any work conducted at those locations.

Survey Methods

We deployed camera traps over approximately 602 sampling locations within the selected 18 counties in Kansas (Fig. 2.1). Using the Program R (R Core Team 2020) and land cover data (NLCD 2001), we randomly, with a systematic filter, selected sampling

points within the target counties. We placed a 1.5 km buffer around each point to ensure spatial independence, based on the reported average of a male spotted skunk's home range size in winter (Higdon & Gompper 2020, LaRose et al. 2022, Lesmeister et al. 2009, Thorne et al. 2017, Wilson et al. 2016). We biased our selection of points to land on cover types associated with plains spotted skunk, such as forest cover, shrubland, grassland, pasture/rangeland, and wetlands (Crabb 1948, Eng & Jachowski 2019, LaRose et al. 2022, Lesmeister et al. 2008, 2009, Nilz & Finck 2008b, Perry et al. 2021, Reed & Kennedy 2000, Sprayberry & Edelman 2018). We also biased the selection toward points on public land to increase accessibility to the sample locations. We initially selected 55 proposed points within each county with this procedure, knowing that many of these points would not be accessible or not adequate for sampling. From the proposed 55 points, we sampled at least 24 sites per county to reach our goal of 600 overall sampling locations. This sampling goal allowed us to have a large spatial distribution within our time and funding constraints of the project.

The greatest detection probabilities for spotted skunks have historically occurred from January to March (Hackett et al. 2006, Higdon & Gompper 2020, Wilson et al. 2016); as such, we focused our sampling effort in the winter to early spring (November–March). Even though the literature suggests avoiding low-detection summer sampling efforts (Hackett et al. 2006), we also deployed a subset of our cameras during the late spring to summer (May–August) to confirm negative detections for Kansas' summer season. Our study began during February 2022 and ended in July 2023. Camera settings and placements followed published protocols (Higdon & Gompper 2020, Thorne et al. 2017, Wilson et al. 2016). Each site's location was recorded using a Garmin handheld

GPS unit and the program OnX (https://www.onxmaps.com/). All cameras used for this study were Browning Recon Force Elite, set to a three-shot rapid fire photograph, 1-second photo delay to standardize camera quality and number of captures per trigger (Higdon & Gompper 2020). Camera traps were baited with sardines in soybean oil (Dukes et al. 2022).

We deployed the camera 0.45–0.50 m off the ground with the bait set at the same height, 3–4 m away from the camera. If a tree was present at the sampling location, we affixed the camera to the tree with a strap. At sites without trees, we affixed the camera to a fence post and camera block (wooden 12 x 20 x 5 cm), which provided stability to the camera. We affixed the camera block to the metal T-post with either a screw or hose clamp (Perkins 2022). Existing fencerows were also used for camera placement, if available. If a tree was available opposite the camera, we nailed the can of sardines to the tree above a 5 cm wooden scent block, so the oil from the sardine flowed over and was absorbed by the scent block (Hays et al. 2021). If a tree was not present opposite the camera, the bait was wired to a wooden stake, which acted as a scent block, with bailing wire 0.45 m off the ground. All vegetation in front of the camera in a 4 m x 2 m area was cut to the ground in order to reduce false triggers of the camera.

All images taken by the camera had bait situated just above the center of the frame. All cameras were directed to face North or South to avoid interference from shadows and glare. With each trigger of the camera, the photograph recorded the date, time, and temperature at capture. Based on similar studies that employed sardines as bait and reported average latency to initial detection between two to three weeks (Dukes et al. 2022, Wilson et al. 2016), we ran our cameras for four weeks at one site location with

one rebaiting event after two weeks (Perkins et al. 2022). When camera malfunctions occurred during one of the two-week periods, capturing no photographs or if the bait was not present in the camera frame, we attempted to rebait and redeploy the camera for an additional two weeks to record a minimum of 14 trap nights per site. Camera sites with less than 14 trap nights (i.e. interference from livestock, grass, etc., n = 6; theft / vandalism, n = 5) were excluded from our dataset. Photographs were downloaded and cataloged from each camera every two weeks. All camera trapping methods were approved by the Fort Hays State University Institutional Animal Care and Use Committee (#22_0003).

Data Analysis

Each photograph was manually assessed for species presence and then uploaded to the web-based application RECONN.ai (2023). This program exercises an AI algorithm to recognize and flag images of any mammal activity. We trained the AI algorithm until its detection rate reached a species identification confidence of at least 80%. Then, we applied the application to assess photographs for mammal presence and species identification automatically for every single collected image per the program manual guidelines (A. O'Donnell, Michigan Aerospace Corporation, pers. comm.). We manually examined each image in order to verify the correct species identification following the RECONN.ai annotations.

We reviewed and recorded data on animal identifications (e.g., species, abundance, and other notable features) for all mesocarnivores and Kansas Species of Greatest Conservation Need (SGCN species; Rohweder 2022). RECONN.ai software also collected detection data, such as the date and time of each detection, and number of

trap nights (i.e., effort) for each location. Detection rate was calculated as the number of observations divided by total trap nights, with observations defined as one independent detection separated by 30 minutes from another independent detection (Burton et al. 2015).

Habitat Assessment

Vegetation surveys provide important local and landscape-scale insight into critical habitat associations of plains spotted skunks in Kansas. We planned to conduct vegetation surveys upon any positive spotted skunk detections following standardized protocol to quantify land cover, land use, and habitat associations at detection sites at a landscape and local scale. At the landscape scale, we planned to utilize cover types from the most recent National Land Cover Database raster available to characterize landscape composition (NLCD 2019) and determine if landscape-scale forest, agricultural, and urban habitats influence the presence of the plains spotted skunk.

For the local scale, we planned to perform habitat surveys within a standard 0.04 ha plot (11.3 m radius; James & Shugart 1970), centered at each camera location. Within each plot, we planned to assess the following habitat variables within each plot that may have contributed to preferred spotted skunk habitats: dominant tree species, tree abundance, canopy cover with a convex spherical densiometer, and stand density (basal area) by measuring the tree's diameter at breast height (DBH) (Crabb 1948, Hackett et al. 2007, LaRose et al. 2022, Lesmeister et al. 2009, 2013). We would have estimated the forest's understory density with a Nudd's board in each cardinal direction from the plot's center (Nudds 1977). If a positive detection occurred in a grassland habitat, vegetation density would have been measured using a Robel pole (Robel et al. 1970). Percent

ground cover would have been assessed in five randomly located quadrats in the vegetation sampling plot with a Daubenmire frame (55 cm x 25 cm; Bonham et al. 2004). The following ground cover classes would have been used to characterize the vegetation: woody, herbaceous, leaf litter, bare soil, rock, and coarse woody debris.

RESULTS

Over the course of our study, we did not detect plains spotted skunks at any of our 602 unique camera sites over a total of 18,313 trap nights (Fig. 2.1; Table 2.1). The majority (73%) of these sampling efforts were conducted during the winter season. While we did not detect a spotted skunk, we did detect ten species of mesocarnivores (Table 2.2), two of which were listed as SGCN in Kansas at the time of their detection: the Gray Fox (*Urocyon cinereoargenteus*) and Swift Fox (*Vulpes velox*) (Fig. 2.2, 2.3, 2.4). Gray Fox detections occurred at six cameras sites, including two county records (Benson et al. *Accepted*), and Swift Fox were detected at 18 sites. Incidentally, we also detected three additional species of SGCN: the Southern Flying Squirrel (*Glaucomys volans*) at eight sites, the Lesser Prairie Chicken (*Tympanuchus pallidicinctus*) at four sites, and the Black-tailed Prairie Dog (*Cynomys ludovicianus*) at one site (Fig. 2.5, 2.6, 2.7). We programmed our RECONN.ai annotations to sample mammal species, so the number of sites with Lesser Prairie Chicken is potentially an underestimate.

Table 2.1. We sampled 18 Kansas counties for plains spotted skunks (Feb 2022–Jun 2023). The number of sampling locations and trap nights were dependent on accessibility, the extent of public land within a county, approval from landowners, and spatial constraints.

County	**Camera Sites**	**Trap Nights**
Anderson	35	965
Barton	30	799
Butler	33	976
Chautauqua	30	852
Cherokee	41	1347
Cowley	31	877
Crawford	47	1338
Ellis	40	1238
Finney	41	1153
Ford	29	1101
Grey	37	1267
Labette	37	1361
Montgomery	36	1033
Sedgwick	30	850
Sumner	24	654
Trego	26	857
Wilson	30	892
Woodson	25	753
Total	**602**	**18,313**

Table 2.2. Mesocarnivores detected (n = 10) across sampling locations. Species designated as Tier 2 SGCN by the KDWP (Rohweder, 2022) are denoted with an asterisk (*).

Species	**Scientific Name**
American Badger	*Taxidea taxus*
Bobcat	*Lynx rufus*
Coyote	*Canis latrans*
Domestic Cat	*Felis catus*
Domestic Dog	*Canis lupus familiaris*
*Gray Fox	*Urocyon cinereoargenteus*
Northern Raccoon	*Procyon lotor*
Red Fox	*Vulpes vulpes*
*Swift Fox	*Vulpes velox*
Striped Skunk	*Mephitis mephitis*

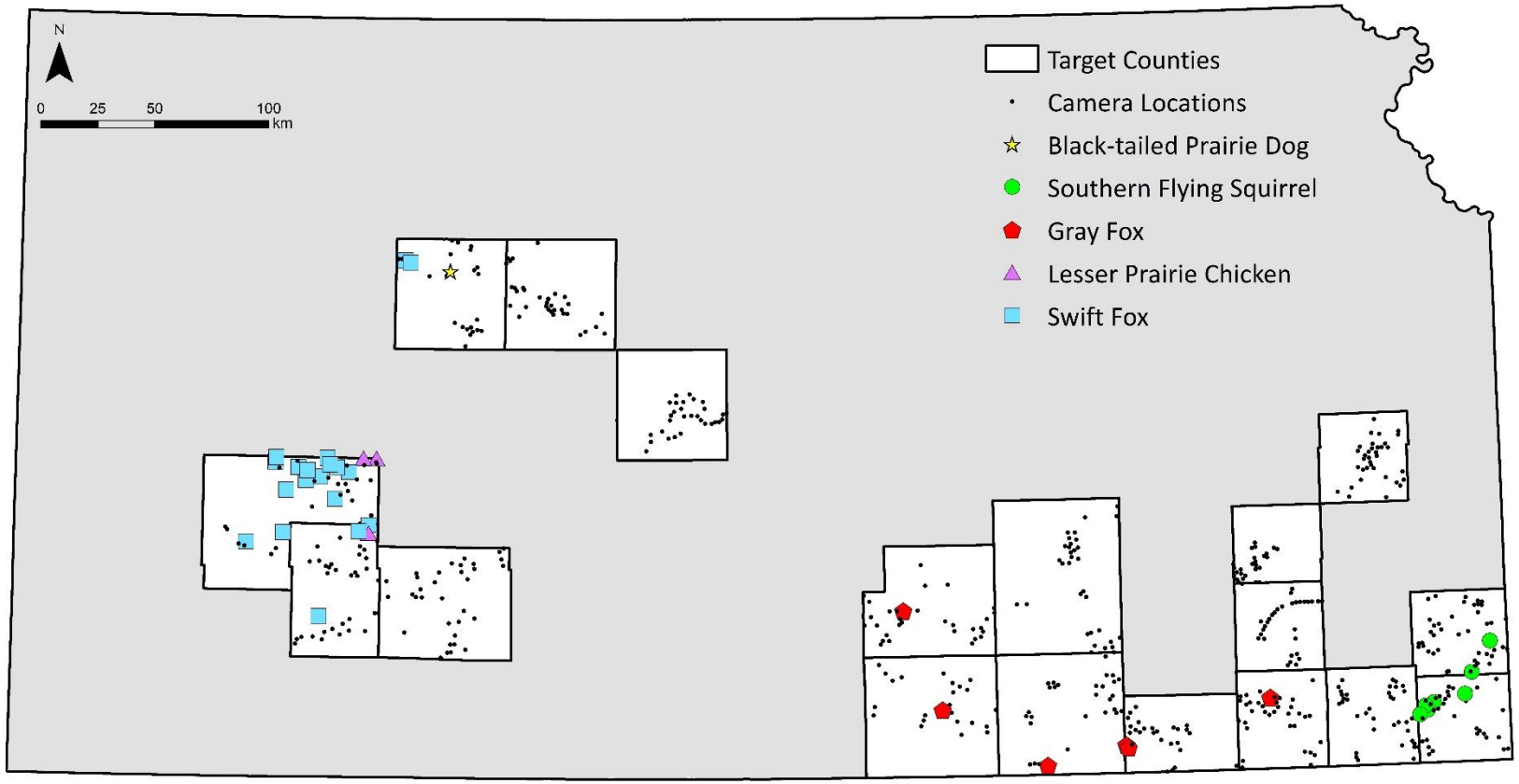

Figure 2.2. Map of our 18-county study area, camera locations, and locations at which Species of Greatest Conservation Need (SGCN) were detected. We detected five SGCN: Gray Fox (*Urocyon cinereoargenteus*), Swift Fox (*Vulpes velox*), Southern Flying Squirrel (*Glaucomys volans*), Lesser Prairie Chicken (*Tympanuchus pallidicinctus*), and the Black-tailed Prairie Dog (*Cynomys ludovicianus*).

Figure 2.3. Camera trap images of Gray Fox (*Urocyon cinereoargenteus*) captured on a game camera in Sumner County (top), a county record (Benson et al. *Accepted*), and Sedgewick County (bottom).

Figure 2.4. Camera trap images of Swift Foxes (*Vulpes velox*) detected at two locations within Finney County.

Figure 2.5. Camera trap images of Southern Flying Squirrels (*Glaucomys volans*) in Crawford (top) and Cherokee (bottom) Counties.

Figure 2.6. Camera trap images of Lesser Prairie Chickens (*Tympanuchus pallidicinctus*) detected in Finney (top) and Gray (bottom) Counties.

Figure 2.7 Camera trap images of Black-tailed Prairie Dogs (*Cynomys ludovicianus*) detected in Trego County

DISCUSSION

Despite conducting an intensive and comprehensive survey across a broad spatial and temporal scale, we were unable to locate any plains spotted skunks in Kansas. This highlights the ongoing lack of knowledge regarding their distribution in the state. Although we could not provide evidence of plains spotted skunks in our study area, even in their designated critical habitats and historical sighting locations, they were previously widespread throughout the state (Choate 1973, Nilz & Finck 2008a). Thus, the need for additional data to ascertain the presence of plains spotted skunks is critical for the state, especially to determine if they have been extirpated from Kansas.

Initiated during 2005 and 2007, trapping efforts by Nilz & Finck yielded two detections (2008b). Two parallel investigations in Kansas were conducted during the same period and both reported no sightings of spotted skunks (Davis 2005, Taggart 2007). No subsequent research was conducted until 2017. The most recent confirmed detections of plains spotted skunks in Kansas (Z. Cordes, KDWP, pers. comm. 2020) remain unpublished, contributing to the paucity of systematic studies and an incomplete understanding of the contemporary distribution of spotted skunks within the state. The cause for the species' decline remains unclear and it is important to continue to address the extensive data needs concerning their distribution.

In addition to Kansas, the current distribution and abundance of the plains spotted skunk in the neighboring states of Nebraska, Oklahoma, Arkansas, and Missouri lacks clarity and require assessment. Despite previous detections within regions with verified records (Fino et al. 2019, Perry et al. 2021), the species' elusive and cryptic nature remains a persistent challenge for its detection. The plains spotted skunk is categorized as

a SGCN, critically imperiled, or locally endangered in Kansas and neighboring states (Eastern Spotted Skunk Cooperative Study Group 2020). Nebraska, for instance, has not recorded a spotted skunk sighting since 2017, and recent attempts involving a game camera detection study over the past 1.5 years yielded no positive identifications (S. Dunn, Nebraska Game and Parks Commission, pers. comm. 2023). In Oklahoma, spotted skunks have been detected in both the western and eastern parts of the state over the last decade (Shaughnessy et al. 2016, Branham & Jackson 2021); however, comprehensive, long-term monitoring projects have not been initiated (Eastern Spotted Skunk Cooperative Study Group). For Arkansas and Missouri, predictive models suggest the species might inhabit a substantial portion of these states (LaRose et al. 2022). Even so, recent records have been primarily limited to the Ouachita and Ozark Mountains of both states (Higdon & Gompper 2020, Lesmeister 2010). It is concerning that despite the relatively favorable conditions in Arkansas (i.e. forested habitats, limited human disturbance), the plains spotted skunk mean annual survival rate in this regions was relatively low (0.354; Lesmeister et al. 2010). This underscores the pressing need for contemporary research efforts, including recurrent monitoring and exploratory studies aimed at identifying historically understudied or undocumented populations. A thorough evaluation of the plains spotted skunks status in the central region of its range is crucial to understanding population dynamics and gathering data to develop potential conservation strategies.

Incorporating citizen science initiatives, trapper engagement, and systematic surveys, among other approaches, holds promise for enhancing data collection (Dukes et al. 2021, Hays et al. 2021, Perkins et al. 2022). The Missouri Department of

Conservation's Natural Heritage Program database currently solicits the trapping community, public, and Department of Conservation staff to catalogue all positive detections. Beginning in 2017, the state of Nebraska initiated citizen science surveys using camera traps. Within the same year, Oklahoma began soliciting observations from the public through social media platforms. Leveraging citizen science efforts has proven to be a powerful tool for expanding monitoring coverage and engaging the public in the process of data collection (Perkins et al. 2022, Perry et al. 2021). This approach has the potential to be particularly beneficial in Kansas, where a comprehensive understanding of the species status is unclear. As collective efforts coalesce, the resultant data can enhance a more comprehensive understanding of the plains spotted skunk's distribution, population trends, and conservation requirements.

The results of our camera trapping study are concerning, and the apparent absence of the species implies the possibility of a very limited population or even extirpation. These findings highlight the urgency for further investigation into the status of the plains spotted skunk across the central United States and, notably, in Kansas, where an assessment of their presence in this region is warranted. We propose a comprehensive approach within the state involving citizen science to collect data. We suggest conducting public surveys that extend beyond the designated critical habitat. In addition to community engagement, we propose the strategic placement of semi-permanent survey efforts, including game cameras, statewide at sites where positive sightings have been recorded over the last decade. Expanding our monitoring efforts beyond our study area is crucial, and deploying camera traps in potential habitats along state borders with verified detections in neighboring regions is also suggested.

Given the plains spotted skunk's historical enigmatic occurrence in Kansas, current efforts to ascertain its population are crucial. Each investigative avenue contributes to our understanding of the status and ecological interactions of this elusive mesocarnivore. The inconspicuous behavior of the species within their historical range becomes evident due to the absence of any detections during our study, emphasizing the need for further inquiry into the reasons behind their apparent scarcity across surveyed areas and throughout the entire state. By refining our understanding of their presence and distribution, we can implement more focused and informed conservation strategies, ensuring the species' survival within the region.

CONCLUSIONS

Our extensive survey efforts revealed the troubling absence, and possible extirpation, of the plains spotted skunk within Kansas. Despite historical records of their presence, recent detections have been scarce and their conspicuous nature poses a considerable challenge for researchers. This study highlights the urgent need for a further comprehensive assessment of plains spotted skunk distribution in Kansas, but also in neighboring states. We propose a long-term camera trapping monitoring effort paired with the integration of citizen science initiatives across the state, encompassing regions with verified detections. This multifaceted approach is essential to elucidating the current status of the plains spotted skunk, its ecological interactions, and reasons for its apparent scarcity within this region. By enhancing our understanding of its population status, we can develop more targeted conservation strategies to promote the survival of plains spotted skunks in the central United States, and if detected in the future, within the state of Kansas.

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APPENDIX

Appendix I. Reference list of all publications (n = 170) used in our systematic literature review.

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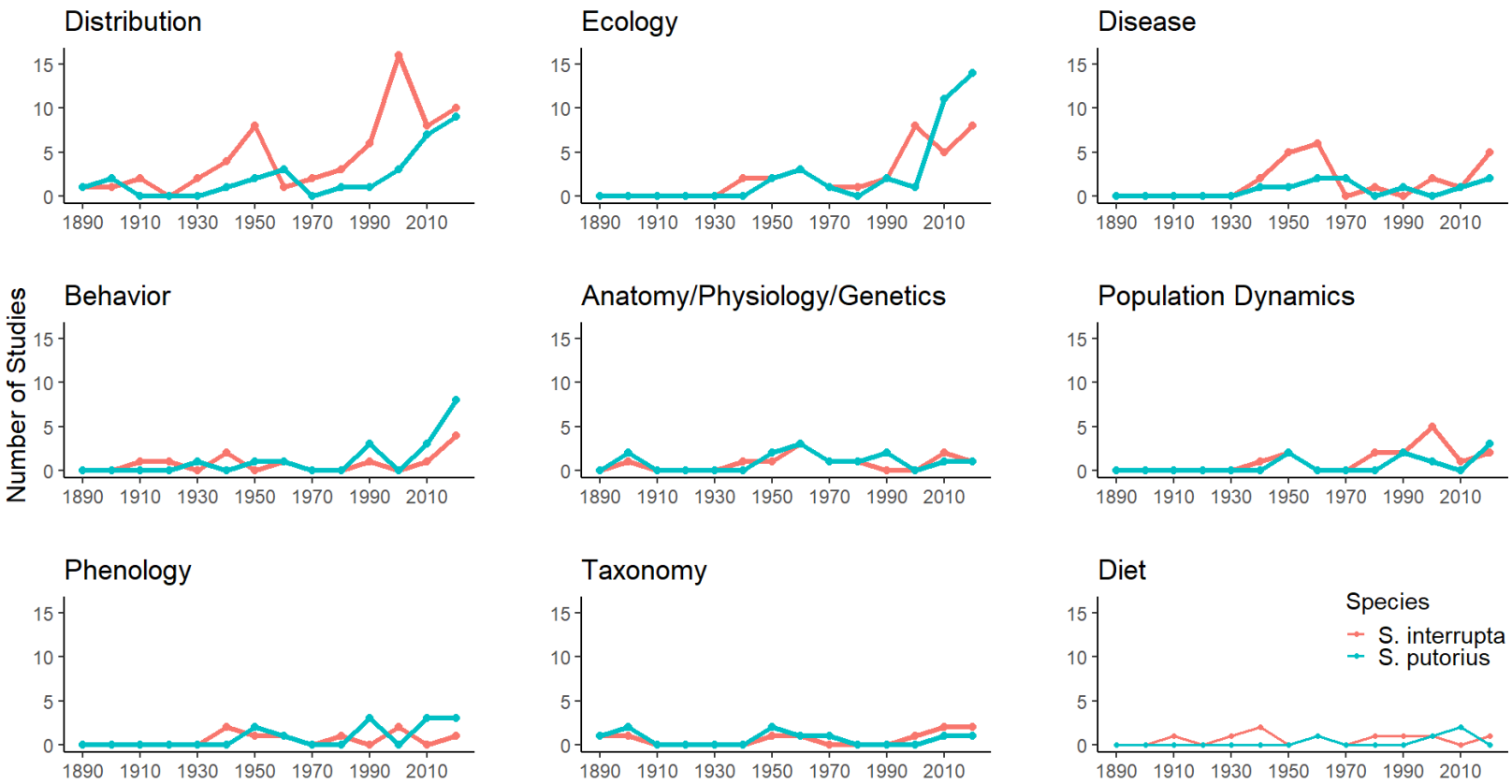

Appendix II. Temporal trends of eastern (blue line) and plains (red line) spotted skunk study topics researched between 1890 and 2023, ordered from most to least common. Note that one publication may encompass multiple studies on a variety of topics.

Appendix III. Total publications (n = 170) per scientific journal and additional publication sources (e.g., state reports) (n = 74). Journals are ordered from most to least prevalent in the eastern and plains spotted skunk literature.

Source	Publications
Southeastern Naturalist	25
Journal of Mammalogy	23
The Journal of Wildlife Management	10
The American Midland Naturalist	9
Journal of the Arkansas Academy of Science	5
The Journal of Parasitology	5
Journal of Wildlife Diseases	4
Proceedings of the Iowa Academy of Science	4
Transactions of the Kansas Academy of Science	4
American Journal of Veterinary Research	3
Journal of the American Veterinary Medical Association	3
Museum of Texas Tech University	3
Chesapeake Science	2
Ecosphere	2
Kansas Department of Wildlife and Parks	2
Missouri Department of Conservation	2
Northeastern Naturalist	2
Proceedings of the Oklahoma Academy of Science	2
Public Health Reports (1896-1970)	2
The Prairie Naturalist	2
The Texas Journal of Science	2
American Journal of Epidemiology	1
Animal Conservation	1
Arkansas Academy of Science	1
Banisteria	1
Bulletin of the American Museum of Natural History	1
Canadian Journal of Zoology	1
Comparative Biochemistry and Physiology Part A: Physiology	1
Comparative Biochemistry and physiology	1
Comparative Mammalian Cytogenetics	1
Ecological Monographs	1
Ecology	1
Ecology and Evolution	1
Florida Academy of Sciences, Inc.	1

Source	Publications
Florida Field Naturalist	1
Florida Scientist	1
Functional Ecology	1
Human-Wildlife Interactions	1
Indiana Academy of Science	1
Iowa Department of Natural Resources	1
Journal of Anatomy	1
Journal of Animal Ecology	1
Journal of Ethology	1
Journal of Field Ornithology	1
Journal of Herpetology	1
Journal of Kansas Herpetology	1
Journal of Medical Entomology	1
Journal of Nematology	1
Journal of Threatened Taxa	1
Journal of Zoology	1
Journal of the Iowa Academy of Science	1
Journal of the Tennessee Academy of Science	1
Mammalia	1
Molecular Phylogenetics and Evolution	1
Natural Areas Journal	1
North American fauna	2
Occasional Papers, Museum of Texas Tech University	1
Oklahoma Academy of Science	1
Proceedings of the South Dakota Academy of Science	1
Publications of the Oklahoma Biological Survey	1
Quarterly Journal of the Florida Academy of Sciences	1
Quaternary Research	1
Research Bulletin (Iowa Agriculture and Home Economics Experiment Station)	1
Restoration Ecology	1
Small Carnivore Conservation	1
Texas Comptroller's Office	1
The Anatomical Record	1
The Journal of Protozoology	1
The Minnesota Department of Natural Resources and The Zoological Society of Minnesota	1
Transactions of the Missouri Academy of Science	1
Transactions of the Nebraska Academy of Sciences and Affiliated Societies	1

Source	Publications
Vector-Borne and Zoonotic Diseases	1
Western North American Naturalist	1
Wildlife Biology	1

Appendix IV. States in which studies on eastern and plains spotted skunk occurred (n = 27). Values following each state indicate the number of studies in which spotted skunks in that state were surveyed. No publications reported on eastern or plains spotted skunks in Ohio or Wyoming, respectively, even though these states are within published range maps. Note that one publication may have reported on studies where data was collected in multiple states.

Eastern Spotted Skunk	Plains Spotted Skunk
Virginia (16)	Arkansas (31)
Alabama (15)	Iowa (27)
North Carolina (15)	Texas (25)
Georgia (11)	Kansas (24)
South Carolina (11)	Oklahoma (18)
West Virginia (11)	South Dakota (16)
Tennessee (9)	Minnesota (14)
Mississippi (7)	Missouri (14)
Louisiana (7)	Nebraska (9)
Kentucky (6)	North Dakota (4)
Maryland (5)	Wisconsin (3)
Pennsylvania (4)	Colorado (2)
Florida (3)	Wyoming (0)
Ohio (0)	