CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

CALIFORNIA BOBCAT POPULATION MONITORING

Report of Findings | AUGUST 2026

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CHAPTER 1. INTRODUCTION

The bobcat (*Lynx rufus*), one of North America's few spotted wild felines, can be found in nearly every terrestrial habitat in California. Bobcats have long been respected by Native American tribes for their hunting skills, were feared by some European settlers for their perceived supernatural powers, and sought after by many for their high quality, uniquely patterned pelts (Young 1958, Hanson 2007). Bobcat conservation and management and public attitudes toward bobcats in California have changed over time. These changes prompted the need for a statewide assessment of bobcat populations and the development of a bobcat conservation and management plan.

Throughout its history of bobcat management, the California Department of Fish and Wildlife (CDFW) has compiled information from Hunter Game Take Questionnaires, produced yearly bobcat harvest assessments, and completed three movement studies among four bobcat populations (Lembeck 1978, Gould 1980, Zezulak 1980, Zezulak and Schwab 1980), on which statewide population estimates, and hunting regulations were based. Over the last 40+ years, many other studies on bobcat ecology and population dynamics have been conducted in California (Table 1).

During the same period, laws and regulations related to bobcat management have changed based on shifting needs and views of California's citizens and their leaders. In October 2019, the California Legislature passed California Assembly Bill 1254 (AB 1254), titled "*Bobcats: take prohibition: hunting season: management plan.*" This bill became effective January 1, 2020, and made it unlawful for a person to hunt, trap, or otherwise take a bobcat in California. AB 1254 added Section 4158 to the Fish and Game Code (FGC § 4158) which directed CDFW to develop a bobcat conservation and management plan to inform California's management decisions about bobcat populations using credible science[1] and an ecosystem-based approach[2]. The law specified that the management plan includes:

(1) A current statewide bobcat population estimate based on the best available science[1].

(2) An assessment of the overall health[3] of the statewide bobcat population.

(3) A comprehensive strategy to manage bobcat populations and their habitat throughout the state.

(4) An investigation of nonlethal solutions to prevent bobcat predation on livestock.

(5) Recommendations for regulatory or statutory changes necessary to implement the bobcat management plan.

[1] "Credible science" means the best available scientific information that is not overly prescriptive due to the dynamic nature of science, and includes the evaluation

principles of relevance, inclusiveness, objectivity, transparency, timeliness, verification, validation, and peer review of information as appropriate. Credible science also recognizes the need for adaptive management, as scientific knowledge evolves (FGC § 33).

[2] *The ecosystem approach takes into consideration that all components of the ecosystem, including its processes, structure, and conditions, are interrelated, and should be maintained and enhanced to conserve ecological integrity and biological diversity (CDFW SWAP 2025).*

[3] *We defined the overall health of California's bobcat populations through data collection on key indicators such as population size and dynamics, survival, movement, disease monitoring, genetics, habitat availability and use, and factors affecting survival.*

The Legislature provided funding to CDFW to implement a statewide bobcat population monitoring project (California Bobcat Project) and to develop California's first bobcat conservation and management plan. The methods, analysis, and results of the California Bobcat Project are presented here, alongside the existing information about bobcats in California (Table 1). The work outlined in this report addresses the project objectives below, has provided the critical information for the development of the Bobcat Conservation and Management Plan (the Plan), and is meant as a support document for the Plan.

Photo by the CDFW Bobcat Project

Table 1. List of studies done on bobcat in California, the location of the study, and details of what information are reported in those studies.

Source	Location (County)	Population Density	Home Range	Resource Selection/ Food Habits	Reproduction	Mortality/ Survival	Disease	Genetics	Human-Wildlife Conflict
Alonso et al. 2015	Orange	✓	✓						
Brown 2021	Inyo & Mono	✓	✓	✓					
Dunagan et al. 2019	Los Angeles		✓	✓					✓ urbanization
Fraser et al. 2018	Los Angeles							✓	✓ AR exposure
Jennings 2013	San Diego & Orange		✓	✓					✓ urbanization
Lembeck 1978	San Diego	✓	✓		✓	✓			
Moriarty 2007	Los Angeles & Ventura		✓	✓	✓	✓			✓ urbanization
Moriarty & Riley 2011	Los Angeles & Ventura		✓		✓	✓			
Neale et al. 1998	Mendocino		✓	✓					✓ predation
Neale & Sacks 2001	Mendocino		✓	✓					
Ng et al. 2004	Ventura								✓ roads
Riley et al. 2003	Los Angeles & Ventura		✓	✓		✓			✓ urbanization
Riley et al. 2004	Marin		✓				✓		
Riley et al. 2006a	Los Angeles & Ventura		✓					✓	✓ roads

Source	Location (County)	Population Density	Home Range	Resource Selection/ Food Habits	Reproduction	Mortality/ Survival	Disease	Genetics	Human-Wildlife Conflict
Riley 2006b	Marin		✓	✓					✓ roads
Riley et al. 2007	Los Angeles & Ventura		✓			✓	✓		
Riley et al.2010	Ventura & Orange	✓	✓			✓	✓		✓ urbanization
Ruell et al. 2009	Los Angeles & Ventura	✓							
Schmidt et al. 2023	San Diego	✓	✓	✓					
Serieys et al. 2013	Los Angeles, Ventura, Orange, Contra Costa, & San Diego						✓		
Serieys et al. 2015	Los Angeles & Ventura						✓	✓	✓ urbanization
Serieys et al. 2018	Los Angeles & Ventura						✓		✓ urbanization
Serieys et al. 2021	Santa Clara, San Benito, & Monterey			✓		✓	✓		✓ roads
Smith et al. 2018	San Mateo			✓					
Smith et al. 2020	Los Angeles, Ventura, Orange, San Diego Counties, Golden Gate National Recreation Area, & San Jose							✓	✓ urbanization
Zezulak & Schwab 1980	San Bernardino	✓	✓	✓					

1.1 PROJECT GOALS AND OBJECTIVES

Consistent with FGC § 4158, CDFW established the following goals and objectives for the California Bobcat Project:

GOAL 1: Determine statewide bobcat population density and abundance.

Objective 1.1: Design and implement a bobcat population survey, using fecal DNA, remote camera surveys, and GPS-collar telemetry data, across numerous California ecoregions to better understand bobcat populations statewide.

Objective 1.2: Use the survey data from Objective 1.1 to model how bobcat density varies across different California ecoregions and habitats and better understand interspecies interactions through multi-species occupancy and abundance analysis.

Objective 1.3: Use the spatial density model to generate a robust statewide population estimate as well as estimates for smaller regions of management interest.

GOAL 2: Assess the overall health of the bobcat population in California.

Objective 2.1: Collect survey data using a design that can be periodically replicated to allow assessment of long-term population trends.

Objective 2.2: Collect biological samples to assess disease prevalence, toxicant exposure, and other health risks to bobcats.

Objective 2.3: Collect biological samples to evaluate genetic variation, genetic population structure, and gene flow among bobcats.

GOAL 3: Develop an adaptive conservation and management framework to address stressors on bobcat populations in California.

Objective 3.1: Use the statewide density model developed for Objective 1.2 and ecoregionally specific population estimates, to identify stressors and potential management actions as they pertain to factors such as climate change, catastrophic wildfires, drought, and human-driven habitat loss or fragmentation.

Objective 3.2: Use the results from Objective 1.2 to identify factors affecting survival for guidance of management actions as they pertain to statewide bobcat populations.

Objective 3.3: Develop an adaptive bobcat conservation and management plan, using an ecosystem-based approach, to inform future conservation and management of bobcats, co-occurring species, and their habitats in California.

GOAL 4: Understand the efficacy of nonlethal solutions to mitigate bobcat depredation on domestic animals.

Objective 4.1: Analyze CDFW records of bobcat depredation and other conflict incidents to find patterns and trends related to bobcat depredation.

Objective 4.2: Compile other data and literature to investigate the efficacy of mitigation measures for reducing human-bobcat conflict and negative impacts on domestic animals.

Objective 4.3: Provide guidance and recommendations for nonlethal human-bobcat conflict mitigation solutions.

GOAL 5: Outline guiding principles, strategies, and adaptive management recommendations for the long-term monitoring and conservation of bobcats in California.

Photo by the CDFW Bobcat Project

CHAPTER 2. DATA COLLECTION METHODS

2.1 STUDY AREA SELECTION

California is a large state with many unique vegetation types, ecological features, and significant elevational and climatic diversity. To sample its geographic and ecological diversity, we adopted the ecoregional approach used in California's State Wildlife Action Plan (SWAP; Gonzales et al. 2015). Within the SWAP, ecoregions are defined using a combination of the U.S. Forest Service "*Bailey's Ecoregions and Subregions*" classification (Bailey 2016) and the Watersheds Boundary Dataset used by U.S. Geological Survey. This system divides California into 19 ecoregions based on terrestrial, ecological, and terrain attributes (Figure 1).

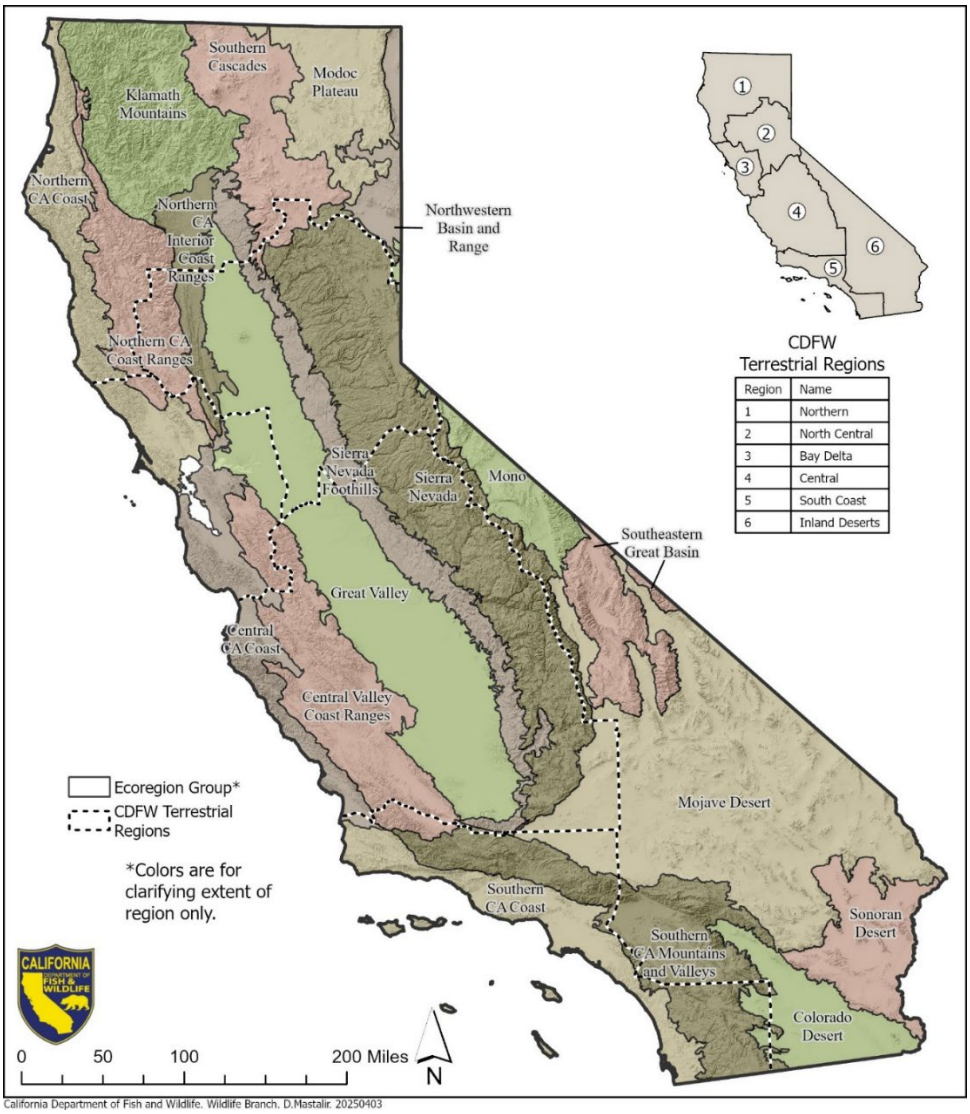

Figure 1. The 19 California ecoregions used to determine study area locations and the six CDFW terrestrial regions.

We selected 48 study areas in California, proportionally distributing them across the 19 ecoregions based on the calculated area of the state each ecoregion encompasses. We formed six regional bobcat teams, comprised of three people, per each of the six CDFW terrestrial administrative regions. Eight study areas were assigned to each regional team to disperse the work evenly (Figure 2 & Table 2) while also distributing study areas proportionally throughout the ecoregions. This number of study areas was chosen to maximize our sample size while allowing time for travel between sites, trapping, and unforeseen delays. Each study area was 40 km^2 and was subdivided into 1 km^2 grid cells. We selected the study area size based on the largest average bobcat home range size from the literature which would allow for recapturing individual bobcats during our capture-recapture surveys (Ruell et al. 2009, Morin et al. 2018, Young et al. 2019, Lombardi et al. 2020, 2022; Bolze et al. 2021, Moreno-Sosa et al. 2022) while also surveying the large amount of environmental variability throughout the state. These 48 study areas were the locations for remote camera stations and fecal DNA surveys. Additionally, bobcat GPS-collar data was collected at 16 select study areas based on where other concurrent study efforts were already ongoing, and feasibility.

To help standardize the process of study area selection, we used a Generalized Random Tessellation Stratified (GRTS; Stevens and Olsen 2004) sample to select 480 cells from a statewide grid, each cell matching the study area size of 40 km^2 (9,884 acres). This gave 10 options for each study area needed, providing some flexibility for regional staff while maintaining some randomness in our procedure. Regional project staff, with local knowledge of suitable land, worked closely with the two lead project coordinators (Rachel Roberts and John Nettles) to choose study areas that were as close to one of these randomly selected cells as possible while maximizing various measures of diversity (elevation, vegetation communities, land ownership) between sites. We selected study areas (Table 2) based on a variety of criteria. Land ownership, terrestrial land cover classification (Figure 3), and survey access were three of the main selection criteria. Vegetation type diversity within the study area was another important factor, with favor given to sites that covered multiple vegetation types. Other factors included elevation, topography, aspect, agricultural use, road and trail access, and human presence. Field work was conducted year-round, although seasonal constraints and property access limitations (e.g., snow, closed roads, etc.) influenced survey times for some study areas.

We conducted a pilot project in November 2020 to test study methods. Outcomes of the pilot project included adjusting camera placement to maximize bobcat detections, improving scat collection protocols, experimenting with photo identification methods, and deciding best practices for data storage and processing. Field teams were established in each CDFW terrestrial region, and by March 2021, at least one study area in each region was being surveyed. Each of the six teams completed surveys in their eight study areas within 15 months, and all the 48 surveys were completed by June 2022.

Code	Name
ABB	Anza Borrego
ANF	Angeles
ASB	Annadel - Sugarloaf - Bothe
BCF	Bristlecone Forest
BOD	Bodie Hills
CACK	Cache Creek
CDCO	Canada - Coe
CGO	Cerro Gordo
CHO	Chorro Creek
CHSP	Chino Hills
CKW	Chuckwalla
CMP	Camp Pendleton
CPER	Chimineas
DG	Devil's Garden
DHSV	Daugherty Hill - Spencevile
FIAB	Fort Irwin
FRES	Fresno
HC	Happy Camp
HJWA	Hallelujah Junction
HVWA	Hope Valley
JF	Jackson State Forest
JLD	Dangermond
JOTR	Joshua Tree
LDSF	Latour
MAM	Mammoth

Code	Name
MCC	McCloud Flats
MOJ	Mojave
OG	Oak Grove
PAN	Panoche
PR	Point Reyes
PW	Peninsula Watershed
RED	Redwoods
SA	Sierra Azul
SBNF	San Bernadino
SC	Summer Camp
SEQ	Sequoia
SHRS	Sagehen
SKE	Skedaddle
SMNF	South Mendocino
SPUR	Spur Ranch
SRWA	Sacramento River
TEHA	Tehama
TL	Trinity Lake
TNC	Tehachapi
TUN	Tungsten Hills
TUO	Tuolumne
UBBW	Upper Butte Basin
WIS	Wishon
YBWA	Yolo Basin

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Figure 2. CDFW Bobcat Population Monitoring Project Study Areas listed alphabetically along with the abbreviated project code name.

Table 2. CDFW Bobcat Population Monitoring Project Study Areas, grouped by ecoregion and listed from west to east, for northern, central, and southern California.

Study Area Name (Abbreviation)	Ecoregion	Elevation Range (Feet)	Dates Studied	Land Ownership
Annadel - Sugarloaf - Bothe (ASB)	Northern California Coast	344 - 2487 ft	09/20/2021 - 11/10/2021	Annadel State Park, Sugarloaf State Park, Bothe State Park (California Department of Parks and Recreation), and Mt. Hood County Park
Jackson State Forest (JF)	Northern California Coast	509 - 1778 ft	08/02/2021 - 09/16/2021	Jackson Demonstration State Forest
Point Reyes (PR)	Northern California Coast	49 - 1135 ft	11/22/2021 - 01/21/2022	Point Reyes National Seashore (National Park Service)
Redwoods (RED)	Northern California Coast	256 - 1644 ft	03/10/2022 - 04/23/2022	Prairie Creek State Park (California Department of Parks and Recreation) and Green Diamond Resource Company
Happy Camp (HC)	Klamath Mountains	1883 - 4537 ft	04/24/2022 - 06/08/2022	Klamath National Forest
Trinity Lake (TL)	Klamath Mountains	2536 - 4472 ft	11/30/2021- 02/16/2022	Shasta-Trinity National Forest and Sierra Pacific Industries
South Mendocino (SMNF)	Northern California Coast Ranges	2369 - 4367 ft	03/28/2022 - 05/16/2022	Mendocino National Forest
Summer Camp (SC)	Northern California Coast Ranges	1693 - 4072 ft	03/28/2022 - 05/17/2022	Private (managed by North Coast Resource Management)
Cache Creek (CACK)	Northern California Interior Coast Ranges	1155 - 2100 ft	02/12/2021 - 04/26/2021	Bureau of Land Management
Latour (LDSF)	Southern Cascades	4590 - 6722 ft	10/11/2021 - 11/24/2021	Latour Demonstration State Forest and Lassen National Forest
McCloud Flats (MCC)	Southern Cascades	3730 - 4062 ft	06/21/2021 - 08/18/2021	Shasta-Trinity National Forests

Study Area Name (Abbreviation)	Ecoregion	Elevation Range (Feet)	Dates Studied	Land Ownership
Devil's Garden (DG)	Modoc Plateau	4908 - 5568 ft	08/23/2021-10/07/2021	Modoc National Forest
Skedaddle (SKE)	Northwestern Basin and Range	4459 - 5341 ft	05/04/2021 - 06/17/2021	Bureau of Land Management
Chorro Creek (CHO)	Central California Coast	118 - 2434 ft	11/22/2021 - 02/24/2022	CDFW Chorro Ecological Reserve and SLO Wildlife Area, El Chorro Regional Park (SLO County), California Polytechnic State University, Los Padres National Forest, and Camp San Luis Obispo (Cal Guard)
Peninsula Watershed (PW)	Central California Coast	289 - 1542 ft	03/10/2021 - 05/06/2021	San Francisco Public Utilities Commission
Sierra Azul (SA)	Central California Coast	817 - 3136 ft	01/24/2022 - 03/16/2022	Mid-Peninsula Open Space Preserve
Canada - Coe (CDCO)	Central California Coast Ranges	1043 - 2336 ft	05/03/2021 - 06/10/2021	CDFW Cañada de los Osos State Ecological Reserve and Henry W. Coe State Park
Chimineas (CPER)	Central California Coast Ranges	2182 - 2986 ft	03/02/2021 - 05/06/2021	CDFW Chimineas Units of CPER
Panoche (PAN)	Central California Coast Ranges	1027 - 2008 ft	02/28/2022 - 04/14/2022	Center for Natural Lands Management
Spur Ranch (SPUR)	Central California Coast Ranges	902 - 1716 ft	04/18/2022 - 06/07/2022	Private
Fresno (FRES)	Great Valley	262 - 387 ft	03/21/2022 – 04/20/2022	County Parks, County Roads, Private
Sacramento River (SRWA)	Great Valley	82 - 151 ft	12/6/2021 - 03/07/22	CDFW, USFWS, TNC, and private property
Upper Butte Basin (UBBW)	Great Valley	59 - 95 ft	03/10/2021 - 05/17/2021	CDFW Upper Butte Basin Wildlife Area

Study Area Name (Abbreviation)	Ecoregion	Elevation Range (Feet)	Dates Studied	Land Ownership
Yolo Bypass (YBWA)	Great Valley	3 - 16 ft	06/14/2021 - 07/29/2021	CDFW Yolo Bypass Wildlife Area
Daugherty Hill – Spenceville (DHSV)	Sierra Nevada Foothills	276 - 1404 ft	01/19/2021 - 04/15/2021	CDFW Donovan Hill Wildlife Area, Quail Valley Wildlife Area, and Spenceville Wildlife Area
Tehachapi (TNC)	Sierra Nevada Foothills	1693 - 3996 ft	05/05/2021 - 06/23/2021	The Nature Conservancy
Tehama (TEHA)	Sierra Nevada Foothills	1716 - 3097 ft	03/10/2021 - 04/29/2021	CDFW Tehama Wildlife Area and Lassen National Forest
Hope Valley (HVWA)	Sierra Nevada	7100 - 9377 ft	06/28/2021 - 10/05/2021	CDFW Hope Valley Wildlife Area and Humboldt-Toiyabe National Forest
Sagehen (SHRS)	Sierra Nevada	6263 - 7674 ft	10/11/2021 - 12/02/2021	Tahoe National Forest
Sequoia (SEQ)	Sierra Nevada	7769 - 8999 ft	06/29/2021 - 08/12/2021	Sequoia National Forest and Golden Trout Wilderness Area
Tuolumne (TUO)	Sierra Nevada	4567 - 5922 ft	10/06/2021 - 11/18/2021	Calaveras Big Trees State Park (California Department of Parks and Recreation), Sierra Pacific Industries, and Stanislaus National Forest
Tungsten Hills (TUN)	Sierra Nevada	4649 - 6401 ft	03/28/2021 - 05/13/2021	Bureau of Land Management and Inyo National Forest
Wishon (WIS)	Sierra Nevada	6699 - 8094 ft	08/17/2021 - 09/29/2021	Sierra National Forest
Bodie Hills (BOD)	Mono	6834 - 8963 ft	10/27/2021 - 12/12/2021	Bureau of Land Management and Humboldt-Toiyabe National Forest
Bristlecone Forest (BCF)	Mono	7139 - 10636 ft	05/17/2021 - 07/01/2021	Inyo National Forest

Study Area Name (Abbreviation)	Ecoregion	Elevation Range (Feet)	Dates Studied	Land Ownership
Hallelujah Junction (HJWA)	Mono	4938 - 5994 ft	04/21/2021 - 06/16/2021	CDFW Hallelujah Junction Wildlife Area
Mammoth (MAM)	Mono	7559 - 8530 ft	07/06/2021 - 08/20/2021	Inyo National Forest
Camp Pendleton (CMP)	Southern California Coast	23 - 472 ft	08/10/2021 - 09/29/2021	United States Marine Base
Dangermond (JLD)	Southern California Coast	233 - 1148 ft	06/08/2021 - 07/28/2021	The Nature Conservancy
Angeles (ANF)	Southern California Mountains and Valleys	5194 - 7477 ft	10/11/2021 - 11/19/2021	Angeles National Forest
Chino Hills (CHSP)	Southern California Mountains and Valleys (M262B)	741 - 1535 ft	02/21/2022 - 04/12/2022	Chino Hills State Park (California Department of Parks and Recreation)
Oak Grove (OG)	Southern California Mountains and Valleys (M262B)	2733 - 4652 ft	01/13/2021 - 03/24/2021	CDFW Oak Grove Unit of the San Felipe Valley Wildlife Area
San Bernardino (SBNF)	Southern California Mountains and Valleys	6188 - 7953 ft	04/26/2022 - 06/14/2022	San Bernardino National Forest
Cerro Gordo (CGO)	Southeastern Great Basin	4921 - 9088 ft	08/23/2021 - 10/19/2021	Bureau of Land Management
Fort Irwin (FIAB)	Mojave Desert	2379 - 3960 ft	11/30/2021 - 02/02/2022	United States Army Base
Joshua Tree (JOTR)	Mojave Desert	4147 - 5049 ft	12/28/2021 - 02/17/2022	Joshua Tree National Park (National Park Service)
Mojave (MOJ)	Mojave Desert	4754 - 5420 ft	04/18/2022 - 06/02/2022	Mojave National Preserve (National Park Service)

Study Area Name (Abbreviation)	Ecoregion	Elevation Range (Feet)	Dates Studied	Land Ownership
Chuckwalla (CKW)	Sonoran Desert	1339 - 2182 ft	02/23/2022 - 04/13/2022	Bureau of Land Management
Anza Borrego (ABB)	Colorado Desert	230 - 696 ft	04/06/2021 - 06/03/2021	Anza-Borrego Desert State Park (California Department of Parks and Recreation)

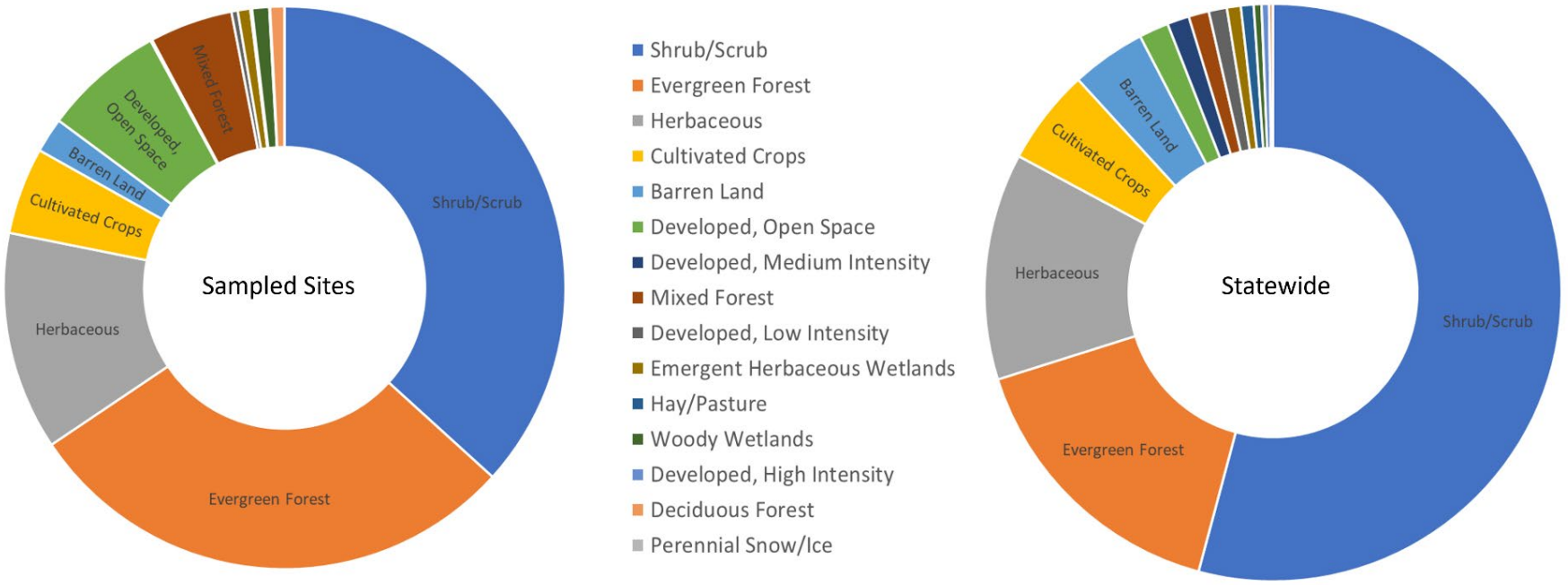

Figure 3. Proportions of terrestrial land cover classes at the statewide and sample wide levels based on the 2019 National Land Cover Database.

2.2 CAMERA SURVEYS

Within each study area, we deployed two paired *RECONYX* HyperFire2 Professional Series cameras (Reconyx Inc., Holmen, WI) within each of the 40 grid cells (80 cameras per study area). We programmed cameras to take a burst of three rapidfire photos when triggered, with no delay between bursts, and set camera sensitivity to the highest level appropriate for the target feature.

Camera stations were placed as close to the center of each grid cell as possible to keep an equidistant spacing throughout the grid (Figure 4). The best location for camera stations was on a smaller unimproved road (< 5 meters across, e.g., logging roads, fire roads, off-highway vehicle [OHV] roads, etc.) or a trail (e.g., hiking, multiuse trail, or game trails, etc.). If a grid center point did not fall on a road or trail, we set up the camera station at a suitable point within 250-meters of the center point (e.g., a road, trail, rocky outcropping, or water source).

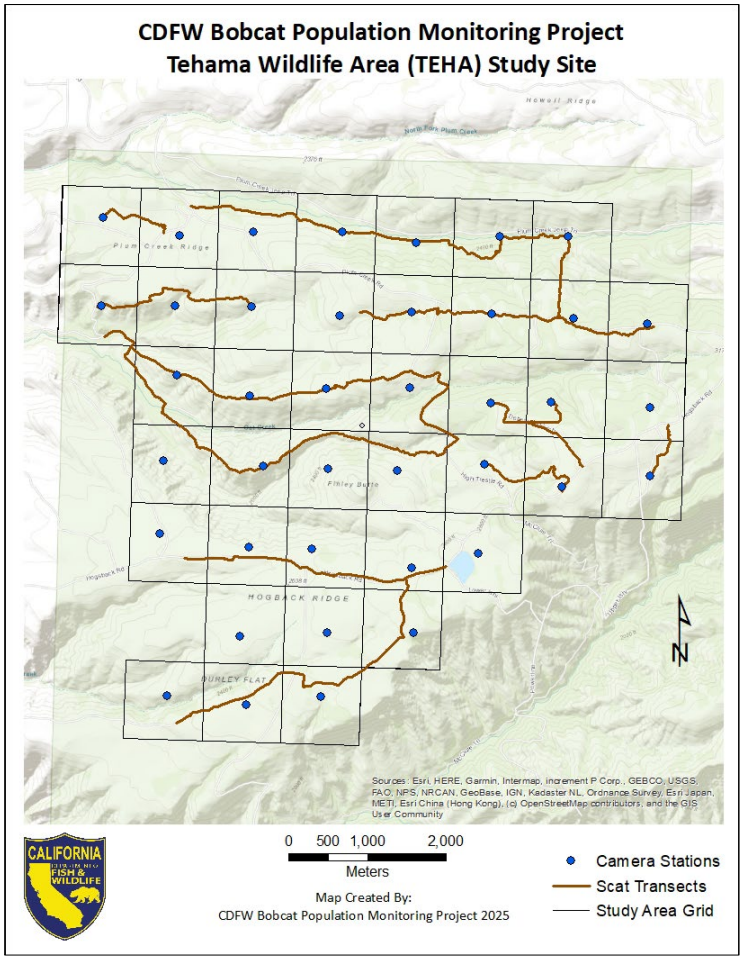

Figure 4. Map of Tehama Wildlife study site, presented here as an example camera grid, camera stations, and transects types used for scat collection.

The paired cameras were set in a perpendicular orientation and on opposite sides of the target feature, (e.g., roads and trails) with the intention of capturing pictures of both sides of a passing bobcat. We staged cameras 3 to 4.5 m (10 to 15 feet) across from each other on either side of the road or trail, with an offset distance of 0.5 to 1 m (2 to 3 feet)to prevent over-exposing photos from the infrared flash of the opposing camera. We mounted cameras 0.2-0.6 m (0.6 to 2 feet) above the ground using an existing structure,such as a tree or fence post, or a t-post. We secured cameras with straps and cable locks, and in areas with black bears cameras were placed inside a protective metal case. We measured and recorded all camera staging details in the field and took a series of test photos to ensure proper camera placement.

At approximately 22% (n=433) of stations, a suitable location for cameras could not be found due to inaccessible terrain, property ownership or land use, or the lack of roads, trails, or a significant land feature within the 250-meter buffer. For these camera stations, we used a scent lure (Caven's Gusto or O'Gorman's Cat Passion, Minnesota Trapline Products, Pennock, MN) to attract wildlife to the site. We applied the lure to a rock or stick between the cameras to keep the lure elevated and off the ground, thus encouraging the animals to stand in front of the camera instead of crouching or rolling on the ground.

Cameras were active within each study area for six weeks and were checked by project staff at least once within that six-week period, as close to the three-week midpoint as possible. The six-week camera deployment period was determined to be long enough to collect the data that we needed per site while also allowing enough time to complete all study areas within the two-year data collection period. During camera checks, we replaced batteries and memory cards as needed, ensured proper camera placement and sensitivity, removed any newly grown vegetation from the camera view, and reapplied lure when applicable.

2.3 SCAT COLLECTION

Within each 40 km^2 study area, we identified 40 km (24.8 mi) of scat survey transects (Figure 4) to attain an approximate sampling effort of 1 km of transects per 1 km^2 of area surveyed. Scat transects were initially identified as roads or hiking trails spaced throughout the study area, then as field staff grew more familiar with study areas features other transects such as game trails where added. Each transect was walked three times during a six-week period (concurrent with the camera survey). To support independence between visits, we completed each visit in as few days as possible and separated visits by approximately two weeks. Scat transects followed dirt roads, hiking trails, game trails, desert washes, or any other feature that wildlife were likely to use to travel through the area. To the extent workable, transects were spatially distributed throughout the study area, with the intent of capturing the variability of available habitat and land uses. However, in some cases, access and terrain limited their distribution. The length of individual transects and total number of transects varied

among sites, but each site held a consistent total length of 40 km. When possible, we selected scat transects near camera stations so scat surveys and camera visits could be completed simultaneously. Scats were also collected opportunistically as project staff traveled throughout the study area. Scats collected off transect or outside of sampling times were not included in capture histories for our density model but were used to determine sampling effectiveness.

Surveyors were given written and visual guidelines and field training on the typical size and characteristics of the scats from native local carnivores. Surveyors investigated each scat they found along the transect and collected a one-inch section of those scats thought to have originated from either a bobcat, coyote, or whose ID was unclear. Scats that were not collected or where only a part was collected were marked with a rock, stick, or toothpick so they would be ignored on the subsequent visit(s). Only new scats were collected on later visits. Transect routes were digitally logged onto a handheld Garmin unit and all scats collected on that transect were marked with a GPS location, assigned a unique ID, and photographed.

Dry scats collected in dry environments were preserved in paper bags, further dried using a food dehydrator, and then stored in plastic bags with silica desiccant beads. Wet scats and all scats collected in moist environments were preserved in sample tube containing molecular biology grade absolute (200 proof) ethanol. DNA extraction and analysis for all samples was conducted by the Wildlife Genetics Research Unit of the CDFW Wildlife Health Laboratory and the Mammalian Ecology and Conservation Unit of the Veterinary Genetics Laboratory at the University of California, Davis (Ahrens et al. 2024).

2.4 BOBCAT CAPTURES AND GPS COLLAR DEPLOYMENT

Between one and eight bobcats were captured and up to six GPS collars were deployed in 16 study areas (Figure 5). A higher number of collars per study area would have been ideal, but limited resources and project timing dictated these results. Study areas in which collars were deployed were selected based on data needs (i.e., areas of the state with no or limited prior bobcat telemetry data) and logistical considerations (i.e., accessible for trapping and monitoring).

In the project planning phase, 60 GPS collars were bought for the whole state, allowing for ten collars to be given to each of the regional bobcat teams. It was planned that more collars would be purchased as needed, although this need did not arise due to the project's focus on camera and fecal DNA data collection. We decided that a maximum of six GPS collars deployed in each study area would produce enough information on the movement and home range, while allowing us to have enough resources to be spread across the state.

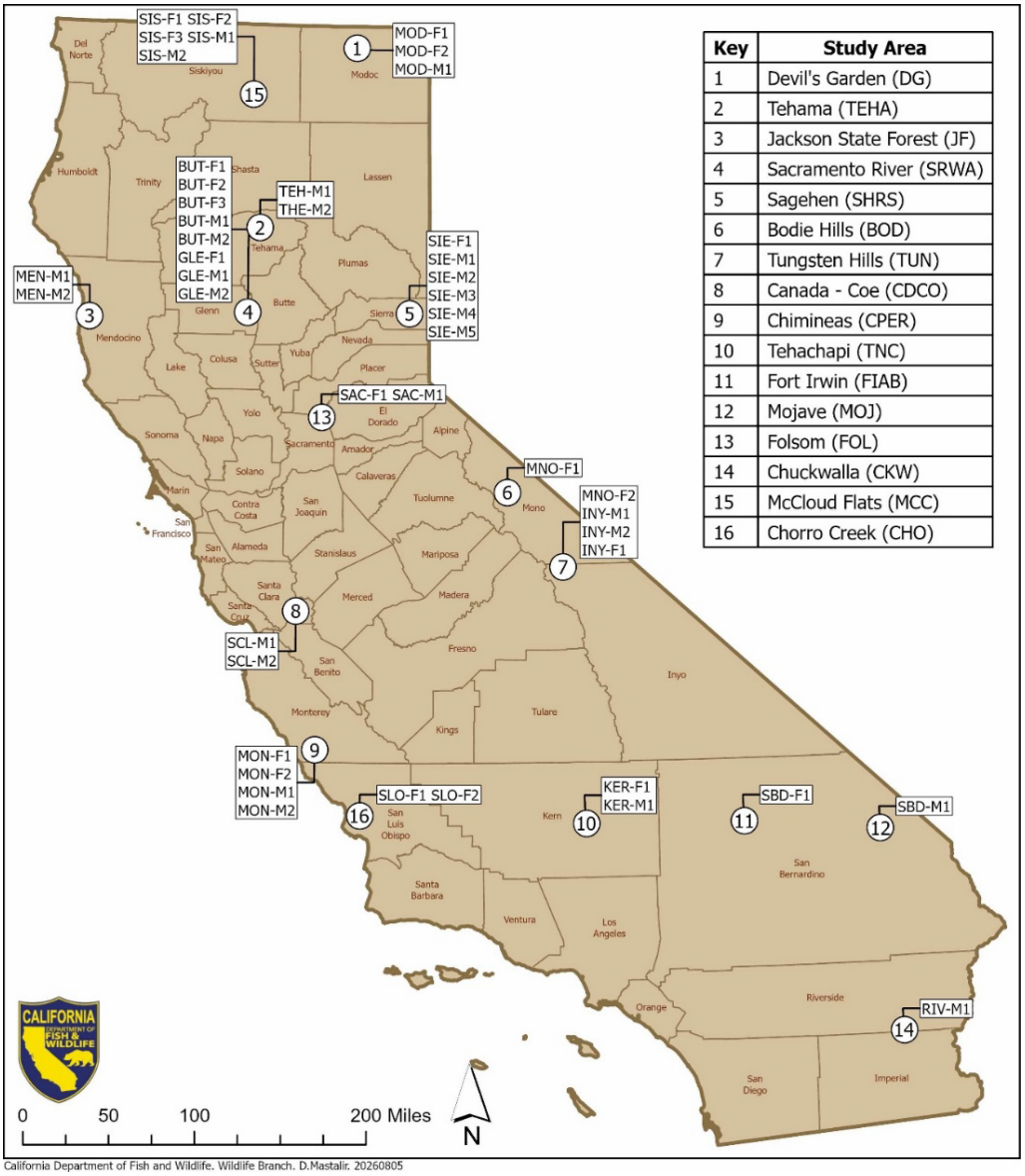

Figure 5. Study area locations where bobcats were captured, and the code name associated with each bobcat collared in that area, between March 2021 and December 2023 as part of the statewide bobcat population monitoring project.

We captured bobcats, either using cage traps (Mercer Lawing, Camtrip Cages) or specially trained hounds. Details of capture methods and procedures can be found in the bobcat capture plan, Appendix A. Cage-trapped bobcats were chemically immobilized by hand injection with Tiletamine/Zolazepam at a dose of 10 mg/kg estimated bodyweight. Hound-captured bobcats were immobilized using a combination of Ketamine (5-7 mg/kg) and Medetomidine (0.08-0.10 mg/kg) administered by pole syringe, blow gun, dart gun, blowpipe, or hand syringe. Atipamezole (0.1 – 0.3 mg/kg) was used to reverse the effects of Medetomidine and speed anesthetic recovery.

Immobilized bobcats were examined for injuries, body condition, ectoparasites, reproductive status, and outward signs of disease. Several biological samples and body measurements were collected from each animal (Appendix A). The samples and body measurements were used to assess bobcat health, disease prevalence, toxicant exposure, and genetic variation. Numbered ear tags were placed in the ear pinna, and photos of the body, the abdomen, and insides of the legs were captured along with photos of any special individual markings, wounds, scars, or capture injuries. The approximate age class of the bobcat was estimated based on overall dentition, tooth size, wear, and gum recession (Section 3.1).

The GPS collars used were Vectronic Aerospace VERTEX Lite Iridium V 1.5 (Vectronics Aerospace GmbH, Berlin, Germany) and Telonics TGW-4270-4 Iridium (Telonics Inc., Mesa, AZ). Vectronic collars weighed between 355 and 360 grams and Telonics collars weighed between 265 and 270 grams. All collars included very high-frequency (VHF) beacon transmitters. We programmed collars to collect a GPS location every three hours. This programming allowed the collars to record data for a minimum of 12 months. Collars included a mortality function that would send a notification if the collar had not moved for 18 hours and they included a drop-off mechanism that could be remotely triggered or activated automatically before the end of the battery life. Initially, bobcats weighing ≥ 6 kg and estimated to be >1 year old were fitted with a GPS collar. Later in the study we increased the bobcat weight threshold to ≥ 7 kg to ensure collar weight did not exceed a maximum of 5% of body weight (Appendix A.).

2.5 DATA MANAGEMENT AND WILDLIFE INSIGHTS

Field data, including information about camera deployment, camera checks and retrieval, scat collection, and trap sets and checks, were captured using the ArcGIS Online (AGOL) platform, Survey123 (v 3.11; Environmental Systems Research Institute (ESRI) 2011b). Statewide project staff used electronic forms to document their work. Location information was collected for each field record through the GPS function on Survey123, and on mapping applications such as CalTopo, or on a handheld Garmin GPS unit.

Camera images were uploaded to Wildlife Insights (http://wildlifeinsights.org), an online platform for storing, organizing, and processing images via machine learning (ML) tools. Wildlife Insights provisionally identified each image as either a particular animal or as a blank photo or misfire (e.g., waving grass). Project staff and volunteers then reviewed and tagged each image correctly by either accepting or revising the automated identification.

2.6 STATEWIDE BOBCAT HEALTH SURVEILLANCE

Bobcat Carcass Submissions. To gain a better understanding of disease, rodenticide exposure, and causes of mortality for bobcats, the California Bobcat Project and the

CDFW Wildlife Health Laboratory (WHL) sent a request to wildlife managers, university affiliates, wildlife rehabilitation centers, zoos, private biological consultants, partner agencies (state and federal agencies, and animal control), and CDFW regional biologists to submit bobcat carcasses for assessment. The timeframe for carcass submission was January 2020 through June 2023. Submitters were asked to complete a submission form, providing any details about how and where the carcass was found. For example, if the animal was found on the side of the road with evidence that it had been hit by a car, those details would have been relayed to the WHL along with the animal's remains.

Postmortem Examination. Postmortem examinations (necropsies) of bobcat carcasses were performed at the WHL or at the California Animal Health and Food Safety Laboratory, University of California Davis (CAHFS) under a contract with the WHL. If carcasses could not be necropsied within 48-hours of collection, they were stored in a -20°C freezer until a necropsy could be performed. Sex, age class, reproductive condition, and body condition (based on assessment of internal fat reserves and muscle condition) were determined. Age class was determined by weight. tooth replacement, dental coloring, and attrition, and defined by the following categories: kitten (< 1 year), yearling or juvenile (1-2 years), and adult (>2 years). Body condition, by the WHL, was assessed on a 1–5 scoring system (body condition score, BCS): 1 (emaciated), 2 (thin), 3 (average/normal), 4 (heavy), and 5 (obese). A detailed systematic external and internal examination of all organs was performed to document any abnormalities (e.g., broken bones, foreign bodies such as bullet fragments, hemorrhage (bleeding), tissue deviations from normal anatomical appearance) that may have caused or contributed to death. The presence of any endoparasites and ectoparasites, along with parasite burden, were noted. When present, the stomach contents were noted and described. If skin and coat changes consistently with mange were observed (e.g., hair thinning and loss, skin coloration change, thickening and crusting), skin scrapings were performed in affected areas to confirm the presence of mites and morphologically identified mite species. All animals were given a mange class score from 0 to 4: 0 (no mange), 1 (up to 25% body infested), 2 (25 to 50% body infested), 3 (more than 50% of body infested), and 4 (recovered due to treatment).

CHAPTER 3. DATA ANALYSIS METHODS

3.1 GENERAL METHODS FOR ANALYSES

This section describes general methods that were used for all analyses unless otherwise noted.

Bobcat age classes were defined as: kitten (< 1 year old), yearling (1-2 years old), and adult (> 2 years old; Anderson and Lovallo 2003).

We defined season as three ecologically relevant categories based on female annual reproductive cycle (Moriarty 2007, Brown 2021): Kitten/Denning-spring, when most bobcats are denning and birthing kittens (March-May); Dry-summer (June-November) also known as late kitten seasons when kittens emerge from the den and eventually learn to hunt on their own; and Wet-winter/Mating (December-February) when bobcats are mating and kittens, or "young of the year" are independent.

All analyses were conducted in R (v. 4.2.0, R Core Team 2021) unless otherwise noted and $p \leq 0.05$ was considered significant. Continuous covariates were standardized to a mean of 0 and a standard deviation of 1 using the scale() function within the *raster* package (v3.6-21; Hijmans 2023). No covariates with a correlation coefficient greater than |0.7| were included in the same candidate model.

3.2 GENOTYPING AND FECAL DNA

Scat samples from the 48 study areas were analyzed using single nucleotide polymorphism (SNP) markers for individual identification (Ahrens et al. 2024). Scat processing was performed in a dedicated trace DNA workspace, where 15-20 mg of scat was aliquoted in a 2 ml tube. DNA extraction was then performed using the Qiagen QIAmp Fast DNA Stool Mini Kit (Valencia, CA). Negative controls were included in extractions to detect potential cross-contamination. We genotyped extracts, using a panel of 96 SNPs designed to identify individual bobcats, determine sex, and differentiate bobcats from common non-target species such as coyote and mountain lion. Extracts were genotyped two times to ensure the validity of the genotype. The SNP panel was designed for the Fluidigm platform and follows the protocol for SNP Type assays with the 96.96 Dynamic Array integrated fluidic circuits (IFC; Standard BioTools, South San Francisco, CA). We used the Fluidigm Juno or Biomark HD for thermocycling and the Biomark HD for fluorescence detection. Negative controls, positive controls of known individuals, and no template controls were included on each IFC. We followed modifications for degraded samples developed to enhance the pre-amplification PCR, similar to those outlined in von Thaden et al. (2020). Genotypes were analyzed using the Fluidigm SNP Genotyping Analysis Software.

Samples with greater than 20% missing loci were removed from the dataset to minimize genotyping error (primarily allelic dropout) associated with low-quality samples (von Thaden et al. 2020). To identify individuals (i.e., matching genotypes), a matrix of pairwise genotype comparisons (specifically, proportions of identical alleles) was calculated and visualized as a frequency distribution. The frequency distributions revealed two modes, the lower of which (e.g., approx. 70% matching alleles) corresponded to distinct individuals and the larger of which (100%) corresponded to genotypes of the same individual. Due to low levels of genotyping error (i.e., false homozygotes), a cutoff of >95% was used to identify two samples as from the same individual. Most comparisons (>99%) were unambiguous, meaning that either <85% of alleles matched, implying distinct (but possibly related) individuals, or >90% of alleles matched, implying same individual (Ahrens et al. 2024). Borderline cases were considered failed.

3.3 CAMERA SURVEYS AND PELAGE ID ANALYSIS

The patterns of spots and stripes on each bobcat are unique to that individual and cameras can thus be used to identify individuals (pelage ID) within a given area (Heilbrun, 2003). A capture history for each bobcat can be created from its detections within a study area and used in a spatial capture-recapture (SCR) model to create an estimate of bobcat density within the study area (Heilbrun 2003, Alonso et al. 2015, Thornton and Pekins, 2015).

Artificial Intelligence (AI) programs, such as Wildlife Insights, use machine learning tools that can identify different animals (Bolger et al. 2012, Crall et al. 2013, Berger-Wolf et al. 2017, Tuia et al. 2022). However, because machine learning to identify the specific spot pattern of bobcats had not yet been well tested when we began our pelage identification analysis, we used manual classification methods (Heilbrun, 2003) for this project.

All bobcat photos taken from a given camera station were grouped into 5 minute "bursts". Bobcat photos within each burst that were of a high enough quality, with a clear image of the bobcat's pelage patterns were then reviewed by the project lead, who was experienced in the pelage identification methods. If a bobcat's identification within a photo burst was unclear to the project lead reviewer, a second researcher would study the photos and make a final determination of the individual's identification (Heilbrun 2003, Negrões et al. 2010, Jacques et al., 2019). Once a bobcat was identified, it was assigned an identification number. Later bursts were either labeled with a previously identified bobcat identification number or, for individuals not seen previously, a new identification number. In most study areas, each individual bobcat was represented in multiple photo bursts, allowing us to identify that individual from photos of both sides of its body. However, if an individual was only identified based on one side of its body, we marked its folder as such and removed those individuals from future analysis, indicating that they could not be identified due to a lack of detections. The

number of unidentifiable one-sided individuals was not large enough for us to consider analyzing them separately.

We considered one bobcat to be different from another only if three distinct natural characteristics were present (Heilbrun 2003; Figure 6). We used both time-stable and time-variable characteristics when identifying individuals. As described by Negrões et al. (2010), time-stable identification characteristics are those features on the body that do not change over time, whereas time-variable characteristics may change over time. Examples of time-stable characteristics that we used for pelage ID include the shape or placement of spots or stripes on the body, legs, tail, or face, a rarely seen extremely short tail, or a kinked tail. Time-variable characteristics included obvious physical abnormalities or scars such as a unique piece of the ear pinna that was missing, a lump on the eye, or the presence and severity of notoedric mange.

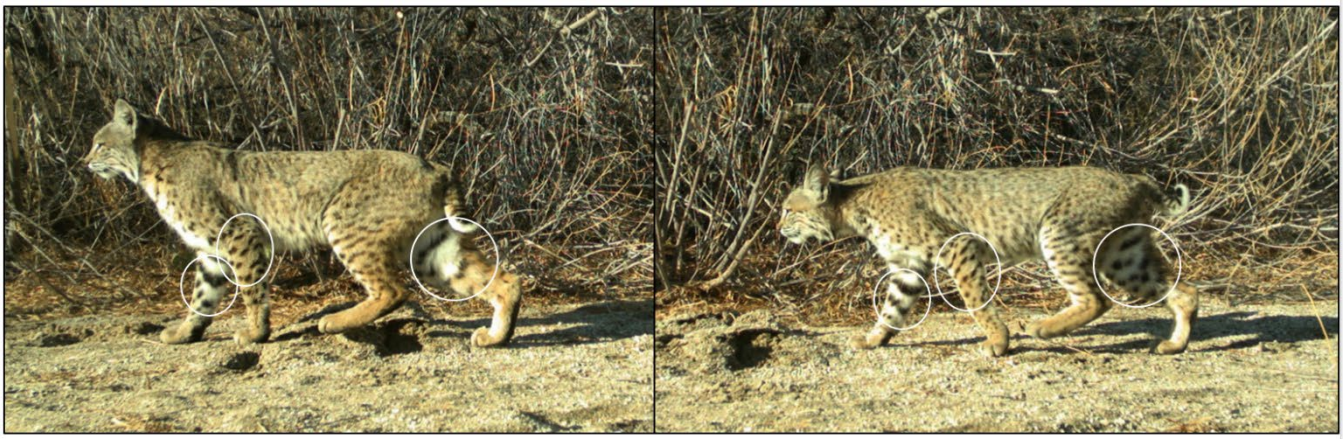

Figure 6. How to tell the difference between two bobcats based on pelage ID. The inside of the front right leg, the outside of the front left leg and the inside of the right hind leg are good areas of the bobcat in which to spot different pelage patterns. These two cats were seen in the same 5-minute burst of photos; the photo on the left was taken 12 seconds before the one on the right.

While the growing bodies and changing pelts of kittens represented time-variable characteristics (Heilbrun 2003), we used those characteristics to identify individuals due to the short duration of our camera surveys (i.e., those characteristics would have changed little during our six-week camera survey). We considered a bobcat to be a kitten if it was less than a year old, as determined by body size, or because it was viewed in photos with another cat assumed to be the mother (Figure 7). When applicable, we also used project-driven markers such as the presence of a GPS-collar or an ear tag to identify individuals (Heilbrun 2003).

Figure 7. Series of photos taken of two smaller bobcats in the background assumed to be kittens and a larger bobcat in the foreground assumed to be the mother cat. Photos taken in Siskiyou County, August 2021; kittens are estimated to be 5 to 6 months old.

Once all bobcats detected within photo bursts from a given study area had been assigned an ID number or marked as unknown, we added each identifiable detection, including the camera number, study area, sampling occasion, and individual ID, to a compiled pelage ID text file. We defined each day as a separate sampling occasion, so in the spatial capture-recapture modeling framework, a capture event was any identified bobcat detected at a given camera station within a 24-hour period. A capture was considered a recapture if the same cat was detected at multiple stations (regardless of occasion) or at the same station on a different sampling occasion. As a result, if an individual cat lingered at a camera station or revisited a camera station within the same 24-hour period, we considered it a single capture event. However, if more than one cat with different ID numbers were detected at the same camera within a 24-hour period, those were considered separate capture events.

3.4 DENSITY MODELING

We developed two spatial capture-recapture (SCR) models (Borchers and Efford 2008, Royle et al. 2013), one for scat using fecal DNA results and one for camera surveys with pelage identification (hereafter "photo") results. To prepare the camera data for density estimation, we created a text file for each study site with the coordinates of each camera station along with the detection covariates of season (see General Methods Section 2.7), lure use, feature type (e.g., game trail, dirt road, recreation trail, etc.), and percent natural habitat (the portion of the study area and surrounding 5km buffer made up of large natural habitat blocks). The resulting text files were combined with the compiled pelage identification results text file (with study area, camera number, individual ID, and sampling occasion), and we used the *secr* package (v4.6.1; Efford 2023) to create site-specific capture histories. The photo model also included two covariates created through the *secr* package; a learned response (*b*) and a site-specific learned response (*bk*) that allowed the probability of a bobcat being detected

at a camera station to change depending on whether the bobcat had previously visited that station. This allows the model to account for individuals potentially returning to camera stations to reinvestigate those stations where scent lure was used (Efford 2023). Lure was used at 22% (n=433) of the camera stations.

To model the fecal DNA results, we mapped the survey features (e.g., game trail, dirt road, recreation trail, etc.) and loaded the GPS tracks for each transect into ArcMap (v10.8.2, ESRI 2011a). If a single transect had multiple feature types, we split each type into its own transect. We then converted the transects into discrete traps with 500-meter segments adjacent to one another to simplify the SCR analyses using the 'discretize' function in the *secr* package. In addition to feature type, we assigned season (dry, wet, and kitten; Section 3.1), percent natural habitat, and the temporal interval between sampling visits as potential detection covariates (Table 3).

In formatting our models, we treated each study site as a separate session within the same model so that a bobcat at one site can't be detected at any other site. This allowed us to incorporate independence between study sites while still producing a single statewide model that incorporated variation across the state. For the camera model, we considered each day a new sampling occasion and marked a camera station inactive for the day only if both cameras at the station were not functioning. For the scat model, we also considered each transect visit as a distinct sampling occasion. We formatted all detectors as 'count' detectors since each could detect multiple uniquely identified individuals during the same occasion and a single individual could also be identified at multiple detectors during the same occasion.

We created a point-based habitat mask, which distinguishes habitat from non-habitat in the modeling space, following the recommendations of Efford (2025) with spacing of 800 meters and buffers around cameras of 2800 meters. We clipped these masks to the California border and removed any major lakes, reservoirs, and highly developed (defined as impervious surfaces account for 80% to 100% of total cover) urban land cover areas (Table 3). We later confirmed the appropriateness of this buffer using the esa.plot() function within the *secr* package. We considered several continuous habitat covariates supplied to the habitat mask as drivers of bobcat density to capture the high level of habitat diversity present throughout the state.

To find the most appropriate detection function, we fit two null models and compared values of Akaike's Information Criterion corrected for small sample sizes (AICc; Burnham and Anderson 1998, Stanley and Burham 1998). Based on the *secr* package documentation (Efford 2023) we chose to use detection functions parameterized in terms of cumulative hazard, as is common for 'count' detectors. The first model used a hazard half normal detection function and the second used a hazard exponential function (Efford 2023).

We did consider sex-specific differences in detection parameters, but it did not have a significant effect or improve the model fit and so did not include it in our models. We believe this was unlikely to bias the results, as we saw a roughly 50/50 split between male and female genotypes, which resembles sex ratios observed in previous studies from across the United States (e.g., Allen et al. 2020, Crowe 1975a, Fox 1990, Landry 2017). We fit several *a priori* candidate models focused either only on detection parameters or on density parameters. Given the considerable number of covariates included in the density models, we conducted a two-stage selection approach. Specifically, we first grouped the habitat covariates thematically into precipitation, anthropogenic disturbance, vegetation, and topographic variables. We then separately tested combinations of variables in each group using AICc and arrived at three separate top models in stage one. In stage two, we tested combinations of the variables from the separate top models, dropping variables when it improved AICc, to find the most supported overall model (Bidder et al. 2023).

For extrapolation statewide and to provide a confidence interval for our estimate, we used a bootstrapping procedure with our fecal DNA model to predict density in unsampled areas while accounting for associated uncertainties and the covariance structure of the model coefficients. Specifically, we selected an additional 48 extrapolation sites from our statewide habitat mask (to match the 48 sites where we collected the data that was used to fit the model). We then drew random samples from the covariate coefficient values using a multivariate normal distribution to account for their covariance and calculated the predicted density at each from those values. We repeated this process (starting with selecting 48 extrapolation sites) 10,000 times to create a distribution of predicted density statewide from which to derive our mean and 90% confidence intervals for the statewide population size.

Through our modeling process we determined that the SCR results of the density model based on the photo data had some complications and produced different results from the fecal DNA based density model. Photo SCR results seemed to indicate that there were fewer bobcats in most of the study areas than the fecal DNA SCR results suggested. The photo SCR results also indicated that bobcats were traveling farther distances across their home ranges then were detected with the scat SCR and they were being detected at camera stations that were widely spaced out. Due to the somewhat subjective, and difficult, nature of the pelage ID process compared to the more definitive identification based on DNA, we believe the fecal DNA model to be stronger than the photo model. All of this indicated possible flaws with the photo methodology and results, such as misidentifying individuals, and the resulting model for this source of data was put on hold until refinements could be made to the pelage ID or modeling process (see Discussion Section 5.3).

Lastly, we calculated the average bobcat density of each ecoregion and study area by cropping the density map from our fecal DNA SCR model and using the zonal statistics function in ArcGIS (v10.8.2, ESRI 2011a). We then multiplied the average density

by the area of each ecoregion and study area to estimate population size for these respective portions of the state.

Table 3. List of covariates used for SCR= Spatial capture recapture model, Occu= occupancy model, RSF= resource selection function, Temporal= temporal analysis, description and source.

Covariate	Use	Model(S)	Description	Source
b	Detection	SCR	Learned response	Secr package
bk	Detection	SCR	Site-specific learned response	Secr package
Feature Type	Detection, lambda	SCR	Game trail, recreation trail, dirt road, wash, or other	Project staff
Interval	Detection, lambda	SCR	Average time between transect visits at a particular study site	Project staff
Season	Detection, sigma and lambda,	SCR	The biological season the data collection took place. Wet: Dec-Feb, Kitten: Mar-May, Dry: June-Nov	Project Staff
	Covariate	RSF Temporal		
Cat ID	Grouping Factor	RSF	Unique ID given to each collared bobcat.	Project Staff
Sex	Covariate	RSF	Sex (male or female) of each collared bobcat.	Project Staff
Ecoregion	Covariate	SCR Temporal	Ecoregion classification (SECTION NAME) at the point location.	USDA Ecoregions (CDFW GIS Library)
Elevation	Covariate	SCR Occu RSF	Measured on a 30-m grid. Included both linear and quadratic effects.	CDFW GIS Library
Precipitation	Covariate	SCR Occu RSF	30-year normal for average annual precipitation on an 800m grid for SCR and RSF. Daily value averaged over 1 week for occu.	PRISM Climate Group
Maximum Daily Temperature	Covariate	SCR Occu RSF	30-year normal for average annual maximum temperature on an 800m grid for SCR and RSF. Daily value averaged over 1 week for Occu.	PRISM Climate Group

Covariate	Use	Model(S)	Description	Source
Connectivity	Covariate	SCR	Mean connectivity rank (1-5) within 800-m buffer.	Terrestrial Connectivity (BIOS ds2734)
Drought	Covariate	SCR Occu RSF	Index of atmospheric thirst based on NOAA meteorological data; aggregated across 5 years leading up to conclusion of data collection (July 2017-July 2022). Measured at 4km scale.	Evaporative Demand Drought Index (EDDI; Hobbins et al. 2016, McEvoy et al. 2016); GridMET-4km-Pentad. Accessed via Climate Engine (2023)
NDVI	Covariate	SCR Occu RSF	Remote sensing measure of vegetative health, averaged across 18-month sampling period. Included both linear and quadratic effects.	Normalized Difference Vegetation Index; Landsat 5/7/8/9 Surface Reflectance; courtesy of USGS. Accessed via Climate Engine (2023)
Wildfire	Covariate	SCR Occu RSF	Remotely sensed raster of burn severity across 2020 and 2021, the 2 years preceding this project. Severity= "Degree to which a site has been altered or disrupted by fire; loosely, a product of fire intensity and residence time"	Monitoring Trends in Burn Severity Program (MTBS 2021)
Habitat Variation	Covariate	SCR Occu	Shannon Diversity Index of WHR classification (LIFEFORM) within 800-m buffered area.	CAL FIRE FRAP (fVeg)
Percent Conifer	Covariate	SCR Occu Temporal	Proportion of 30-m pixels within 800-m (SCR) or 500-m (Occu) buffer area classified as conifer habitat.	CAL FIRE FRAP (fVeg)

Covariate	Use	Model(S)	Description	Source
Percent Hardwood	Covariate	SCR Occu Temporal	Proportion of 30-m pixels within 800-m (SCR) or 500-m (Occu) buffer area classified as hardwood habitat.	CAL FIRE FRAP (fVeg)
Percent Shrub	Covariate	SCR Occu Temporal	Proportion of 30-m pixels within 800-m (SCR) or 500-m (Occu)buffer area classified as shrub habitat.	CAL FIRE FRAP (fVeg)
Percent Herbaceous	Covariate	SCR Occu Temporal	Proportion of 30-m pixels within 800-m (SCR) or 500-m (Occu) buffer area classified as herbaceous habitat.	CAL FIRE FRAP (fVeg)
Percent Agriculture	Covariate	SCR Occu Temporal	Proportion of 30-m pixels within 800-m (SCR) or 500-m (Occu) buffer area classified as agriculture land.	CAL FIRE FRAP (fVeg)
Percent Urban	Covariate	Occu	Proportion of 30-m pixels within 500-m buffer area classified as urban landscape.	CAL FIRE FRAP (fVeg)
Percent Developed	Covariate	SCR	Proportion of 30-m pixels within 800-m buffer area classified as developed, high intensity (category 24 – impervious surfaces account for 80% to 100% of total cover).	USGS NLCD
Percent Natural Habitat	Covariate	SCR	Proportion of the study area and surrounding 5 km buffer made up of large natural habitat blocks. Included linear effect for lambda (detection likely more difficult in modified habitats), quadratic effect for sigma (movement likely maximized at moderate levels of natural habitat).	Conservation Biology Institute. Accessed via CDFW's Biogeographic Information and Observation System (Spencer et al. 2017)
Percent Desert	Covariate	SCR Occu Temporal	Proportion of 30-m pixels within 800-m (SCR) or 500-m (Occu) buffer area classified as desert habitat.	CAL FIRE FRAP (fVeg)

Covariate	Use	Model(S)	Description	Source
Percent Barren/Other	Covariate	SCR Occu Temporal	Proportion of 30-m pixels within 800-m (SCR) or 500-m (Occu) buffer area classified as bare ground.	CAL FIRE FRAP (fVeg)
Percent Water	Covariate	SCR Occu	Proportion of 30-m pixels within 800-m (SCR) or 500-m (Occu) buffer area classified as water.	LANDFIRE 2020
River Distance	Covariate	RSF	Distance to the nearest major river or creek	USGS National Hydrography Dataset; Major Rivers and Creeks
Road Distance	Covariate	RSF	Distance to the nearest secondary road	TIGER database from US Census
Conifer Distance	Covariate	RSF	Distance to nearest patch of conifer trees, based on WHR habitat classifications. Measured on 30-m scale	CAL FIRE FRAP (fVeg)
Hardwood Distance	Covariate	RSF	Distance to nearest patch of hardwood trees, based on WHR habitat classifications. Measured on 30-m scale	CAL FIRE FRAP (fVeg)
Shrub Distance	Covariate	RSF	Distance to nearest patch of shrub, based on WHR habitat classifications. Measured on 30-m scale	CAL FIRE FRAP (fVeg)
Herbaceous Distance	Covariate	RSF	Distance to nearest patch of herbaceous, based on WHR habitat classifications. Measured on 30-m scale	CAL FIRE FRAP (fVeg)
Agriculture Distance	Covariate	RSF	Distance to nearest agricultural field, based on WHR habitat classifications. Measured on 30-m scale	CAL FIRE FRAP (fVeg)
Urban Distance	Covariate	RSF	Distance to nearest urban area, based on WHR habitat classifications. Measured on 30-m scale	CAL FIRE FRAP (fVeg)

Covariate	Use	Model(S)	Description	Source
Desert Distance	Covariate	RSF	Distance to nearest patch of desert, based on WHR habitat classifications. Measured on 30-m scale	CAL FIRE FRAP (fVeg)
Barren/Other Distance	Covariate	RSF	Distance to nearest bare patch, based on WHR habitat classifications. Measured on 30-m scale	CAL FIRE FRAP (fVeg)
Aspect	Covariate	RSF	Measured on a 30 m grid, from elevation layer. Included both linear and quadratic effects.	CAL FIRE FRAP (fVeg)
Terrain Ruggedness Index	Covariate	RSF	Percent difference in elevation between each pixel and all neighboring pixels (averaged over 800m buffer)	CAL FIRE FRAP (fVeg)

3.5 OCCUPANCY ANALYSIS

We analyzed the occupancy of various wildlife species (Table 4) at the camera station level. We considered one target wildlife photo at either camera, from a given station, to be one detection. Because carnivores generally have low detection rates and require longer capture occasions to avoid underestimating their occupancy (Lesmeister et al. 2015), we used a one-week capture occasion, recording a single detection if the target species was detected at least once within each seven-day period and a non-detection otherwise. For each capture occasion we identified all species detected. To understand how bobcats interacted with other species we focused our analysis on bobcats, their potential competitors, disturbance species (species that tend to disturb the area or the camera; human, domestic cattle, and wild pig), and their potential prey. Table 4 lists these species and groups. To ensure all camera stations were comparable we used exactly 6 weeks of data from each station, removing cameras with less than 6 weeks of data and truncating data from cameras with more than 6 weeks. This period is short enough to allow for the necessary assumption of a closed population (MacKenzie et al. 2002). Two study areas had less than 6 weeks of data resulting in 46 of the 48 study areas being included in the occupancy analysis.

For each species group we ran a single season, single species occupancy model (MacKenzie et al. 2002) in the *unmarked* package (v. 1.4.1; Fiske and Chandler 2011) to determine which landscape variables affected their occupancy and which climate variables affected their detection. We used a backwards stepwise approach to remove the covariate with the highest p-value until only significant covariates remained. We then carried those significant covariates forward to a single season, two species

occupancy model (Rota et al. 2016) for bobcat and each of the competitor, disturbance, and prey species. Our primary interest for this analysis was the interactions between species, as we had already measured habitat selection in both the density and resource selection analyses, so the landscape covariates were used only to account for variation in the models. We did not add covariates for the interaction so as to not overburden the model. We used these two species models to determine if and how bobcat occupancy was potentially influenced by other species.

Table 4. Type of species, groupings, and the species that were included in those groups for occupancy analysis.

Type	Group Name	What Species are included
Competitor	Mountain Lion	*Puma concolor*
	Black Bear	*Ursus americanus*
	Coyote	*Canis latrans*
	Gray Fox	*Urocyon cinereoargenteus*
Disturbance Species	Domestic Cattle	*Bos taurus*
	Human	*Homo sapiens*, not in vehicle, on horse, or researchers
	Wild Pig	*Sus scrofa*
Prey	Skunk	Mephitidae
	Small Mustelid	Mustelidae, not badgers or otters (primarily long-tailed weasel, marten, or fisher)
	Wild Turkey	*Meleagris gallopavo*
	Quail and Pheasant	Galliformes, not Turkeys
	Squirrel	Sciuridae
	Rabbit	Lagomorpha
	Small Rodent	Rodentia and Soricidae, not Sciuridae
	Small Bird	Passeriformes, Columbiformes, Piciformes

We measured landscape variables (Table 3) including elevation, Normalized Difference Vegetation Index (NDVI), drought as Evaporative Demand Drought Index (EDDI), wildfire severity, habitat diversity, and the percent cover (hardwood, shrub, herbaceous, barren, agriculture, urban, and water, each as separate variables) within a 500-meter buffer around each camera station. Climate variables (Table 3) included drought, maximum daily temperature, and precipitation (National Oceanic and Atmospheric Administration; www.ncdc.noaa.gov) averaged over the one-week capture occasion for each study area. Variables were the same as those in the scat SCR model except for a few that were excluded from the occupancy model so as not to overburden the model (Table 3). Not all cameras were set at the same time of year, but we tested for a seasonal difference in occupancy in each single species model and found no statistically significant effect for any species, so it is unlikely this has an effect on our statewide results. It is possible that seasons affect species' occupancy on more local scales.

3.6 TEMPORAL ACTIVITY ANALYSIS

We compared the temporal activity of bobcats with the same competitor, disturbance, and prey species, as in the occupancy analysis, using the *Activity* package (v. 1.3.4; Rowcliffe, 2021). We converted the time stamp of each detection at a camera station to radian solar time and fit a kernel density to that for each species to create a distribution of their activity over a 24-hour period (Ridout and Linkie 2009). We then compared this distribution for bobcats to that of the other species and measured overlap using the compareCkern function. This function creates a null distribution by randomly sampling from the observed data and then compares the null and observed distributions to determine if the observed distributions were likely to have happened by chance (i.e., is there a pattern to the observed overlap in activity or is it random as in the null hypothesis). This also generates a $Dhat_4$ value of overlap where 0 is no overlap and 1 is total overlap between the activity of two species.

We then assessed the potential effect of prey and competitor species relative abundance on the daytime activity patterns of bobcats at the camera level using linear regressions. While this is a simplified analysis, our goal was to characterize general patterns and not to make predictions. Based on our temporal analysis, bobcats were more often active at night, between the hours of 17:00 and 06:00. This led us to consider that an increase in daytime activity suggests a potential change in behavior. We therefore focused our analysis on daytime activity between the hours of 05:00 and 17:00, to determine what factors may affect (i.e., cause a change in) bobcat temporal activity. A high abundance of sympatric carnivores may cause bobcats to shift their temporal activity to avoid competition or intraguild predation. In such a scenario, and where other carnivores are more active during nighttime hours, bobcats could be more active during daytime hours, limiting their temporal overlap with common prey species activity. To estimate daytime activity patterns of bobcats, other carnivores, and potential prey, we calculated the proportion of photos that were captured between

the hours of 05:00 and 17:00. Because lures were suspected to heavily influence the amount of time an individual spent in view of the camera, we excluded camera stations (n=433) with lures from our analysis.

For a simple indicator of relative abundance of competitor (coyote, mountain lion, gray fox) and prey species (Leporidae, Sciuridae, Rodentia-all rodent except Sciuridae) we calculated the average number of days each species was detected per camera station (Table 5). While not true abundance, this does provide an estimate of how active a species is in an area which is likely to influence bobcat behavior. To allow for direct comparison, we included exactly six weeks of data from each camera and removed any cameras that had less. We refer to this as our relative abundance index. We log-transformed the relative abundance index to reduce skewness. We also included land cover, season, and ecoregion covariates from our density analysis (Table 3) as well as interaction terms, such as Leporidae-Sciuridae and coyote-gray fox. We fit candidate models with various combinations of our covariates and examined residual plots to assess model fit. When necessary, we removed outliers from the data and refitted the model.

Photo by the CDFW Bobcat Project

Table 5. Bobcat day use [a] and species activity levels [b] across land cover types. Excludes the two outlier sites from the activity level analysis.

	# of Sites	# Bobcat Photos	Day Use[a] (%)	Night Use (%)	Relative Abundance[b]					
					Bobcat	Gray Fox	Coyote	Rodent	Sciuridae	Leporidae
Barren Land	1	18	0	100	0.03	0.28	1.15	3.48	1.68	5.30
Cultivated Crops	1	515	20.97	79.03	1.63	0.00	0.73	0.10	2.34	8.51
Developed, Open Space	2	213	21.13	78.87	0.43	1.29	5.49	2.50	3.73	3.25
Evergreen Forest	12	2641	60.05[1]	39.95[1]	0.67[1]	2.56	0.79	2.11[1]	11.68[1]	1.91[1]
Herbaceous	5	2847	17.39[2]	82.61[2]	1.76	0.08	3.70	6.65[2]	4.56	8.78[2]
Mixed Forest	3	6966	35.01	64.99	3.67[2]	5.14	0.52	2.28	3.99	2.53
Shrub/Scrub	19	8959	30.68[2]	69.32[2]	1.77	2.56	2.48	4.87	3.57[2]	6.75[2]

Superscripts represent statistical differences ($p < 0.05$) across land cover types, using Tukey's HSD. Within each column, ones and twos are significantly different from each other but not from others of the same number. For example, day use is significantly higher in evergreen forests than in herbaceous and shrub/scrub habitats but there is no difference between shrub/scrub and herbaceous. All other differences were not significant.

[a] Day use was defined as the proportion of photos taken between the hours of 05:00 and 17:00.

[b] Relative Abundance represents the average number of days per camera station that that species was detected.

3.7 GPS COLLAR DEPLOYMENT, HOME RANGE, AND MOVEMENT ANALYSIS

GPS Collar Deployment. We set the GPS collars to store two-thirds of the location data onboard the collar to extend battery life, which caused the need for retrieval of collars from the field, either after the animal died or after the collar was given a drop-off command. Drop-off commands were only sent to collars that had been deployed for over 365 days, and functional collars remained deployed on study animals for as long as possible. After collar retrieval, we filtered location data to remove any erroneous data points, and locations that were attained with fewer than three satellites or had a Dilution or Precision (DOP) value more than 10 (Lewis et al. 2007).

Home Range. We analyzed collar locations with the *adehabitatHR* package (Calenge 2024) to find home range size using an adaptive Local Convex Hull (LoCoH) estimator. The LoCoH estimator calculates minimum convex polygons for each used point based on a pre-defined distance parameter and as a result, can account for hard boundaries such as lakes, highways, and cliffs (Getz et al. 2007). We used LoCoH instead of Kernel Density Estimation because the latter can overestimate home range (Lichti and Swihart 2011, Chirima and Owen-Smith 2017). The adaptive LoCoH maximizes the number of included points within a specified total distance (*a*) from the reference point. We calculated 50%, 95%, and 99% LoCoH home range estimates at *a* value from 1-15 km. To find the most appropriate *a* value and home range percentage, we examined the resulting plots and trends in area estimates. An *a* value of 14 km visually depicted use well and allowed for a plateau in area estimations while limiting incidental coverage of unused areas and the inclusion of superfluous holes. We analyzed seasonal changes in home range size for male and female bobcats that were collared for over 365 days to ensure that all seasons were represented in the full dataset.

We calculated a Pearson correlation coefficient for point estimates of three different combinations, 1) elevation and home range size (99% LoCoH), 2) elevation and density, and 3) density and home range size (99% LoCoH) to compare the relationships between bobcat density, home range, and elevation. The bobcat density estimates that we calculated per study area, as described in Section 3.4 above, where used here for each area where GPS collars had been deployed.

Movements. We used ArcMap's *Field Calculator* tool to calculate the distances between the coordinates of the eight locations each day collected by the GPS collars. We then used the *Dissolve* tool to sum the distances between each consecutive pair of points and calculated the statistics on the sum of distances for each day. This sum serves as an absolute minimum estimate of distance traveled by bobcats each day since it does not account for any movements that were made between the recorded locations.

3.8 RESOURCE SELECTION FUNCTION AND PERCENT LAND COVER USE ANALYSIS

Once telemetry data had been cleaned (as described above), we used the *adehabitatHR* package to calculate 100% minimum convex polygon (MCP) home ranges for each individual. We defined the resulting polygons as 'available' habitat for third-order selection (selection within a home range; Johnson 1980) by a bobcat. To minimize spatial autocorrelation between collar GPS points, hereafter referred to as 'used' points, we randomly thinned the data, keeping 25% of each individual's locations, approximately two locations per day (Royle et al. 2013; Schmidt et al. 2023). We did not thin the data further so that we did not lose too much statistical power. For every remaining location, we then randomly sampled an additional 10 'available' locations within the MCP (Schmidt et al. 2023). We used the *lme4* package (Bates et al. 2015) to develop binomial generalized linear mixed effects (GLME) models to estimate the relative probability of use given various fixed and random effects. The inclusion of random effects can help account for unbalanced sample sizes, variation in selection among individuals, and variation in selection based on availability (i.e., functional response; Gillies et al. 2006). Given our sample size of 30 collared individuals, we only included one random intercept, Cat ID, and no random slopes in our models and carried out our model selection in one step. We compared *a priori* models with fixed effects of habitat variables and their interactions with sex and season (Table 3) using AICc. The fixed effects included proximity to landcover types—0 means the point is in that habitat— as this better allowed us to identify edge use without having to add another variable to an already complex model and reduced misclassification from GPS error (Conner et al. 2005). The model with the lowest AICc value was selected as our final model. Model averaging was not necessary as our top model carried 100% of the weight. To confirm our model fit, we ran the final model using four additional random samples of available points, checking for consistency among the resulting coefficients.

To further explore how much time bobcats were spending in the different landcover types we calculated the percentage of GPS points found each of the landcovers available in each collared bobcat's home range. We used the California Department of Forestry and Fire Protection land cover dataset (CAL FIRE FRAP (fVeg); Table 3) that includes the following landcover types: Agriculture, Barren/Other, Conifer, Desert, Hardwood, Herbaceous, Shrub, Urban, Water, and Wetland.

3.9 SURVIVAL AND FACTORS EFFECTING SURVIVAL

Survival models are a class of time-to-event models and determine the probability an event (e.g., death of an individual) happens before or at a certain time (*T;* Cox and Oakes, 1984*)*. The Cox proportional hazard model uses the duration of time between when animals are collared and when they meet their fates to estimate mortality probability; survival probability is then derived (1 – mortality probability). Animal fates

can be varied (e.g., dropped collar or predation) but are categorized into two groups: deaths (1) and censored (0), with an animal considered censored when we know it doesn't die before or at the time we are no longer able to track it. In summary, survival models require three pieces of information: the date the animal was first collared, the date the animal met its "fate", and the fate of the animal.

We created a data point (hereafter, bobcat-year) for each biological year a unique individual was monitored. Because recruitment of new individuals into the population requires bobcats to survive until they give birth, we designated the start of the biological year as August 1st, and the end as July 31st. As an example, Bobcat A is first collared on March 31st, 2018, and dies on October 20th, 2018: Bobcat A would have two data points corresponding to 2017 and 2018.

Because survival models require a first capture date, a "fate" date, and a fate, we removed bobcats with no first capture date, no fate date, and no known fate. Three individuals with an unrecorded fate were determined to have a last observed date where they were noted to be alive; thus, we created a new fate date equal to this last observed date and marked their fate as 'censored'. The dataset included 32 bobcats that were collared for statewide effort with the California Bobcat Project between 2021 and 2023 and were comprised of 11 females and 21 males (Table 6).

Table 6. Summary of collared individuals included in Bayesian survival analyses to estimate bobcat annual survival. Number in parentheses represents bobcat-years, the sum of the number of biological years each individual was monitored, measured from August 1- July 31.

	Number of individuals (bobcat-years)
TOTAL	32 (63)
Females	11 (22)
Males	21 (41)
Region 1	5 (12)
Region 2	13 (22)
Region 3	3 (6)
Region 4	5 (10)
Region 5	1 (2)
Region 6	5 (11)

We ran Bayesian Cox proportional hazard models using code modified from Eacker et al. (2022) using Nimble (De Valpine et al. 2017) to derive overall bobcat survival. See Eacker et al. (2022) for a more detailed description of the model, prior specifications, and how we assessed model convergence.

In brief, we first ran a model including individual ID, sex, CDFW region, area of capture, and biological year as covariates. Because none of these covariates came out as important—i.e., 90% credible intervals (CIs) overlapped zero—we ran a final model with only individual ID as a covariate.

3.10 STATEWIDE HEALTH SURVEILLANCE

Diagnostic Testing. In addition to gross necropsy, mortality investigations included microscopic evaluation of tissues (histology) when available, and focused pathogen and toxicology testing (Table 7). Samples from all major tissues were collected, placed in 10% buffered formalin, and submitted to the CAHFS Lab. At the CAHFS Lab the tissues were trimmed, embedded in paraffin, thinly sectioned, and stained with hematoxylin and eosin for histopathological evaluation by a veterinary pathologist. Representative tissue samples, heart or chest blood, and swab samples from the rectum, nasal cavity, conjunctiva (under eyelid), and oropharynx were archived in -80C° freezers to be available for additional testing if indicated based on histology results. When present, blood collected from the heart or chest cavity (if heart blood was not available) was tested for feline leukemia virus (FeLV) antigen and feline immunodeficiency virus (FIV) antibodies using the Witness® in house Rapid test kit (Zoetis, Parsippany, New Jersey, USA). For carcasses where the brain was present and in suitable post-mortem condition, rabies virus direct fluorescent antibody (DFA) testing was performed by the Viral and Rickettsial Disease Laboratory of the California Department of Public Health. Additional disease testing (i.e., polymerase chain reaction, immunohistochemistry assays) was performed as needed to achieve a final diagnosis, determine the species of a pathogen, or attempt to determine what pathogen was associated with tissue changes.

Carcasses in advanced stages of decomposition were necropsied, however, tissues were not collected or submitted for histology because autolysis obscures and destroys microscopic lesions. In these cases, tissue samples were collected for toxicology testing, but changes in tissues that could indicate disease processes or toxicoses were not able to be determined.

Table 7. Summary of bobcat health and disease surveillance conducted by CDFW 2020-2023 based on testing of 128 individual bobcat carcasses from across California. This data does not include the 10 collared bobcats.

Disease	Number of Carcasses Tested	Percentage of Carcasses Positive	Reason for Surveillance
Viral Diseases			
Feline leukemia virus	94	0%	Potential wildlife epidemic
Feline immunodeficiency virus	94	1%	Domestic animal health concern
Rabies virus	43	2%	Human health concern
Highly pathogenic avian influenza	3	0%	Potential wildlife epidemic and human health concern
Bacteria			
Leptospirosis	49	2%	Wildlife health concern
Parasitic Diseases			
Notoedric mange	118	30%	Wildlife health concern
Heartworm disease	83	1%	Wildlife health concern
Rodenticide Exposure			
Brodifacoum	119	58%	Wildlife health concern
Bromadiolone	119	60%	Wildlife health concern
Chlorophacinone	119	22%	Wildlife health concern
Difethialone	119	26%	Wildlife health concern
Diphacinone	119	66%	Wildlife health concern
Warfarin	119	1%	Wildlife health concern
Bromethalin	98	11%	Wildlife health concern

Testing for Rodenticides. All toxicology testing was performed at the CAHFS Laboratory. Liver samples from necropsied carcasses were submitted for testing of eight anticoagulant rodenticides (ARs) belonging to two groups: the first-generation anticoagulant rodenticides (FGAR) warfarin, coumachlor, diphacinone, and chlorophacinone, and the second-generation anticoagulant rodenticides (SGAR) brodifacoum, bromadiolone, difenacoum, and difethialone (Figure 8).

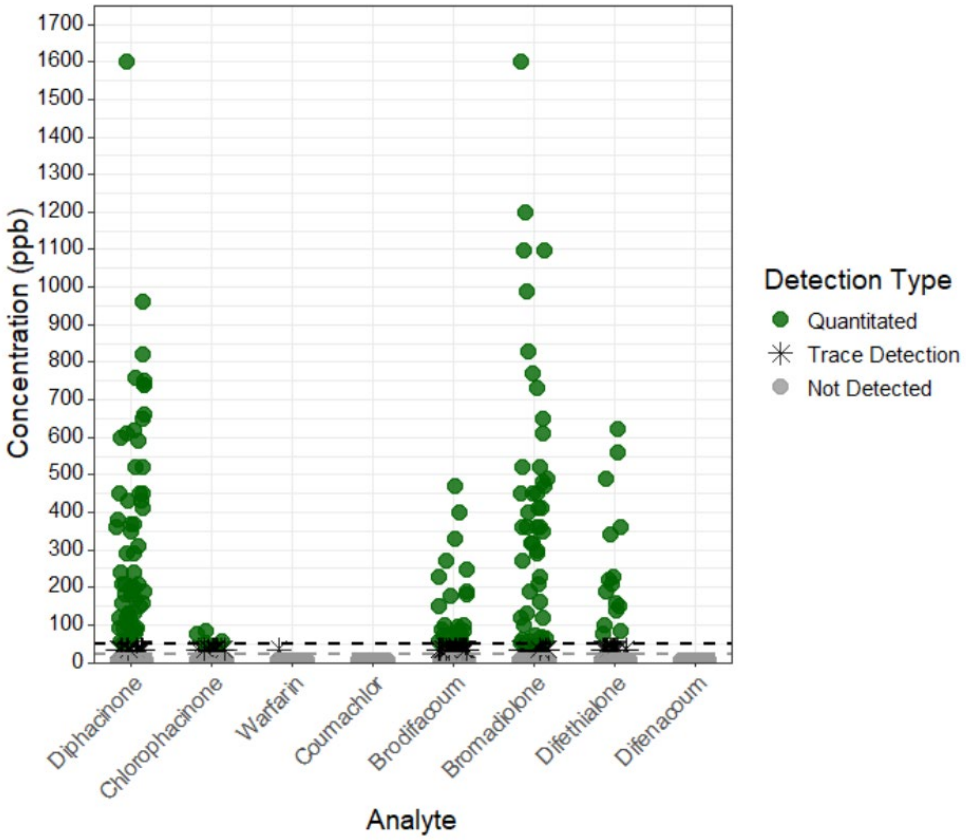

Figure 8. Raw anticoagulant rodenticide concentrations data for all necropsied bobcats (n=129) in the study.

SGARs were created in response to the development of FGAR resistance in rodents, and are more potent, require fewer feedings to achieve toxic doses, and are retained in liver tissue for a longer time (Fisher et al. 2003, Berny et al. 2018). Anticoagulant rodenticide analyses were performed using quantitative ultraperformance liquid chromatography and mass spectrometry (Smith et al. 2017). Results for each AR detected were reported in parts per billion (ppb). The lowest limit of detection (LOD) for tested ARs was 20 ppb, and the lowest limit of quantitation (LOQ) was 50 ppb for each AR, and results were reported as 'trace' if an AR was detected above the LOD but below the LOQ. Although reported as trace amounts, these cases are still considered as positive exposure results.

Additionally, necropsied bobcats were tested for the presence of Bromethalin using the biomarker desmethylbromethalin (DMB). Bromethalin is an acutely neurotoxic, single-feed rodenticide used for the control of commensal rodents (Jackson et al. 1982, Van Lier and Cherry 1988) and is currently available to licensed applicators and at the general consumer level (Coppock 2013). When ingested, it is rapidly converted into the more toxic metabolite, DMB. Unlike ARs, there is no antidote for Bromethalin exposure (Coppock 2013). Bromethalin use has increased after passage of legislation restricting the applications of certain ARs (CDFW 2024), and while bromethalin use is

conventionally considered to pose low risks to non-target species through secondary exposure (Jackson et al. 1982, U.S. EPA 2024), exposure and toxicity risk assessments are largely based on laboratory studies and feeding trials and are data deficient in ecological settings. Non-target bromethalin exposures and fatalities have been detected in multiple wildlife species including carnivores and scavengers (Bautista et al. 2014, McMillin et al. 2016, CDFW 2021, 2022, 2023, 2024, Cox et al. 2022, Murray and Cox 2023a, 2023b, Rudd et al. 2024). DMB is highly fat soluble which is why adipose tissue makes for the ideal choice for DMB testing due to its high lipid content; brain tissue also has high lipid content and may also be tested when adipose stores are unavailable (Murray and Cox 2023a, 2023b, Rudd et al, 2024). Accordingly, adipose or brain tissue were tested for DMB using reverse phase ultrahigh performance liquid chromatography-mass spectrometry protocols established at the CAHFS Lab (Filigenzi et al. 2015). The reporting limit for a positive detection was 1 ppb; if DMB was detected in tissue below the reporting limit the result was reported as 'trace'. Additional toxicology testing was conducted at the discretion of the pathologist.

Determination of Rodenticide Exposure & Toxicosis. Rodenticides, including ARs, are not always acutely fatal and there is a high degree of variability among species and individuals in their vulnerability. Toxicosis occurs when illness, disease or death are caused by a poison or toxin. For ARs, there is no universal threshold detection value that could indicate AR toxicosis, thus we must also rely on antemortem and postmortem evidence of coagulopathy (impairment of blood clotting ability causing bleeding) unrelated to another identifiable cause of hemorrhage (e.g., trauma, disease, infection). For this study, AR 'toxicosis' was determined to be a cause of death or morbidity if one or more ARs were detected in the liver and coagulopathy was present with no other cause (e.g., trauma, disease) identified. Individuals were considered to have AR 'exposure' if their livers had detectable levels of one or more ARs (regardless of concentration) and they lacked antemortem or postmortem evidence of coagulopathy.

For non-anticoagulant rodenticides (i.e., bromethalin), diagnosing toxicosis requires the detection of the compound in the appropriate tissue sample or gastrointestinal contents, and antemortem or postmortem evidence in the absence of another identifiable cause (e.g., disease, infection, trauma). In some cases, rodenticide residues are detected in the tissue sample, but postmortem evidence cannot confirm or exclude toxicosis due to tissue decomposition or freeze-thaw artifact. Therefore, based on the totality of the case, these diagnoses were reported as 'suspect' toxicosis or 'undetermined'.

Cause of Death and Rodenticide Detections. We used a mixed effects logistic regression model to investigate how AR detections are related to primary cause of death using the package glmmTMB (Brooks et al. 2017). AR exposure (not detected = 0; positive detection = 1) was used as the dependent variable, primary cause of death as a fixed effect with Trauma-Hit-By-Car as the reference variable. To account for space and time,

we included ecoregion, land cover (Dewtiz 2023), and sample year as random effects. While it is possible AR use varies seasonally, we chose to use year instead of month due to statistical power concerns and the long half-life of SGARs of 12-18 months. There was a notable increase in use of FGARs and decrease of SGARs in 2021 due to legislative changes. Ecoregion and land cover categories were extracted for each carcass with known sampling location using ArcGIS Pro. We excluded two causes of death variables from the analysis: toxicosis because it is correlated with AR exposure and predation-puncture wounds because all cases were positive for ARs (Figure 9). We assessed the quality of the regression models with the package *DHARMa* (Hartig 2024) to confirm no under- or over-dispersion of residuals.

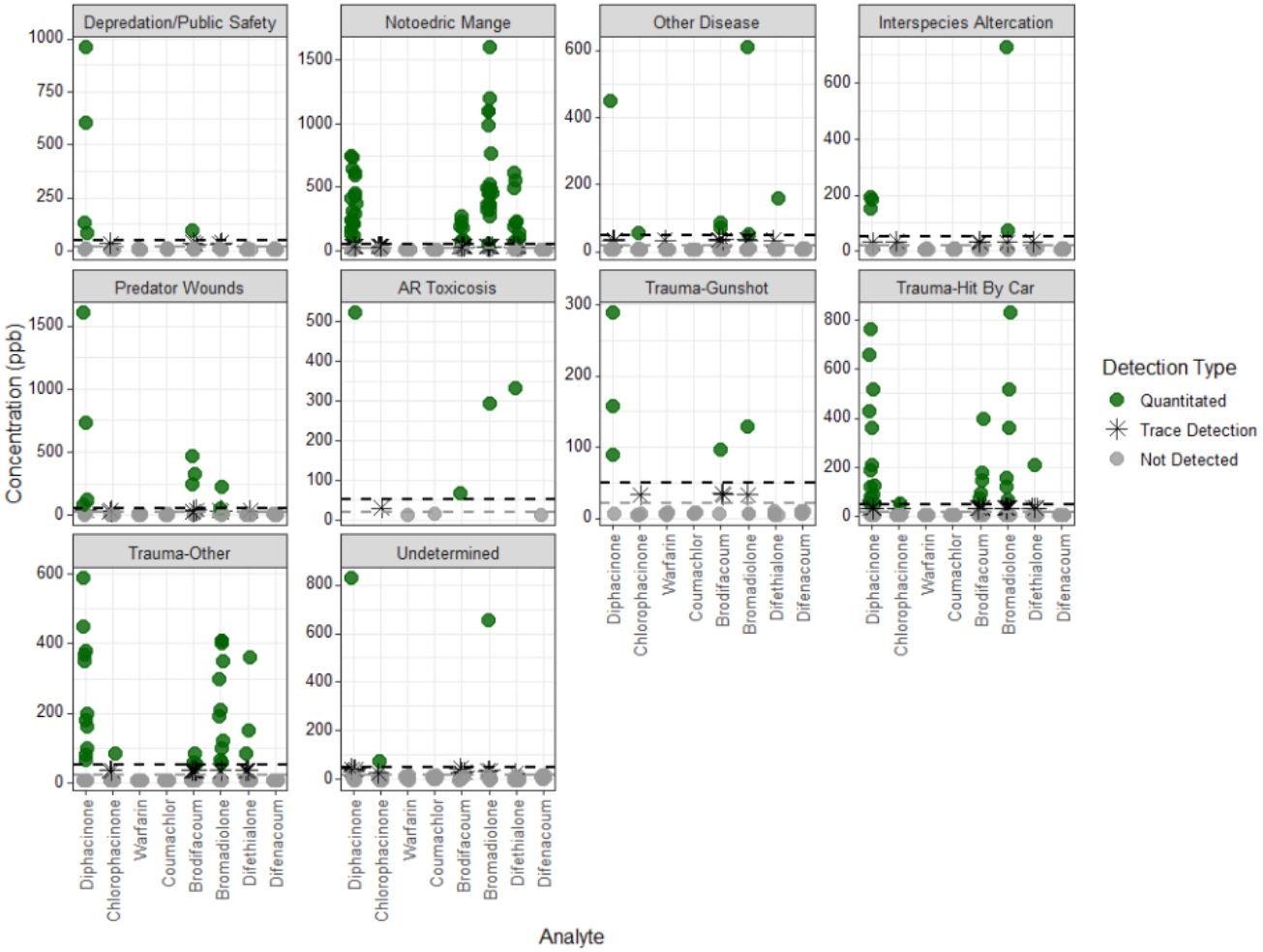

Figure 9. Raw anticoagulant rodenticide concentrations data for all necropsied bobcats (n=129) in the study. This data can inform future research and analyses.

3.11 POPULATION MODELING AND SUSTAINABLE MORTALITY

To estimate the impacts of potential future harvest, we developed a population model to explore the effects of varied mortality levels in California bobcat populations. We

began by conducting a literature search to investigate common bobcat population structures and growth rates. We gathered vital rates, particularly survival and fecundity, from 28 published journal articles and academic theses from across the United States (Table 8).

Table 8. All 28 journal articles and academic theses included in population models and their incorporated demographic estimates for survival probability, proportion of the population that was female and liter size.

Source	Location	Harvest?	Survival Probability	Proportion Female	Proportion of Females Reproducing	Litter Size
Allen et al. 2020	WI	Yes		✓	✓	
Bailey 1974	ID	No	✓	✓		✓
Blankenship et al. 2006	TX	No	✓	✓		
Chamberlain et al. 1999	MS	Yes	✓	✓		
Crowe 1975a	WY	Yes			✓	✓
Crowe 1975b	WY	Yes	✓	✓		
Fox 1990	NY	Yes		✓	✓	✓
Fritts and Selander 1978	AR	Yes		✓	✓	✓
Fuller et al. 1995	MA	Yes	✓	✓		
Fuller et al. 1985	MN	Yes/No	✓	✓		
Gashwiler et al. 1961	UT	Yes		✓		✓
Johnson and Holloran 1985	KS	Yes			✓	✓
Jones et al. 2020	IN	No	✓	✓		
Kamler and Gipson 2000	KS	Yes	✓			
Knick 1990	ID	Yes/No	✓	✓		✓
Knick et al. 1985	WA	Yes		✓	✓	✓
Koehler 2006	IA	No	✓	✓	✓	✓
Landry 2017	WV	Yes	✓	✓	✓	✓
Lovallo 2000a	PA	No		✓	✓	✓
Lovallo 2000b	PA	No	✓	✓	✓	✓
Moriarty 2007	CA	No	✓	✓		✓
Morrison 2022	SD	Yes	✓	✓	✓	✓
Nomsen 1982	SD	Yes		✓		✓
Parker and Smith 1983	Nova Scotia	Yes	✓	✓	✓	✓
Riley et al. 2003	CA	No	✓	✓		
Rolley 1985	OK	Yes	✓	✓	✓	✓
Tycz 2016	SD	Yes		✓	✓	✓
Woolf et al. 2002	IL	No	✓	✓		

We considered three common age categories: kitten (< 1 year old), yearling (1-2 years old), and adult (> 2 years old), and conducted separate analyses for harvested (n=19) and unharvested populations (n=11; Table 9).

Table 9. Average values of demographic parameters across 28 previously published journal articles and academic theses.

Parameter	Harvested?	Kitten (< 1 year old)	Yearling (1-2 years old)	Adult (>2 years old)
Percent survival	Yes	43	66	65
	No	33	82	82
Percent of population that is female	Yes	49	49	49
	No	48	48	48
Percent of females reproducing	Yes	N/A	45	80
	No		69	86
Litter size	Yes	N/A	1.99	2.73
	No		2.19	2.44
Number of female young per female	Yes	N/A	0.44	1.07
	No		0.73	1.01

Using these demographic estimates, we created two post-birth stage structured population models (Figure 10) and then used those to complete a Life Stage Simulation (LSA) analysis (Wisdom et al. 2000). LSA analyses predict how populations will respond to current or altered demographic rates and allow for the incorporation of uncertainty in those rates (see Mills et al. 2025 for details on equations). We randomly selected an observed value from the included literature for each vital rate for harvested and unharvested populations and compiled those values into two separate population matrices. We then used each of these to estimate the corresponding population growth rate and stable stage distribution. To best capture variation and uncertainty in these estimates, we repeated this process 10,000 times using data from only harvested populations and another 10,000 times using data from only unharvested populations. Theoretically, if vital rates stay constant over time, all populations will approach a constant growth rate (lambda) and population structure. The resulting population structure is referred to as the Stable Stage Distribution (SSD). To determine thresholds where mortality causes population declines, we altered survival rates until lambda reached 1.0. Lastly, we used the reproductive value of each stage class, along with the stable stage distribution, to determine the elasticity of each survival rate, or the proportional ability of that survival rate to alter the overall population growth rate. This is especially important when trying to alter estimates of abundance, in either direction, since a survival rate with high elasticity can produce a relatively large change in lambda (population growth rate) with only a slight change in value.

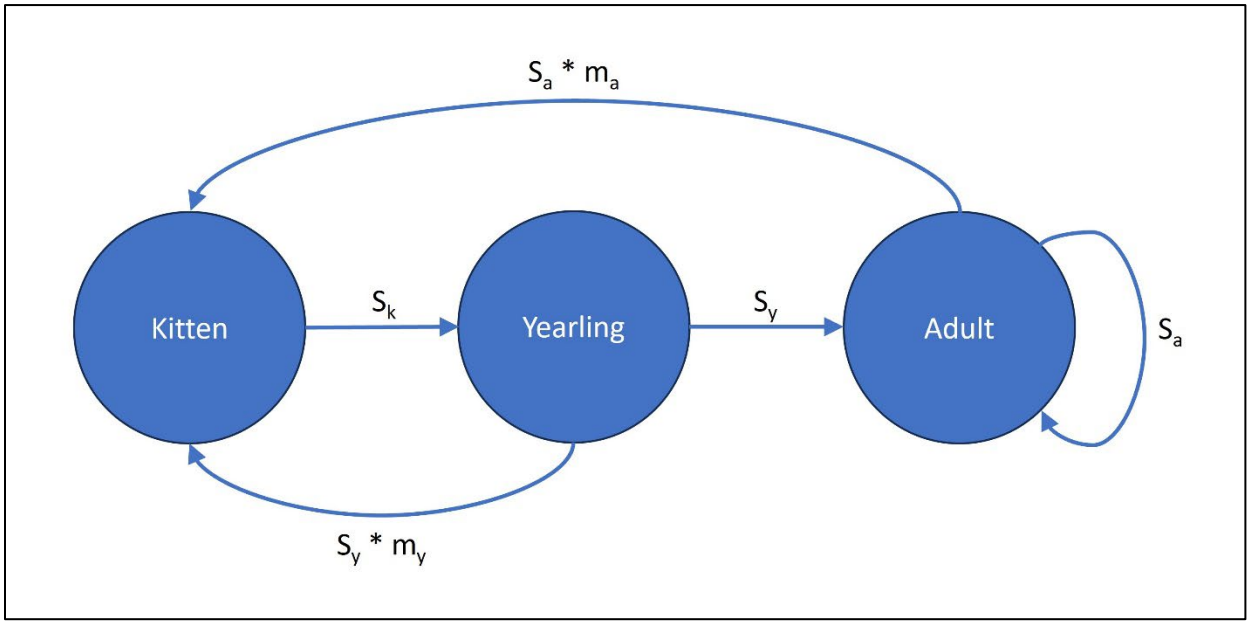

Figure 10. Basic structure of the stage based post-birth population model for bobcats. Note. "S" represents percent survival; "m" represents the number of female newborns per female. These rates represent the probability of transitioning from one stage cl ass to another, along the arrow. For example, "S_k" represents the probability of a kitten surviving the first year and becoming a yearling while S_a*m_a represents the probability of an adult female surviving the year and producing a female offspring.

Photo by the CDFW Bobcat Project

CHAPTER 4. RESULTS

4.1 SCAT COLLECTION AND FECAL DNA

Across the 48 sites, we collected a total of 3,182 scat samples, 2,512 of which were considered likely to be bobcat scats based on the collector's identification at the time of collection, and 670 were thought to be coyote scats. Out of the total 3,182 scats collected, 1,210 (38%) were successfully genotyped as bobcat through Fecal DNA analysis, representing 461 individuals.

We collected an average of 23.3 genetically confirmed bobcat scats per study area, with a maximum of 139 and minimum of zero. The average number of unique genotypes per study area was 8.9, with a maximum of 37 individuals from the Oak Grove study area (Table 10). Genotypes were split nearly evenly between sexes with 212 (46%) male, 228 (49%) female, and 21 (5%) unknowns. The maximum distance between a detection and the centroid of all that individual's detections was 4,619 meters ($\bar{x}$ distance = 723 m, SD = 621 m) for males and 4,093 meters ($\bar{x}$ distance = 617 m, SD = 555 m) for females. However, among all individuals, only 1% of distances were greater than 2,800 meters. As a result, we chose to use a buffer of 2,800 meters for our scat-based SCR habitat mask to capture potential activity centers of detected bobcats and a mask point spacing of 800 meters, as discussed in Section 3.4 above.

Table 10. Study area code, the number of bobcat scats collected in that area, and the number of individual bobcats as determined by fecal DNA results.

Study Area	Bobcat Scats	Individuals	Scats/ Individual	Study Area	Bobcat Scats	Individuals	Scats/ Individual
ABB	1	1	1.0	MCC	6	2	3.0
ANF	8	8	1.0	MOJ	63	18	3.5
ASB	20	15	1.3	OG	139	37	3.8
BCF	26	10	2.6	PAN	39	13	3.0
BOD	4	3	1.3	PR	42	24	1.8
CACK	12	7	1.7	PW	27	16	1.7
CDCO	104	35	3.0	RED	10	4	2.5
CGO	13	5	2.6	SA	76	30	2.5
CHO	69	19	3.6	SBNF	10	8	1.3

Study Area	Bobcat Scats	Individuals	Scats/ Individual	Study Area	Bobcat Scats	Individuals	Scats/ Individual
CHSP	2	2	1.0	SC	11	5	2.2
CKW	24	8	3.0	SEQ	7	4	1.8
CMP	8	4	2.0	SHRS	7	2	3.5
CPER	19	11	1.7	SKE	22	8	2.8
DG	48	12	4.0	SMNF	0	0	0.00
DHSV	24	6	4.0	SPUR	19	7	2.7
FIAB	53	16	3.3	SRWA	65	22	3.0
FRES	0	0	0.0	TEHA	29	15	1.9
HC	4	1	4.0	TL	13	3	4.3
HJWA	28	6	4.7	TNC	1	1	1.0
HVWA	13	7	1.9	TUN	27	9	3.0
JF	10	8	1.3	TUO	7	5	1.4
JLD	37	18	2.1	UBBW	7	5	1.4
JOTR	44	11	4.0	WIS	1	1	1.0
LDSF	5	4	1.3	YBWA	1	1	1.0
MAM	0	0	0.0	**TOTAL**	**1205**	**457**	**2.2**

4.2 CAMERA SURVEYS AND PHOTO ANALYSIS

A total of 1,920 camera stations were deployed for this study, producing 148,994 trap nights when considering both cameras at a station. Stations were deployed in 13 of the 15 available land cover categories in California that were included in the 2019 National Land Cover Database; Open Water and Perennial Snow/Ice were omitted (Dewitz 2021). The three most common land cover types for camera deployment were Shrub/Scrub, Evergreen Forest, and Herbaceous. Approximately 75% of our sites were in these cover types, which collectively cover 83% of the state (Figure 3). We captured

over 23 million images, 4.1 million of which were non-blank and included approximately 1.7 million photos of nearly 170 species. The five most common non-human animals photographed, listed in descending order, were: domestic cattle (*Bos taurus*), mule deer (*Odocoileus hemionus*), hare *(Lepus sp.*), California ground squirrel (*Otospermophilus beecheyi*), and American black bear (*Ursus americanus*). Birds were also prevalent but were sometimes difficult to identify to species. As a result, they were often tagged at higher taxonomic classifications (e.g., genius, family, etc.). Overall, there were 17 commonly detected species or groups (Table 11).

Table 11. Commonly detected species across all cameras and sites. LTD= latency to detection which is the number of days between camera deployment and first detection of the species averaged over all cameras that had at least one detection of that species.

Species	# of Images	% of Non-Blank Images	LTD (# of days)
Domestic Cattle	965,705	26.0	9
Bird	325,417	8.8	8
Mule Deer	272,421	7.3	11
Human (excluding researchers)	258,815	7.0	12
Rabbit (*Sylvilagus* spp.)	226,262	6.1	10
Squirrel (*Sciuridae* family)	225,508	6.1	9
Rodent (excluding squirrels)	201,946	5.4	11
Hare (*Lepus sp.*)	126,762	3.4	10
American Black Bear	77,061	2.1	13
Gray Fox	68,999	1.9	9
Coyote	54,919	1.5	14
Vehicle	53870	1.5	-
Bobcat	51,313	1.4	14
Wild Pig	37,707	1.0	14
Striped Skunk	30,495	0.8	13
Northern Raccoon	28,029	0.8	13

Species	# of Images	% of Non-Blank Images	LTD (# of days)
Kit Fox	27764	0.8	4
Elk	26645	0.7	17
Domestic Dog	17616	0.5	15
Domestic Donkey	14769	0.4	14
Domestic Horse	13597	0.4	14
Virginia Opossum	7487	0.2	19
Pronghorn	7313	0.2	10
Mountain Lion	5,993	0.2	20
Large Mustelid (American Badger or North American River Otter)	4,300	0.1	19
Small Mustelid (Marten, Fisher, or Long-tailed Weasel)	2,630	0.1	19

Out of the 1.7 million wildlife photos that were collected throughout this project, 51,313 were of bobcats (Table 11). An estimated 17 kittens were photographed across the state, ranging in body size from small and recently emerged from the den, possibly a few months old, to young of the year, almost as big as an adult. Five study areas had collared bobcats concurrently with camera surveys. In each case, all those marked animals were identified in photos. Mean bobcat latency to detection (LTD: the number of days from camera deployment to first detection, based on all cameras that detected at least one of the target species) was 14 days. Of all species detected at our cameras kit foxes had the shortest LTD at 4 days, and mountain lions had the longest at 20 days (Table 11). Mange was only identified in three bobcats from two study areas; Canada-Coe (CDCO; n=2), and Dangermond (JLD; n=1; Table 2), which is consistent with the known distribution of mange across the state, as discussed in Section 4.9 below.

4.3 DENSITY MODELING

The SCR model has two parts, a model of detection which then informs the second part, a model of density. We fit nine candidate models to the detection portion of the SCR analysis (Table 12). The best supported model had an AICc value approximately four points lower than the next most supported model and incorporated nearly 90% of the

AICc model weight. This model included an effect of season on both lambda (models the encounter rate at the activity center) and sigma (models how these decrease with distance) as well as feature type (e.g., game trail, dirt road, recreation trail, or wash) for lambda and a quadratic effect of natural habitat for sigma.

Table 12. Spatial capture-recapture (SCR) modeling results for detection only (based on fecal DNA results).

Model	Parameters	AICc	Δ AICc	AICc Weight
Lambda ~ Feature Type + Season Sigma ~ Season + Natural Habitat + Natural Habitat^2	13	7082.46	0.000	0.899
Lambda ~ Feature Type + Season Sigma ~ Natural Habitat + Natural Habitat^2	11	7086.84	4.381	0.101
Lambda ~ Feature Type + Season Sigma ~ Season + Natural Habitat	12	7101.06	18.598	0.000
Lambda ~ Feature Type Sigma ~ Season + Natural Habitat	10	7124.47	42.011	0.000
Lambda ~ Feature Type + Season Sigma ~ Season	11	7161.57	79.108	0.000
Lambda ~ Feature Type Sigma ~ Season	9	7183.67	101.212	0.000
Lambda ~ Feature Type Sigma ~ 1	7	7189.93	107.468	0.000
Lambda ~ 1 Sigma ~ Season	5	7263.27	180.805	0.000
Lambda ~ 1 Sigma ~ 1	3	7272.88	190.42	0.000

During the first stage of the density model selection procedure, we fit 56 candidate models across the variable groups and considered 11 different combined candidate models before there were no further improvements in model fit. The top combined

model had 42% of the AICc model weight and consisted of elevation, wildfire history, drought, human population density and its quadratic term, proportion hardwood forest cover, proportion shrub cover, and proportion desert vegetation cover (Table 3 & Table 13). However, the human population density terms had extremely high standard errors in the coefficients, indicating model estimation issues. This was likely due to our limited data in urban areas. Thus, we removed those terms from the model and avoided extrapolating our density model to urban areas.

While season was included in our best supported detection model based on AICc, its effect on sigma was not significant. Because of this we fit two different full SCR models, combining our top density model with each of the top two detection models (one with and one without season). When we compared these two full models, the model that did not include a seasonal effect on sigma had a significantly lower AICc value and received 100% of the AICc model weight. As a result, our final model included the top density model and the second-best detection model.

Of the covariates on lambda (encounter rate), the only feature type whose effect was significantly different from game trails (the reference level) was washes, which had a higher encounter rate (β = 0.62, CI: 0.32 – 0.92). Both kitten (β = 0.30, CI: 0.04 – 0.55) and winter/wet (β = 0.71, CI: 0.43 – 0.99) seasons produced a higher encounter rate than the summer/dry season. For the covariates on sigma (range of animal movement), both the quadratic (β = 0.05, CI: 0.01 - 0.11) and linear (β = 0.18, CI: 0.13 - 0.23) terms for natural habitat were positive, suggesting movement is least in areas with moderate levels of natural habitat. Given our use of the hazard exponential detection function, the circular.r function (*secr* package) suggests an average home range radius of 4.74 times the predicted value of sigma in our density model. For the density covariates, there was a significant negative response to increasing elevation (β = -0.21, CI: -0.34 - -0.09), wildfire severity (β = -0.36, CI: -0.65 - -0.06) and drought (β = -0.-17, CI: -0.27 - -0.06), and significant positive density responses to increasing proportion hardwood forest cover (β = 0.37, CI: 0.27 – 0.47) and shrub cover (β = 0.37, CI: 0.26 – 0.48. There was no significant effect of desert vegetation (Table 14).

Using the bootstrapping procedure described in Section 3.4 above, we calculated an average density of 15.72 (SD=1.82) bobcats per 100 square kilometers in California. We also used the predictDsurface tool (secr package) to predict density values for each square kilometer across the entire state for visualization purposes (Figure 11). The bootstrapped density estimates translated to a final abundance estimate of 62,292 (95% CI: 49,672 – 78,454) bobcats across California.

We used these same methods to develop a statewide population estimate based on the photo data. Our results produced an estimate of 35,790 individuals (95% CI: 27,603 – 66,938) which was much lower than our estimate based on the fecal DNA results mentioned above (62,292 individuals; 95% CI: 49,672 – 78,454, Table 15).

Table 13. Top spatial capture-recapture (SCR) models for density only based on fecal DNA results.

Model	Parameters	AICc	Δ AICc	AICc weight
Elevation + Wildfire + Drought + Population + Population^2 + Hardwood + Shrub + Desert	11	7135.14	0.00	0.48
Elevation + Elevation^2 + Wildfire + Drought + Population + Population^2 + Hardwood + Shrub + Desert	12	7136.82	1.68	0.21
Elevation + Elevation^2 + Wildfire + Drought + Population + Population^2 + Conifer + Hardwood + Shrub + Desert	13	7138.50	3.36	0.09
Elevation + Elevation^2 + Wildfire + Drought + Urban + Urban^2 + Hardwood + Shrub + Desert	12	7138.72	3.58	0.08
Elevation + Elevation^2 + Wildfire + Drought + Urban + Urban^2 + Population + Population^2 + Conifer + Hardwood + Shrub +	15	7139.25	4.10	0.06
Elevation + Elevation^2 + Wildfire + Drought + Urban + Population + Population^2 + Hardwood + Shrub	11	7140.44	5.30	0.03
Elevation + Elevation^2 + Wildfire + Drought + Urban + Population + Population^2 + Conifer + Hardwood + Shrub +	14	7140.58	5.44	0.03
Elevation + Elevation^2 + Wildfire + Drought + Urban + Urban^2 + Hardwood + Shrub	11	7143.15	8.01	0.01
Elevation + Elevation^2 + Drought + Population + Population^2 + Hardwood + Shrub + Desert	11	7150.60	15.46	0.00
Elevation + Elevation^2 + Population + Population^2 + Hardwood + Shrub + Desert	10	7151.66	16.52	0.00

Table 14. Coefficient results from final spatial capture-recapture model based on fecal DNA.

Covariate	Parameter	Estimate (β)	95% CI
Density	Density	-6.58	(-6.73, -6.44)
Elevation	Density	-0.21	(-0.34, -0.09)
Wildfire	Density	-0.36	(-0.65, -0.06)
Drought	Density	-0.17	(-0.27, -0.06)
Hardwood	Density	0.37	(0.27, 0.47)
Shrub	Density	0.37	(0.26, 0.48)
Desert	Density	0.003	(-0.13, 0.12)
Lambda	Lambda	-1.10	(-1.4, -0.81)
Feature Type – Multiuse	Lambda	-0.23	(-0.49, 0.02)
Feature Type – Other	Lambda	0.48	(-0.19, 1.14)
Feature Type –Road	Lambda	-0.45	(-0.67, -0.23)
Feature Type – Wash	Lambda	0.62	(0.32, 0.92)
Season – Kitten	Lambda	0.30	(0.04, 0.55)
Season – Wet	Lambda	0.71	(0.43, 0.99)
Sigma	Sigma	5.98	(5.9, 6.07)
Natural Habitat	Sigma	0.05	(-0.01, 0.11)
Natural Habitat^2	Sigma	0.18	(0.13, 0.23)

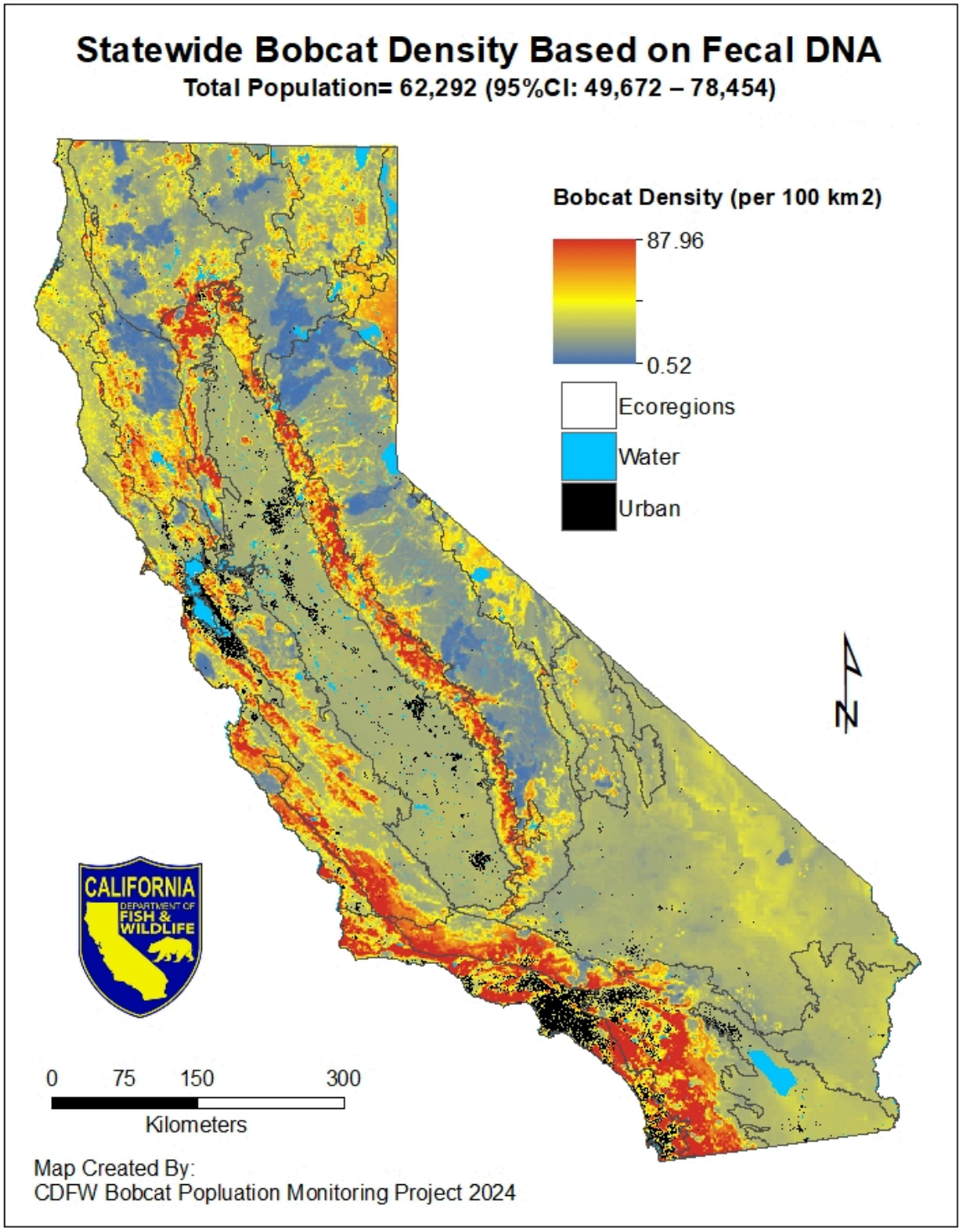

Figure 11. Statewide bobcat density estimates and ecoregion borders. Density estimates are from the final fecal DNA-based SCR model. All major urban areas, lakes and reservoirs have been removed from the estimate. Large patches of low density (dark blue) are the result of fire scars from fires within the previous two years of the study

Table 15. Study area code, the number of bobcat photos taken in that area, the number of quality photos used for pelage ID, percentage of photos used, and number of individual bobcats identified from both pelage ID fecal DNA results.

Site	Total Bobcat Photos	Number of Quality Photos Used for Pelage ID	Percentage of Photos Used for ID	Individuals from Pelage ID	Individuals from Fecal DNA Results
ABB	18	2	11.11%	1	1
ANF	232	215	92.67%	6	8
ASB	768	539	70.18%	19	15
BCF	518	167	32.24%	11	10
BOD	338	165	48.82%	4	3
CACK	317	293	92.43%	7	7
CDCO	3,586	1,796	50.08%	33	35
CGO	314	207	65.92%	6	5
CHO	3,256	2,281	70.06%	23	19
CHSP	183	138	75.41%	3	2
CKW	718	284	39.55%	9	8
CMP	589	409	69.44%	6	4
CPER	1,759	478	27.17%	12	11
DG	384	266	69.27%	7	12
DHSV	448	249	55.58%	5	6
FIAB	118	66	55.93%	6	16
FRES	Scat only	NA	NA	NA	0

Site	Total Bobcat Photos	Number of Quality Photos Used for Pelage ID	Percentage of Photos Used for ID	Individuals from Pelage ID	Individuals from Fecal DNA Results
HC	30	22	73.33%	1	1
HJWA	168	126	75.00%	4	6
HVWA	113	103	91.15%	3	7
JF	247	189	76.52%	10	8
JLD	1,252	596	47.60%	17	18
JOTR	2,447	608	24.85%	10	11
LDSF	568	328	57.75%	4	4
MAM	19	17	89.47%	1	0
MCC	448	196	43.75%	5	2
MOJ	1,701	498	29.28%	12	18
OG	2,120	1,542	72.74%	28	37
PAN	3,256	1,262	38.76%	13	13
PR	3,746	2,467	65.86%	29	24
PW	742	331	44.61%	5	16
RED	165	127	76.97%	2	4
SA	2,639	1,283	48.62%	29	30
SBNF	419	163	38.90%	7	8
SC	414	368	88.89%	6	5
SEQ	93	75	80.65%	3	4

Site	Total Bobcat Photos	Number of Quality Photos Used for Pelage ID	Percentage of Photos Used for ID	Individuals from Pelage ID	Individuals from Fecal DNA Results
SHRS	135	90	66.67%	8	2
SKE	96	39	40.63%	3	8
SMNF	133	83	62.41%	2	0
SPUR	490	120	24.49%	5	7
SRWA	14,530	3,243	22.32%	41	22
TEHA	489	306	62.58%	9	15
TL	95	50	52.63%	2	3
TNC	1,920	508	26.46%	7	1
TUN	1,093	204	18.66%	9	9
TUO	1,466	412	28.10%	5	5
UBBW	515	348	67.57%	6	5
WIS	0	0	NA	0	1
YBWA	0	0	NA	0	1
TOTAL	**55,095**	**24,231**	**43.98%**	**444**	**457**

Abundance estimates for each ecoregion can be found in Table 16. When broken down by ecoregions, the Southern California Coast had the highest average density of 29.4 (SD 3.3) bobcats/100 km^2, followed by the Sierra Nevada Foothills with a density of 27.6 (SD 2.6) bobcats/100 km^2. The Sierra Nevada, at 10.2 (SD1.7) bobcats/100 km^2 and Southern Cascades, at 10 (SD 1.4) bobcats/100 km^2, had the lowest average densities. Despite having a low bobcat density estimate, the Mojave ecoregion supported the largest total bobcat population due to its relative size (1500 km^2 larger than the second largest ecoregion).

Table 16. Spatial capture-recapture (SCR) density results by ecoregion (based on fecal DNA results). Density is reported as the number of bobcats per 100 km^2.

Ecoregion	Area (km^2)	Avg. Density (SE)	Estimated Abundance (95% CI)
Northern CA Coast (263A)	17,110	16.0 (1.5)	2,733 (2161, 3500)
Klamath Mountains (M261A)	22,371	12.5 (1.8)	2,795 (2181, 3745)
Northern CA Coast Ranges (M261B)	15,344	16.8 (2.5)	2,582 (1996, 3568)
Northern CA Interior Coast Ranges (M261C)	7,397	25.0 (3.4)	1,847 (1403, 2518)
Southern Cascades (M261D)	16,903	10.0 (1.4)	1,690 (1323, 2241)
Modoc Plateau (M261G)	13,781	16.3 (1.4)	2,252 (1823, 2793)
Northwestern Basin and Range (342B)	4,684	21.7 (2.0)	1,015 (805, 1288)
Central CA Coast (261A)	13,697	21.0 (2.8)	2,878 (2273, 3,741)
Central CA Coast Ranges (M262A)	24,766	19.9 (2.6)	4,919 (3898, 6,376)
Great Valley (262A)	48,890	11.1 (0.5)	5,420 (4152, 7,080)
Sierra Nevada Foothills (M261F)	17,921	27.6 (2.6)	4,940 (3918, 6,263)
Sierra Nevada (M261E)	51,064	10.2 (1.7)	5,194 (3916, 7210)
Mono (341D)	7,784	15.0 (1.5)	1,167 (887, 1549)
Southern CA Coast (261B)	13,557	29.4 (3.3)	3,991 (2999, 5,361)
Southern CA Mountains and Valleys (M262B)	27,461	27.0(3.3)	7,416 (5720, 9731)

Ecoregion	Area (km²)	Avg. Density (SE)	Estimated Abundance (95% CI)
Southeastern Great Basin (341F)	11,044	11.7 (0.9)	1,289 (899, 1868)
Mojave Desert (322A)	66,766	11.9 (0.6)	7,971 (5420, 11777)
Sonoran Desert (322B)	12,887	12.4 (0.3)	1,592 (1091, 2329)
Colorado Desert (322C)	10,908	12.4(0.4)	1,349 (972, 1883)

Note. *Ecoregions are listed from west to east for northern, central, and southern California.*

4.4 OCCUPANCY ANALYSIS

Our occupancy analysis included 1,761 camera stations from 46 study areas (two study areas were excluded due to less than six weeks of data). Unconditional bobcat occupancy, meaning it was not based on the presence or absence of any other species, across all study areas was 0.39 ± 0.01 SE. Bobcats had the third lowest estimated rate of detection (i.e., the likelihood of detecting a species if it is present, 0.38 ± 0.01) after mountain lion (0.17 ± 0.01) and small mustelids (0.19 ± 0.02), while rabbits had the highest (0.64 ± 0.01). Bobcat occupancy significantly increased with the presence of all other species analyzed except black bears and small mustelids (Table 17 & Figure 12). Small mustelid (Table 4) presence was associated with a significant decrease in bobcat occupancy while the relationship between bobcat and black bear presence was not significant. Mountain lion presence was associated with the largest (β = 1.08 ± 0.18), increase in bobcat occupancy, from the unconditional estimate of 39% to 62% when mountain lions were present. Gray foxes were the competitor associated with the smallest significant change in bobcat occupancy, (β = 1.06 ± 0.11), increasing it to 56% when present. Of the disturbance species, domestic cattle presence (β = 0.59 ± 0.12) was associated with the smallest change, only increasing bobcat occupancy to 52%, while wild pig presence (β = 0.92 ± 0.25) was associated with an increase in bobcat occupancy to 61%. Of the prey species the largest increase was associated with wild turkey presence (β = 1.34 ± 0.13) which increased bobcat occupancy to 69%. The smallest positive change in bobcat occupancy associated with a prey species was with squirrels (β = 0.89 ± 0.11) whose presence only increased bobcat occupancy to 49%. Small mustelid presence (β = -0.66 ± 0.25) was associated with a 33% decrease in the likelihood of a bobcat being present at a camera. Similarly small mustelid occupancy doubled when bobcats were not present (estimated occupancy = 0.08 ± 0.01) compared to when bobcats were present (estimated occupancy =0.04 ± 0.01). While these results suggest a lack of avoidance between bobcats and other species, they do not necessarily show a causal relationship. Increases in cooccurrence between these

species could be due to preferences in environmental variables rather than attraction to each other.

Table 17. Each species combination represents a separate occupancy model. ¥ represents occupancy, d represents detection, and SE is standard error. Lines with Bobcat + "Other Species" (¥) denote if interactions between those species. All other variables were included in models to account for variation within the data but were not of interest in this analysis. All estimates are on the logit scale.

Species	Variables	Estimate	SE	P-Value
Unconditional Bobcat	Intercept (¥)	-0.42	0.05	<0.01
	Herbaceous Cover	-0.32	0.06	<0.01
	Intercept (d)	-0.50	0.04	<0.01
	Maximum Temperature	-0.10	0.04	0.01
Bobcat + Mountain Lion	Bobcat Intercept (¥)	-0.59	0.06	<0.01
	Herbaceous Cover	-0.33	0.06	<0.01
	Mountain Lion Intercept (¥)	-2.33	0.15	<0.01
	Habitat Diversity	0.30	0.09	<0.01
	Hardwood Cover	-0.22	0.11	0.04
	Agricultural Cover	-0.56	0.21	0.01
	Bobcat + Mountain Lion Intercept (¥)	1.08	0.18	<0.01
	Bobcat Intercept (d)	-0.50	0.04	<0.01
	Maximum Temperature	-0.10	0.04	0.01
	Mountain Lion Intercept (d)	-1.59	0.10	<0.01
Bobcat + Black Bear	Bobcat Intercept (¥)	-0.40	0.06	<0.01
	Herbaceous Cover	-0.31	0.06	<0.01
	Black Bear Intercept (¥)	-2.29	0.16	<0.01
	Elevation	-0.67	0.11	<0.01
	Drought	-0.35	0.07	<0.01
	NDVI	-0.32	0.09	<0.01
	Habitat Diversity	0.39	0.08	<0.01
	Shrub Cover	0.44	0.07	<0.01
	Herbaceous Cover	0.24	0.07	<0.01
	Agricultural Cover	-1.70	0.54	<0.01

Species	Variables	Estimate	SE	P-Value
	Urban Cover	-1.11	0.38	<0.01
	Barren Cover	0.82	0.16	<0.01
Bobcat + Black Bear (cont.)	Bobcat + Black Bear Intercept (¥)	-0.12	0.15	0.42
	Bobcat Intercept (d)	-0.50	0.04	<0.01
	Maximum Temperature	-0.10	0.04	0.01
	Black Bear Intercept (d)	-0.36	0.06	<0.01
	Maximum Temperature	-0.47	0.06	<0.01
	Precipitation	-0.19	0.08	0.02
Bobcat + Coyote	Bobcat Intercept (¥)	-0.97	0.07	<0.01
	Herbaceous Cover	-0.29	0.06	<0.01
	Coyote Intercept (¥)	-0.95	0.07	<0.01
	Drought	0.19	0.06	<0.01
	Habitat Diversity	-0.30	0.05	<0.01
	Shrub Cover	0.24	0.05	<0.01
	Agricultural Cover	0.17	0.05	<0.01
	Bobcat + Coyote Intercept (¥)	1.27	0.11	<0.01
	Bobcat Intercept (d)	-0.50	0.04	<0.01
	Maximum Temperature (d)	-0.10	0.04	<0.01
	Coyote Intercept (d)	-0.22	0.03	<0.01
	Maximum Temperature	-0.09	0.04	0.02
	Precipitation	-0.13	0.04	<0.01
Bobcat + Gray Fox	Bobcat Intercept (¥)	-0.81	0.07	<0.01
	Herbaceous Cover	-0.35	0.06	<0.01
	Gray Fox Intercept (¥)	-1.19	0.08	<0.01
	Elevation	-0.39	0.06	<0.01
	Drought	-0.16	0.06	<0.01
	Fire	-0.27	0.07	<0.01
	Habitat Diversity	0.33	0.06	<0.01
	Hardwood Cover	-0.56	0.08	<0.01
	Shrub Cover	-0.37	0.06	<0.01

Species	Variables	Estimate	SE	P-Value
	Herbaceous Cover	-0.10	0.06	0.10
	Agricultural Cover	-0.36	0.07	<0.01
	Urban Cover	-0.23	0.07	<0.01
Bobcat + Gray Fox (cont.)	Barren Cover	0.14	0.07	0.05
	Bobcat + Gray Fox Intercept (¥)	1.06	0.11	<0.01
	Bobcat Intercept (d)	-0.50	0.04	<0.01
	Maximum Temperature	-0.10	0.04	0.01
	Gray Fox Intercept (d)	0.08	0.03	0.02
	Maximum Temperature	-0.08	0.03	0.03
Bobcat + Cattle	Bobcat Intercept (¥)	-0.52	0.06	<0.01
	Herbaceous Cover	-0.30	0.06	<0.01
	Domestic Cattle Intercept (¥)	-2.03	0.10	<0.01
	Drought	-0.29	0.07	<0.01
	NDVI	0.26	0.07	<0.01
	Fire	-0.17	0.09	0.05
	Shrub Cover	0.28	0.06	<0.01
	Herbaceous Cover	-0.25	0.09	0.01
	Barren Cover	0.23	0.05	<0.01
	Bobcat + Domestic Cattle Intercept (¥)	0.59	0.14	<0.01
	Bobcat Intercept (d)	-0.50	0.04	<0.01
	Maximum Temperature	-0.10	0.04	0.01
	Domestic Cattle Intercept (d)	0.06	0.05	0.21
	Maximum Temperature	0.14	0.05	0.01
	Precipitation	-0.16	0.07	0.02
Bobcat + Human	Bobcat Intercept (¥)	-0.75	0.07	<0.01
	Herbaceous Cover	-0.39	0.06	<0.01
	Human Intercept (¥)	-1.12	0.08	<0.01
	Habitat Diversity	0.13	0.06	0.03
	Hardwood Cover	-0.30	0.07	<0.01
	Herbaceous Cover	0.32	0.05	<0.01

Species	Variables	Estimate	SE	P-Value
	Agricultural Cover	-0.16	0.06	0.01
Bobcat + Rabbit	Bobcat + Human Intercept (¥)	0.93	0.12	<0.01
	Bobcat Intercept (¥)	-1.11	0.08	<0.01
	Herbaceous Cover	-0.30	0.06	<0.01
	Rabbit Intercept (¥)	-0.62	0.07	<0.01
	Elevation	0.12	0.05	0.02
	Drought	0.18	0.05	<0.01
	Agricultural Cover	0.11	0.05	0.04
	Water Cover	-0.21	0.08	<0.01
	Bobcat + Rabbit Intercept (¥)	1.35	0.11	<0.01
	Bobcat Intercept (d)	-0.51	0.04	<0.01
	Maximum Temperature	-0.11	0.04	<0.01
	Rabbit Intercept (d)	0.58	0.03	<0.01
Bobcat + Small Bird	Bobcat Intercept (¥)	-1.44	0.10	<0.01
	Herbaceous Cover	-0.38	0.06	<0.01
	Small Bird Intercept (¥)	-0.13	0.06	0.05
	Elevation	-0.34	0.05	<0.01
	Drought	-0.21	0.05	<0.01
	Habitat Diversity	0.26	0.05	<0.01
	Agricultural Cover	-0.16	0.05	<0.01
	Urban Cover	-0.23	0.07	<0.01
	Water Cover	-0.11	0.05	0.03
	Bobcat + Small Bird Intercept (¥)	1.56	0.12	<0.01
	Bobcat Intercept (d)	-0.50	0.04	<0.01

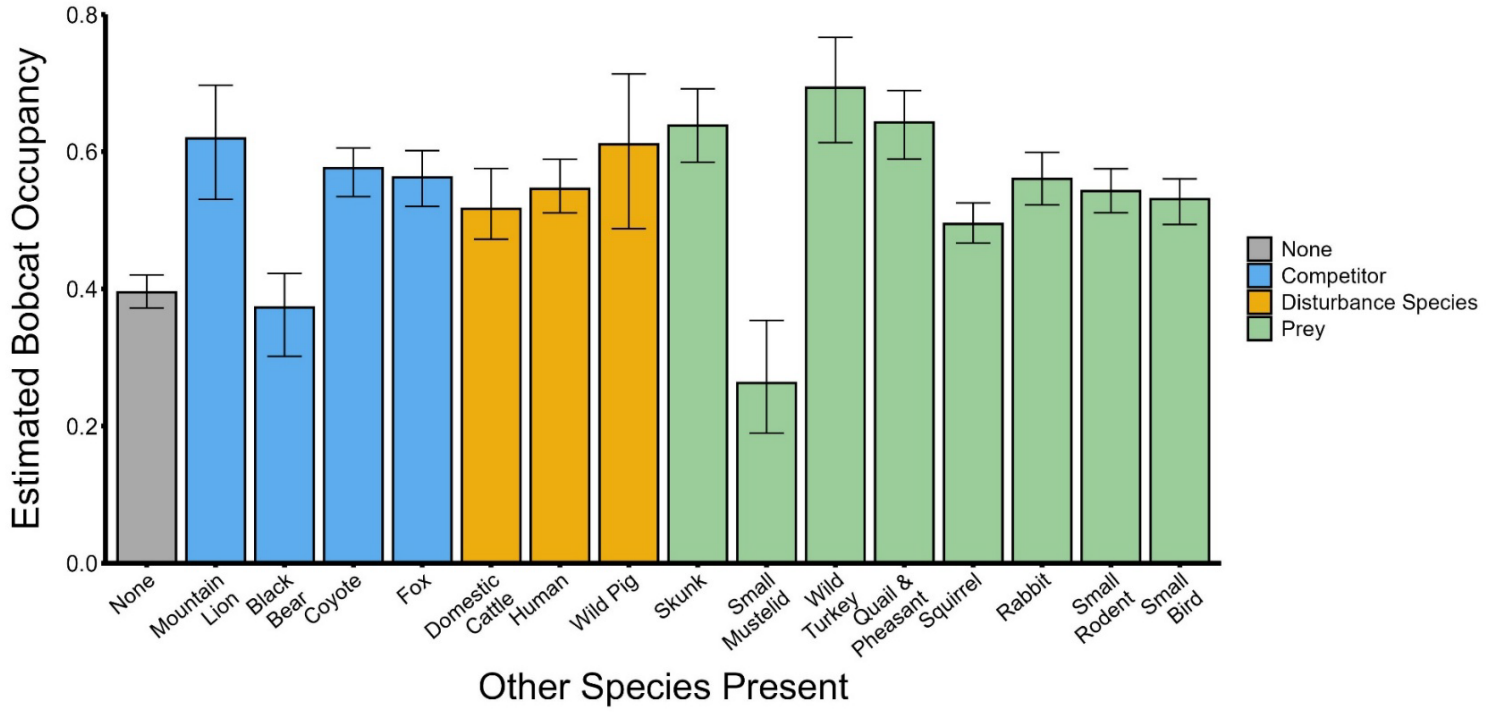

Figure 12. Estimated bobcat occupancy with 95% confidence interval bars based on the presence of competitor, disturbance, and prey species. The bar labeled "None" represents unconditional bobcat occupancy- not based on the presence or absence of any other species. All effects were significant except that of black bears.

4.5 TEMPORAL ACTIVITY ANALYSIS

Bobcats' temporal activity was primarily nocturnal or crepuscular across our study sites in California (Figure 13). Their activity overlapped the most out of all species with coyotes ($Dhat_4$ = 0.89), although mountain lion was a close second ($Dhat_4$ = 0.87). Of the competitors, black bear had the least overlap with bobcat activity ($Dhat_4$ = 0.60). Of the disturbance species, bobcat activity overlapped the most with wild pigs ($Dhat_4$ = 0.76) and the least with humans ($Dhat_4$ = 0.25). Of the prey species, bobcat activity overlapped the most with rabbits ($Dhat_4$ = 0.86) and the least with squirrels ($Dhat_4$ = 0.26). All the species with low temporal overlap with bobcats displayed strongly diurnal activity (Figure 13).

In our temporal activity analysis, the best fitting model of factors influencing bobcat activity patterns (based on adjusted R^2) included Leporidae, Sciuridae, coyote, and an interaction between gray fox and bobcat (adjusted R^2 = 0.41, F (4,39) = 8.58, $p < 0.001$; Table 18). Bobcats were detected at 46 of the 48 full study areas with an average relative abundance index of 1.7 days per camera station. We did not detect any bobcats at the Wishon (WIS) or the Yolo Basin Wildlife Area (YBWA) study areas. Across all land cover types, 36% of bobcat activity occurred between the hours of 05:00 and 17:00 (daytime). We used these daytime hours because most of the study areas used for this analysis (43%) were running through the spring season when daylight hours are shorter. Bobcat daytime activity was greater in areas where squirrels (typically diurnal) had a higher relative abundance index and lower in areas where Leporids (typically nocturnal or crepuscular) had a higher relative abundance index. Further, bobcat daytime activity was significantly higher ($p < 0.05$) in evergreen forests (Table 5), where more Sciuridae activity was detected, compared to either herbaceous or shrub habitats where more Leporids and other rodent species were detected. Rodents had high relative abundance indices in all habitats, with the lowest variation of any prey species (SD = 2.9) and as a result, their relative abundance may not affect bobcat activity patterns as much as those of the more variable squirrel (SD = 5.84) and rabbit (SD = 4.52) populations. Our results also suggest a somewhat negative association between bobcat daytime activity with increasing coyote relative abundance ($p<0.05$). Conversely, bobcat daytime activity increased significantly with a greater relative abundance index of gray foxes, however this effect is moderated by bobcat relative abundance. When bobcat relative abundance was low, the effect of gray fox relative abundance on bobcat daytime activity was much weaker than when bobcat relative abundance was high.

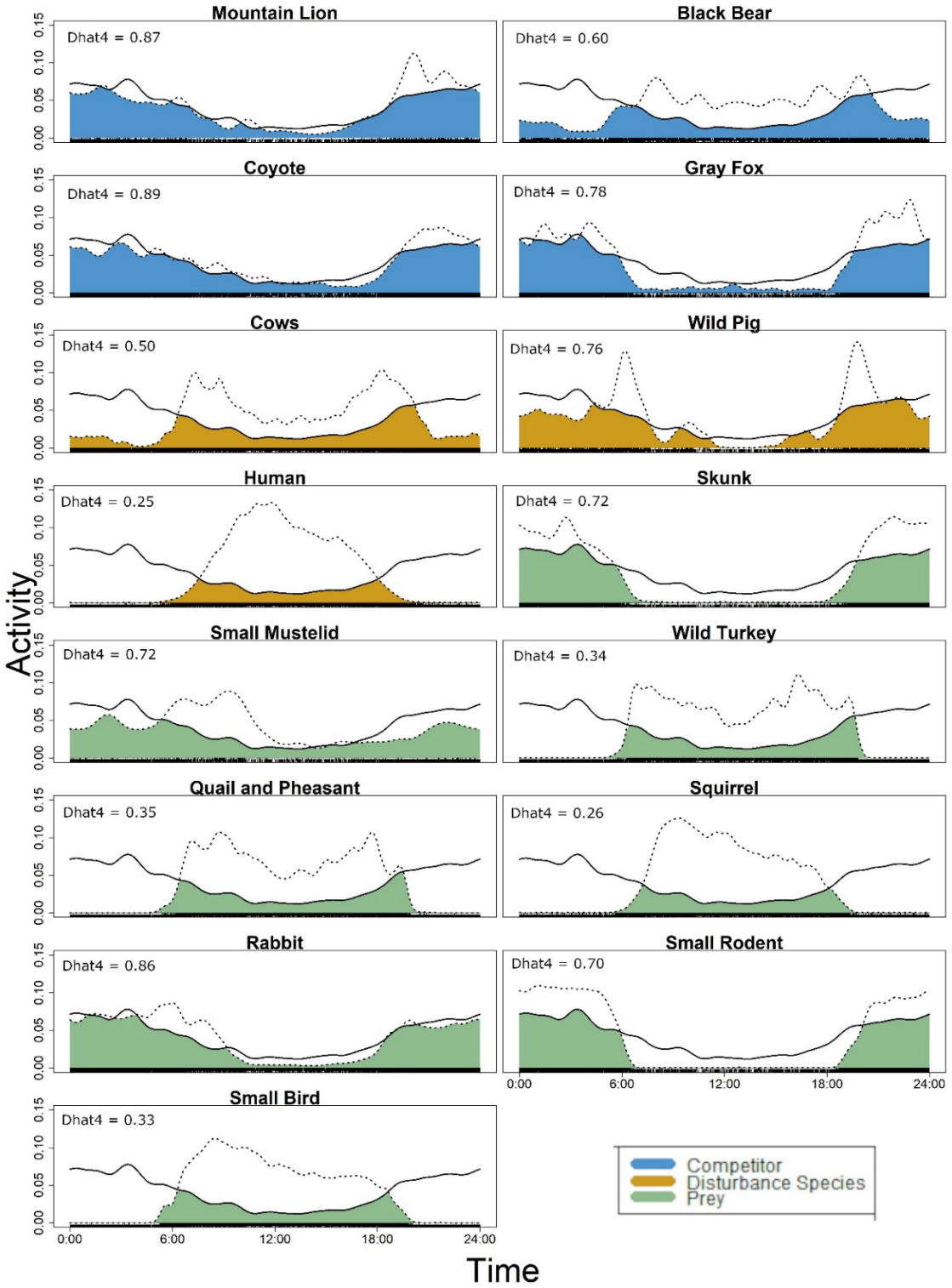

Figure 13. Temporal overlap between bobcats (solid black line) and competitor, disturbance, or prey species (dotted black line, noted at top of each graph). Color under lines indicates amount of overlap. Dhat4 = measure of overlap from 0 (no overlap) to 1 (total overlap). No distributions arose by chance (p-value<0.05 for all).

Table 18. Linear regression results for bobcat day use. All activity levels are log-transformed.

Variable	Coefficient	Standard Error	95% CI	*t* Statistic	*p*-Value
Intercept	39.37	9.44	(20.27, 58.47)	4.17	< 0.001
Leporidae	-10.40	3.97	(-18.42, -2.37)	-2.62	0.01
Sciuridae	9.16	3.47	(2.15, 16.18)	2.64	0.01
Bobcat*Gray Fox	4.08	2.05	(-0.06, 8.22)	1.99	0.05
Coyote	-6.11	4.52	(-15.26, 3.04)	-1.35	0.18

Photo by Jack Clark

4.6 GPS COLLAR DEPLOYMENT, HOME RANGE, AND MOVEMENTS

GPS Collar Deployment. Between March of 2021 and December of 2023, a total of 46 bobcats were captured across 16 counties (Table 19 & Figure 5). Of these, 22 were captured using specially trained hounds, 23 were captured using cage traps, and one was collared before release from a wildlife rehabilitation facility. Forty-one of those individuals weighed enough to be fitted with a GPS collar. Twenty-five male and 16 female bobcats were collared. Four of the five captured bobcats that were too small to collar were female and one was male. All collared bobcats were estimated to be at least one year old, with most estimated to be two to four years of age based upon dental characteristics. The average weight of captured bobcats was 6.9 kgs (15.2 lb.) for females and 9.6 kgs (21.1 lbs.) for males. The largest bobcat was a 16.4 kg (36.1 lb.) male collared on the Tahoe National Forest in Sierra County. The smallest bobcat (too small to collar) was a female (4.8 kgs or 10.6 lbs.) from San Luis Obispo County. Of the 41 deployed GPS collars, 37 collars were retrieved by field staff going to the last known GPS location and listening for the collar's VHF signal until it was successfully found. We collected 78,521 collar locations from those collars. Four collars stopped sending GPS locations and were not retrieved.

Home Range. We completed a home range analysis of GPS collar data for 39 (Figure 5) of the 41 collared bobcats (15 females and 24 males; Table 19). We included all bobcats (n=39) with 100 or more GPS locations, after erroneous data points had been removed. Two bobcats were excluded from this analysis (INY-F1 and RIV-M1) whose collars had failed before collecting 100 GPS locations.

Using the adaptive 99% LoCoH method, home range size for females ranged from 1.3 to 36.6 km^2, with an average of 13.6 km^2 (SD=11.6), and an average core use area—50% LoCoH home range—of 2.4 km^2 (SD=2.1). Home range sizes for male bobcats ranged from 5.4 to 93.4 km^2 with an average of 29.1 km^2 (SD=23.7), and an average core use area of 4.1 km^2 (SD=3.4). We found a significant difference in both 95% and 99% home range size (p=0.05 and 0.03) between sexes and a marginally significant difference in core use area size by sex (p=0.07, Wilcoxon rank sum test).

Home range and core use areas for bobcats that were collared for over a year were compared using a Kruskal-Wallis rank sum test to see if there was any significant difference in home range sizes over different seasons (Table 20). Within each sex, neither overall home range size nor core use area size differed significantly by season ($p > 0.05$). This could be due in part to our limited sample of collared cats in high elevation areas with heavy seasonal variation. We collared nine cats in such areas but only two provided over a year of GPS locations. However, between sexes we had moderate to strong evidence for a difference in both home range size ($p < 0.06$) and core use area ($p < 0.9$) during the wet season as well as moderate evidence ($p < 0.1$) for a difference in home range size during the kitten season.

Investigation of the relationships between population density estimates, home range size and elevation showed a significantly negative correlation between elevation and bobcat population density estimates (Pearson correlation coefficient $r(29) = -.48$, $p = .006$), with population density decreasing at higher elevations. A significantly negative correlation was detected between population density and home range size ($r(29) = -.62$, $p < 0.001$), with home range size decreasing with an increase in population density. Lastly, we detected a significant positive correlation between home range size and elevation ($r(29) = -.58$, $p < 0.001$), with an increase in home range size at higher elevations.

Movements. Female collared bobcats traveled a minimum path distance of 2.9 ± 0.4 km per day on average. The longest path distance calculated for a female bobcat in one day was by SBD-F1 who traveled 14.4 km in San Bernardino County (Table 21). Males traveled an average path distance of 3.8 ± 0.4 km per day, and the longest path distance traveled in one day was 21.5 km by INY-M1 in Inyo County. Among female bobcats, long distance travel occurred evenly across the three seasons (Table 21). However, 12 of the 19 male bobcats (63%) traveled the farthest in the Wet-Winter/Mating season, when most bobcat breeding is known to occur.

There were seven bobcats (one female and six males) who undertook a long-distance travel event outside of their home ranges. These long-distance travel events ranged from two days to one hundred days and the total distances for these movements ranged from 7.9 km to 89 km. The bobcat who traveled for the longest period was a male (SIE-M5) who spent the months of mating season (December–February) outside of his home range. The female who traveled outside of her home range (SBD-F1) mentioned above) did so in height of summer and then died a month later. Two other males (SBD-M1 and SIE-M2) dropped their collars within two days and 22 days respectively, of their travel journeys leaving us with no information about their final whereabouts. One male (SIE-M3) was nine days into his journey and was approximately 18 km straight distance outside of his home range when he died. The final male (SIE-M4) traveled for 22 days between November and December approximately as far out as 21 km direct distance from his home range before returning.

Table 19. List of the bobcats captured for the California Bobcat Project, the county where they were captured, the bobcat's body weight, date of capture and date when the collar stopped being active, the average elevation in their home range, the number of days the collar was active, the number of GPS locations gathered, and the core use area (50% LoCoH) and home range (95 and 99% LoCoH) reported in km^2.

Bobcat ID[1]	County	Body Mass (kg)	Date of Capture	Number of Days Collar Active[2]	Number of GPS Locations[4]	Average Elevation (m) in Home Range[3]	50% LoCoH (km^2)	95% LoCoH (km^2)	99% LoCoH (km^2)
BUT-F1	Butte	6.0	2/15/2022	Not collared	NA	NA	NA	NA	NA
BUT-F2	Butte	6.2	3/4/2022	Not collared	NA	NA	NA	NA	NA
BUT-F3	Butte	7.3	3/7/2022	450	3,546	32	0.4	2.7	3.5
BUT-M1	Butte	10.0	2/8/2022	316	2,420	32	1.6	4.6	6.4
BUT-M2	Butte	11.0	2/26/2022	407	3,155	27	5.7	35.1	44.7
GLE-F1	Glenn	7.3	2/8/2022	450	3,491	40	0.3	3.1	4.1
GLE-M1	Glenn	9.5	2/3/2022	427	3,306	39	1.1	5.8	7.3
GLE-M2	Glenn	8.0	2/16/2022	414	3,282	39	0.7	5.4	10.7
INY-F1	Inyo	7.9	2/3/2023	3 collar failed	6	NA	NA	NA	NA
INY-M1	Inyo	7.9	5/18/2022	457	3,481	1,398	2.2	16.5	23.7
INY-M2	Inyo	7.5	1/31/2023	401	2,874	1,429	9.6	41.1	52.6
KER-F1	Kern	6.5	3/7/2021	501	3,426	1,017	1.0	3.6	4.3
KER-M1	Kern	8.0	3/4/2021	450	3,420	1,027	1.3	4.3	5.4
MEN-M1	Mendocino	6.0	10/13/2021	200	1,353	80	3.1	8.5	12.9
MEN-M2	Mendocino	12.0	10/22/2021	325	2,338	57	1.3	7.6	11.6
MNO-F1	Mono	8.0	5/28/2021	288	2,188	2,226	1.6	11.1	17.0

Bobcat ID[1]	County	Body Mass (kg)	Date of Capture	Number of Days Collar Active[2]	Number of GPS Locations[4]	Average Elevation (m) in Home Range[3]	50% LoCoH (km^2)	95% LoCoH (km^2)	99% LoCoH (km^2)
MNO-F2	Mono	7.5	2/6/2023	396	3,118	1,710	4.0	16.4	19.0
MOD-F1	Modoc	7.0	7/1/2021	410	3,221	1,638	2.6	13.7	16.8
MOD-F2	Modoc	8.0	7/5/2021	405	2,966	1,538	1.3	6.1	7.9
MOD-M1	Modoc	11.3	7/9/2021	400	3,097	1,625	3.9	15.5	20.8
MON-F1	Monterey	6.0	3/22/2021	160	463	407	0.5	1.2	1.6
MON-F2	Monterey	7.0	3/19/2021	17	152	402	0.7	1.1	1.3
MON-M1	Monterey	10.0	3/21/2021	180	1,422	370	1.1	6.0	9.2
MON-M2	Monterey	10.0	3/19/2021	450	3,455	339	0.8	11.6	22.0
RIV-M1	Riverside	7.3	3/3/2022	28 collar failed	53	NA	NA	NA	NA
SAC-F1	Sacramento	6.8	12/10/2023	218 collar failed	368	35	0.5	2.2	2.2
SAC-M1	Sacramento	9.8	1/19/2023	22	167	60	1.5	8.9	12.4
SBD-F1	San Bernardino	7.0	1/22/2022	208	1,522	946	3.0	13.2	22.4
SBD-M1	San Bernardino	8.2	5/19/2022	248	1,923	1,574	5.0	23.7	32.0
SCL-M1	Santa Clara	10.0	3/25/2022	113 collar failed	210	105	1.7	6.7	9.0
SCL-M2	Santa Clara	7.7	6/15/2022	450	3,412	355	1.3	6.5	8.6
SIE-F1	Sierra	9.5	11/3/2021	104	198	1,703	5.0	25.0	36.6
SIE-M1	Sierra	12.7	11/2/2021	314	2,505	1,957	7.2	46.5	64.9
SIE-M2	Sierra	16.4	11/4/2021	312	2,464	1,776	5.3	23.7	31.8
SIE-M3	Sierra	9.5	11/5/2021	132	954	2,018	7.7	32.0	41.7
SIE-M4	Sierra	10.0	11/6/2021	120	925	1,886	3.6	48.5	70.7

Bobcat ID[1]	County	Body Mass (kg)	Date of Capture	Number of Days Collar Active[2]	Number of GPS Locations[4]	Average Elevation (m) in Home Range[3]	50% LoCoH (km^2)	95% LoCoH (km^2)	99% LoCoH (km^2)
SIE-M5	Sierra	10.9	11/8/2021	338	2,744	1,879	11.4	62.2	93.4
SIS-F1	Siskiyou	7.2	11/23/2021	67	159	1,552	2.3	16.6	16.6
SIS-F2	Siskiyou	5.5	11/29/2021	19	129	1,392	6.8	16.1	16.1
SIS-F3	Siskiyou	6.8	12/9/2021	78	551	1,317	6.3	28.8	34.2
SIS-M1	Siskiyou	10.9	11/23/2021	20	148	1,396	10.6	33.6	36.5
SIS-M2	Siskiyou	10.4	11/27/2021	105	554	1,323	9.3	47.9	59.2
SLO-F1	San Luis Obispo	4.8	2/1/2022	Not collared	NA	NA	NA	NA	NA
SLO-F2	San Luis Obispo	5.8	2/9/2022	Not collared	NA	NA	NA	NA	NA
THE-M1	Tehama	6.6	2/1/2022	Not collared	NA	NA	NA	NA	NA
TEH-M2	Tehama	7.8	2/6/2022	424	3,355	797	2.4	8.6	11.5

[1] Bobcat IDs are based on the county code for where they were captured, the sex of the animal (f-female and m-male) and a running number of bobcats captured in that county.
[2] Number of days collar active is calculated from capture date to the date a collar was dropped, the date a mortality signal indicated that the bobcat had died, or the date the collar failed.
[3] Elevation is included here for comparison of home range size at different elevations.
[4] The total number of GPS locations recorded prior to removal of erroneous data.

Table 20. Average male and female bobcat home range sizes (km2) across the three different seasons (winter/wet, kitten, summer/dry) for bobcats whose collar was deployed for over 365 days.

	Winter/Wet (Dec-Feb)		Kitten (March-May)		Summer/Dry (June-Nov)	
	Home Range	Core Use	Home Range	Core Use	Home Range	Core Use
Male (n = 10)	20.0	3.0	18.2	2.5	18.3	3.2
Female (n = 6)	10.6	1.8	8.0	1.9	11.8	1.8

Table 21. Average path distances traveled by male and female bobcats per day, longest path distance traveled in one day and season that the longest distance travel occurred in. SE= Standard Error

Bobcat Id	Sex	Average Travel Distance ± Se (Km/Day)	Longest Distance Traveled (Km/Day)	Season of Long-Distance Travel
BUT-F3	Female	2.7 ± 0.07	7.8	Winter/Wet
GLE-F1	Female	2.1 ± 0.06	5.4	Kitten
KER-F1	Female	3.4 ± 0.05	7.6	Kitten
MNO-F1	Female	3.4 ± 0.10	8.9	Summer/Dry
MOD-F1	Female	3.5 ± 0.08	9.1	Kitten
MOD-F2	Female	4.3 ± 0.08	8.7	Summer/Dry
MON-F1	Female	0.7 ± 0.07	2.4	Kitten
SBD-F1	Female	4.5 ± 0.12	14.4	Summer/Dry
SIE-F1	Female	1.9 ± 0.16	8.7	Winter/Wet
AVERAGE		**2.9 ± 0.4**	**8.1**	
BUT-M1	Male	4.1 ± 0.11	9.7	Kitten
BUT-M2	Male	3.0 ± 0.11	13.5	Kitten
GLE-M1	Male	4.2 ± 0.09	10.1	Winter/Wet
GLE-M2	Male	4.5 ± 0.08	11.0	Winter/Wet
INY-M1	Male	8.5 ± 0.17	21.5	Winter/Wet
KER-M1	Male	3.7 ± 0.06	7.7	Kitten

Bobcat Id	Sex	Average Travel Distance ± Se (Km/Day)	Longest Distance Traveled (Km/Day)	Season of Long-Distance Travel
MEN-M1	Male	0.9 ± 0.05	3.9	Winter/Wet
MEN-M2	Male	3.2 ± 0.08	8.0	Summer/Dry
MOD-M1	Male	5.5 ± 0.12	13.1	Winter/Wet
MON-M1	Male	1.7 ± 0.07	6.0	Summer/Dry
MON-M2	Male	2.0 ± 0.05	6.4	Winter/Wet
SBD-M1	Male	4.5 ± 0.09	9.4	Winter/Wet
SCL-M2	Male	2.7 ± 0.07	9.7	Winter/Wet
SIE-M1	Male	3.8 ± 0.12	10.2	Kitten
SIE-M2	Male	3.9 ± 0.12	10.4	Summer/Dry
SIE-M3	Male	4.5 ± 0.18	9.9	Winter/Wet
SIE-M4	Male	3.3 ± 0.27	14.3	Winter/Wet
SIE-M5	Male	4.6 ± 0.11	12.3	Winter/Wet
TEH-M2	Male	4.4 ± 0.09	10.8	Winter/Wet
AVERAGE		**3.8 ± 0.4**	**10.4**	

Photo by the CDFW Bobcat Project

4.7 RESOURCE SELECTION FUNCTIONS AND PERCENT LAND COVER USE

We fit a total of 26 models in our model selection process. The top model included distance to herbaceous cover, distance to urban areas, aspect, terrain ruggedness, the linear and quadratic term for both aspect and terrain ruggedness, and an interaction between distance to hardwood cover and sex, distance to shrub cover and sex, and elevation and season. It also included a random effect of cat ID (Table 22). Because we used distance-to as a metric for all habitat types, negative beta values show selection for that habitat type. Males were more likely to select hardwood cover (β = -0.74 SE = 0.04 $p < 0.01$) but less likely to select shrub cover (β = 1.25 SE = 0.06 $p < 0.01$) compared to females (Figure 14). Bobcats generally selected for lower elevations within their home range (β = -1.18 SE = 0.09 $p < 0.01$) with minimal seasonal variation (Table 23). Bobcats selected herbaceous cover (β = -2.39 SE = 0.12 $p < 0.01$), and rivers (β = -0.07 SE = 0.06 $p = 0.24$) and avoided urban areas (β = 0.47 SE = 0.02 $p < 0.01$). These did not vary by sex. While the effect of distance to river was not significant, it was in our top model using AICc and therefore still relevant to bobcat habitat selection. Aspect showed a quadratic relationship with bobcat use; bobcats selected south facing slopes (β = -0.02 SE = 0.01 $p < 0.01$ for the quadratic term). Similarly, the quadratic effect of terrain ruggedness showed a selection for areas with moderate elevation change within their home range (β = -0.08 SE = 0.01 $p < 0.01$ for the quadratic term). The use of random intercepts largely accounts for variation in sample sizes and are not directly interpretable (Gillies et a. 2006). We found some variance in selection between individual bobcats ($\sigma^2 = 8.48$).

The percentage of GPS points in each landcover type varied by ecoregion, likely because the available habitat varies by ecoregions. Agriculture was more common for bobcats in the Great Valley than anywhere else, conifer was typically the most common landcover type for bobcats in the Sierra Nevada ecoregion, and hardwood was typically the most common landcover for bobcats at mid to low elevations. Shrub and herbaceous landcovers were used by all the bobcats, but to varying degrees. Overall hardwood and conifer were the most common landcover types used by collared bobcats in this project (Table 24).

Table 22. Top 10 resource selection function models based on AICc. HW= hardwood, Herb= herbaceous, Elev= elevation, TR= terrain ruggedness, Road Distance= secondary roads only.

Model	Parameters	AICc	Δ AICc	AICc Weight
HW Distance*Sex + Shrub Distance*Sex + Herb Distance + Urban Distance + Elev*Season + Aspect + Aspect^2 + River Distance + TR + TR^2 + (1 | Cat_ID)	19	123750	0.00	1.00
HW Distance + Shrub Distance*Sex + Herb Distance*Sex + Urban Distance + Elev*Season + Aspect + Aspect^2 +River Distance + TR + TR^2 + (1 | Cat_ID)	19	124101	351.04	0.00
HW Distance + Shrub Distance*Sex + Herb Distance + Urban Distance + Elev*Season + Aspect + Aspect^2 + River Distance + TR +TR^2 + (1 | Cat_ID)	18	124144	393.6	0.00
HW Distance*Sex + Shrub Distance + Herb Distance + Urban Distance + Elev*Season + Aspect + River Distance + TR +TR^2 + Road Distance + (1 | Cat_ID)	18	124166	416.38	0.00
Conifer Distance*Season + Shrub Distance*Sex + Urban Distance + Herb Distance + TR + TR^2 + Elev*Season + (1 | Cat_ID)	17	124363	613.37	0.00
HW Distance*Sex + Shrub Distance + Herb Distance + Urban Distance + Elev*Season + Aspect +Aspect^2 + River Distance +TR + TR^2 + (1 | Cat_ID)	18	124368.8	618.79	0.00
HW Distance + Shrub Distance + Herb Distance + Urban Distance*Sex + Elev*Season + Aspect + Aspect^2 + River Distance + TR + TR^2 + (1 | Cat_ID)	18	124498.6	748.62	0.00
HW Distance + Shrub Distance + Herb Distance*Sex + Urban Distance + Elev*Season + Aspect + Aspect^2 +River Distance + TR + TR^2 + (1 | Cat_ID)	18	124660.6	910.63	0.00
Conifer Distance*Season + HW Distance + Shrub Distance + Urban Distance*Sex + Herb Distance + (1 | Cat_ID)	13	125120.1	1370.06	0.00
Road Distance + River Distance + Shrub Distance*Sex + TR + Aspect*Season + (1 | Cat_ID)	13	125205.1	1455.13	0.00

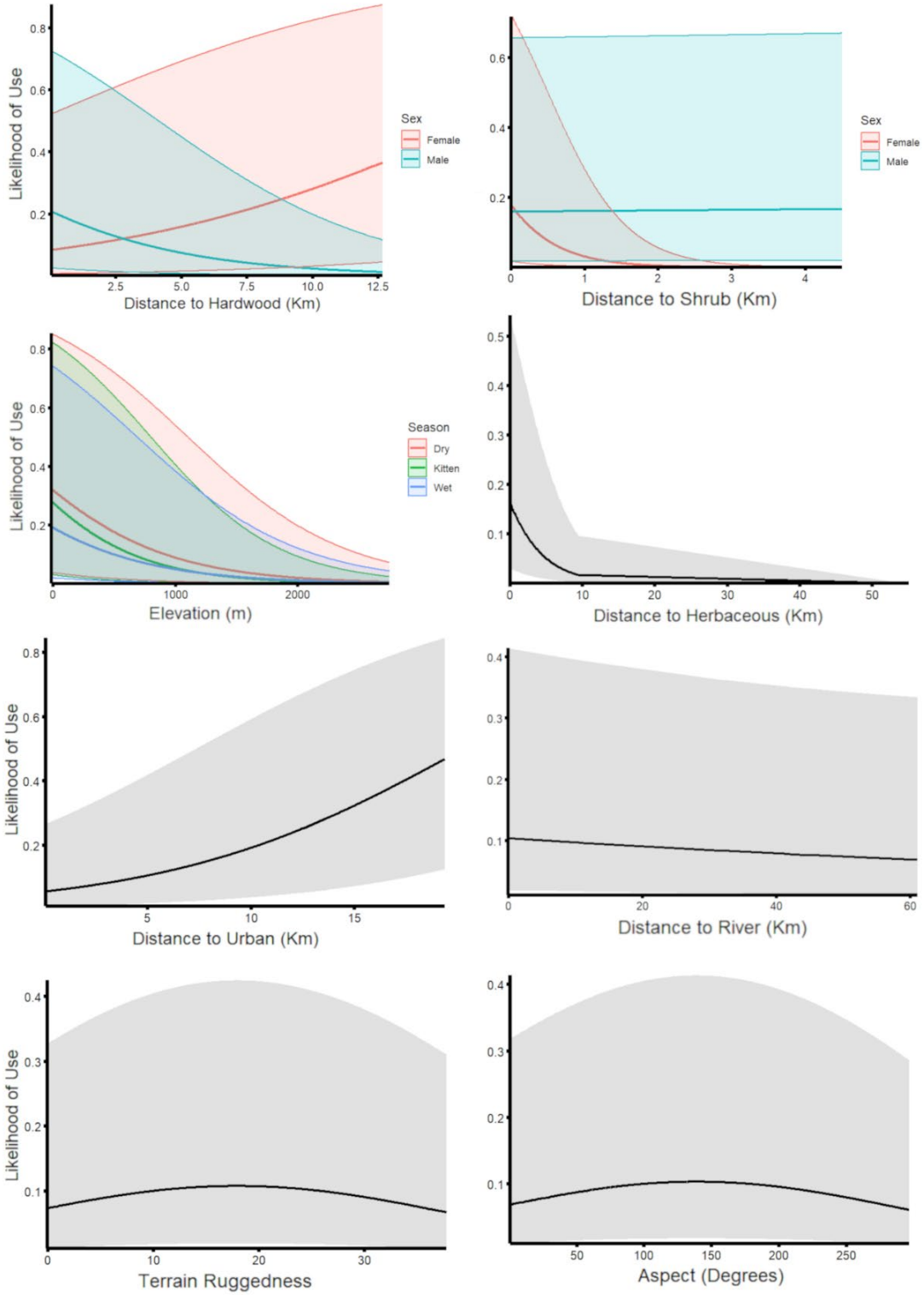

Figure 14. Results from resource selection function top model. Shading around line represents 95% confidence intervals.

Table 23. Resource selection function random and fixed effects results. Negative coefficients indicate selection for distance variables.

Random Effect	Variance	
Cat ID (Intercept)	8.48	
Fixed Effect	**Estimate (β)**	**95% CI**
Intercept	-2.19	(-3.71, -0.67)
Hardwood Distance	0.28	(0.22, 0.34)
Shrub Distance	-1.24	(-1.35, -1.14)
Herbaceous Distance	-2.39	(-2.63, -2.14)
Urban Distance	0.47	(0.43, 0.52)
River Distance	-0.07	(-0.18, 0.05)
Elevation	-1.18	(-1.34, -1)
Aspect	-0.06	(-0.08, -0.04)
Aspect^2	-0.02	(-0.04, -0.01)
Terrain Ruggedness	0.16	(0.11, 0.21)
Terrain Ruggedness^2	-0.08	(-0.11, -0.05)
Sex (Male)	0.53	(-1.31, 2.37)
Season (Kitten)	-0.51	(-0.55, -0.48)
Season (Wet)	-0.64	(-0.67, -0.6)
Hardwood*Male	-0.74	(-0.81, -0.67)
Shrub*Male	1.25	(1.14, 1.36)
Elevation*Kitten Season	-0.25	(-0.29, -0.22)
Elevation*Wet Season	0.04	(0, 0.08)

Table 24. Bobcat GPS collar data broken down by the land cover types* each individual spent time in. The land cover types with the highest percent of GPS locations are presented in **bold**.

Bobcat ID	Number GPS Locations Used	Percent Of GPS Locations In (fVeg) Land Cover Types*
BUT-F1	NA	Not collared
BUT-F2	NA	Not collared
BUT-F3	3545	**Agriculture 29%**, **Hardwood 27%**, **Herbaceous 30%**, Shrub 13%
BUT-M1	2420	**Agriculture 24**%, Barren/Other 1%, **Hardwood 46%**, **Herbaceous 21%**, Shrub 4%, Wetland 5%
BUT-M2	3155	**Agriculture 56%**, **Hardwood 31%**, Herbaceous 7%, Shrub 1%, Wetland 5%
GLE-F1	3491	**Agriculture 65%**, **Hardwood 30%**, Herbaceous 3%, Shrub 1%, Wetland 1%
GLE-M1	3306	**Agriculture 71%**, Barren/Other 1%, **Hardwood 19%**, Herbaceous 1%, Wetland 7%
GLE-M2	3268	**Agriculture 78%**, **Hardwood 18%**, Wetland 3%
INY-F1	6	Omitted - collar failed
INY-M1	3481	**Desert 26%**, Hardwood 13%, **Shrub 18%**, Urban 5%, **Wetland 38%**
INY-M2	2874	**Barren/Other 20%**, **Desert 77%**, Shrub 2%
KER-F1	3426	Conifer 10%, **Hardwood 38%**, **Herbaceous 46%**, Shrub 6%
KER-M1	3420	Conifer 5%, **Hardwood 37%**, **Herbaceous 55%**, Shrub 3%
MEN-M1	1353	**Conifer 85%**, Hardwood 5%, Herbaceous 7%, Shrub 4%
MEN-M2	2338	Baren/Other 1%, **Conifer 76**%, Hardwood 6%, Herbaceous 14%, Shrub 2%
MNO-F1	2188	Hardwood 12%, Herbaceous 5%, **Shrub 81%**, Wetland 2%
MNO-F2	3118	Barren/Other 1%, **Desert 78%**, Hardwood 10%, Shrub 11%
MOD-F1	3221	**Conifer 78%**, Shrub 21%
MOD-F2	2966	**Conifer 59%**, Hardwood 1%, Herbaceous 5%, **Shrub 29%**, Urban 1%, Wetland 6%

Bobcat ID	Number GPS Locations Used	Percent Of GPS Locations In (fVeg) Land Cover Types*
MOD-M1	3097	**Conifer 66%**, Herbaceous 1%, **Shrub 34%**
MON-F1	463	**Hardwood 43%**, Herbaceous 30%, Shrub 27%
MON-F2	152	**Hardwood 70%**, Shrub 30%
MON-M1	1422	**Hardwood 47%**, **Herbaceous 48%**, Shrub 5%
MON-M2	3455	**Hardwood 78%**, Herbaceous 13%, Shrub 9%
RIV-M1	53	Omitted - collar failed
SAC-F1	368	**Hardwood 47%**, **Herbaceous 30%**, Urban 17%, Water 5%
SAC-M1	167	**Hardwood 52%**, **Herbaceous 26%**, Shrub 9%, Urban 11%, Water 2%
SBD-F1	1522	**Desert 94%**, Shrub 2%, Urban 5%
SBD-M1	1912	**Conifer 80%**, Desert 14%, Shrub 6%
SCL-M1	210	**Agriculture 36%**, Barren/Other 1%, **Hardwood 20%**, **Herbaceous 43%**
SCL-M2	3412	Agriculture 2%, **Hardwood 42%**, **Herbaceous 53%**, Shrub 3%
SIE-F1	794	**Agriculture 25%**, **Conifer 30%**, Herbaceous 3%, **Shrub 41%**, Wetland 1%
SIE-M1	2505	**Conifer 39%**, Herbaceous 2%, **Shrub 58%**
SIE-M2	2282	**Conifer 30%**, Herbaceous 5%, **Shrub 64%**
SIE-M3	893	Barren/Other 1%, **Conifer 86%**, Hardwood 1%, Herbaceous 3%, Shrub 6%, Wetland 2%
SIE-M4	759	**Conifer 37%**, Herbaceous 6%, **Shrub 57%**
SIE-M5	2744	**Conifer 72%**, Hardwood 2%, Herbaceous 4%, **Shrub 20%**, Wetland 1%
SIS-F1	159	**Conifer 95%**, Herbaceous 1%, Shrub 4%
SIS-F2	129	**Conifer 96%**, Herbaceous 2%, Shrub 2%

Bobcat ID	Number GPS Locations Used	Percent Of GPS Locations In (fVeg) Land Cover Types*
SIS-F3	453	Barren/Other 1%, **Conifer 92%**, Herbaceous 1%, Shrub 6%
SIS-M1	151	Barren/Other 1%, **Conifer 87%**, Herbaceous 9%, Shrub 4%
SIS-M2	554	Barren/Other 9%, **Conifer 89%**, Shrub 2%
SLO-F1	NA	Not collared
SLO-F2	NA	Not collared
THE_M1	NA	Not collared
TEH-M2	3355	**Hardwood 50%**, Herbaceous 23%, **Shrub 27%**,

***** *For land cover types we used we used the California Department of Forestry and Fire Protection land cover dataset (CAL FIRE FRAP (fVeg); Table 3) that includes the following landscape variables: Agriculture, Barren/Other, Conifer, Desert, Hardwood, Herbaceous, Shrub, Urban, Water, and Wetland.*

4.8 SURVIVAL AND FACTORS EFFECTING SURVIVAL

Of the forty-one bobcats collared during this effort, twenty remained alive with functional collars for approximately a year before the collars were remotely dropped off. The fates of three bobcats were unknown; their collars were found intact after emitting a mortality signal (no movement for at least 18 hours) but no carcass or other evidence of death or predation was found. An additional four collars stopped sending GPS locations prior to their planned drop off date and were not subsequently heard from or located (Table 19).

Fourteen collared bobcats died during the study (Table 25). The carcasses of ten of those individuals were recovered from the field and necropsied by the CDFW WHL to try to determine cause of death. The primary diagnoses for causes of death for necropsied collared bobcats included: one from gunshot trauma, four from disease (one attributed to Highly Pathogenic Avian Influenza H5N1), two from emaciation, two from trauma/injury associated with predation, and one from suspected traumatic injuries from a large wild turkey. In the case of the bobcat presumably killed in an altercation with a wild turkey, the collared bobcat (SIS-M1) was found dead next to the remains of a large turkey. Necropsy of both animals revealed head and neck trauma to the turkey, and trauma to the bobcat's heart and lungs. Based upon the close proximity of the animals in the field (found right next to each other), lack of other identifiable causes for

the trauma, and the fact that the bobcat had lost weight and was smaller than the turkey, it was suspected the animals had engaged in an altercation that ended both of their lives.

Table 25. Necropsies performed, testing for anticoagulant rodenticides, cause of death and primary diagnosis associated with the cause of death for GPS collared bobcats from the California Bobcat Project.

Bobcat ID*	Necropsied	ARs** Detected	Cause of Death	Primary Diagnosis
BUT-M1	Yes	Yes	Disease	Highly pathogenic avian influenza (HPAI H5N1)
MEN-M1	Yes	Yes	Disease	Heart: dirofilariasis w/ pulmonary endarteritis, thrombosis and interstitial pneumonia
MNO-F1	No	Yes	Predation	Predation
MON-F1	No	Yes	Predation	Predation
MON-F2	No	Yes	Predation	Predation
MON-M1	No	Yes	Trauma / Injury	Suspect Gunshot Trauma
SAC-M1	Yes	Yes	Trauma / Injury	Gunshot Trauma
SBD-F1	Yes	Yes	Euthanized	Emaciated/parasitic infection
SIE-F1	Yes	No	Trauma / Injury	Predation
SIE-M3	Yes	Yes	Disease	Emaciation
SIE-M4	Yes	Yes	Trauma / Injury	Predation
SIS-F2	Yes	Yes	Disease	Emaciation w/ cachexia of unknown cause. Cannot r/o collaring issue
SIS-M1	Yes	No	Trauma / Injury	Acute trauma with interalveolar hemorrhage in lungs
SIS-M2	Yes	Yes	Disease	Emaciation/parasitism

** Bobcat IDs are based on the county where they were captured, the sex of the animal and a running number for that county*
*** Anticoagulant Rodenticides (ARs)*

Liver samples from all 10 necropsied collared bobcats were tested for the presence of ARs. Seven of the ten bobcats (70%) had one or more ARs present in their liver indicating exposure: three individuals had a single AR analyte detected, two individuals had two

AR analytes detected, while one individual each had three and four AR analytes detected (see Section 5.9). None of the exposed bobcats had evidence of AR toxicosis. Adipose or brain tissue from nine of the ten bobcats was tested for the presence of DMB, the metabolite of bromethalin. One collared bobcat (11%; MEN-M1) that died from disease had a positive DMB detection indicating bromethalin exposure.

Although no remains were collected for four mortalities, a field investigation was conducted at each site where the GPS collar was retrieved. Three of the mortality sites had evidence of predation by mountain lion or coyote, including minimal carcass remains, piles of fur, skeletal fragments and gut piles that had not been consumed by the predator. In one case, the GPS location of the mortality overlapped with the GPS locations from a mountain lion that been collared in the same area, further suggesting mountain lion predation. In the fourth case, the investigating biologist reported the carcass had a penetrating wound and suspected firearm trauma as the cause of death.

The survival results of the Bayesian Cox proportional hazard model for the California Bobcat Project included 32 individuals with 63 bobcat-years (Table 7). Adult bobcat mean annual survival estimate was 0.77 (90% credible interval: 0.66 – 0.89).

4.9 STATEWIDE BOBCAT HEALTH SURVEILLANCE

The remains of 149 bobcats (71 females, 68 males, and 10 of unknown sex) were submitted to the WHL for analysis as part of the Statewide Bobcat Health Surveillance project between January 2020 and July 2023. These remains were submitted by animal control, wildlife rehabilitators, members of the public, non-profit organizations, universities, CDFW staff and law enforcement, and other agencies. CDFW staff (n=65) and wild animal care facilities (rehabilitation facilities, zoos, and wildlife sanctuaries, n=55) submitted the highest number of bobcat carcasses (Table 26). Geographically, the highest number of carcasses came from Los Angeles County (n=23).

Necropsies were performed on 128 (87%) bobcat carcasses received by the WHL. Twenty-one bobcat carcasses were not necropsied due to lack of sufficiently detailed collection information, advanced decomposition, or scavenging.

Table 26. Number of bobcat remains submitted to the CDFW Wildlife Health Laboratory for postmortem examination from Jan 1, 2020 – Jul 1, 2023, based on the primary submitter's affiliation.

Submitter Affiliation	No. Bobcat Remains Submitted
Animal Control	9
CDFW	55
NGO/Non-Profit/Private Consultant	6
Other Government Agency	7
Public/Other	7
Rehabilitation/Zoo/Sanctuary	55
University Affiliate	6
Unspecified	4
TOTAL	**149**

Causes of Death. The most frequently identified cause of death (Figure 15) for necropsied bobcats was categorized as 'trauma or injury' or 'euthanasia due to trauma' (n=85). The trauma or injury category was further broken up based on the cause of the trauma or primary diagnosis that caused the death of those animals. Within this category, trauma due to vehicular strike was the number one cause of death (n=48, 32%). Other categories of trauma include: trauma due to gunshot (n=4, 3%), trauma associated with interspecies altercations (4 attacked by canids or coyotes, 1 attacked by raccoons, 1 stomped on by alpaca, n=6, 4%), suspected predation and trauma associated with puncture wounds (n=8, 5%), and other generalized trauma such as fractures to various parts of the body that were not otherwise characterized (n=19, 13%).

The second most frequently identified cause of death for necropsied bobcats was 'disease' or 'euthanasia due to disease' (n=38). Mange was listed as the primary cause of death or secondarily diagnosed issue contributing to death for 76% (n=29) of these diseased bobcats, 11 of which had lesions affecting more than 50% of their bodies (mange class score 3). The mange mite *Notoedres cati* was identified via microscopic examination of skin scrapings or via histology in these cases, with one *Notoedres* infested bobcat also having *Sarcoptes scabeii* mites present in the skin scraping. Forty bobcats had skin lesion evidence of mange infestation of varying severity, and the geographic distribution of mange infestations was limited to roughly the southern 2/3 of the state

(south of San Francisco Bay area), which could have been due to submission bias with more willing submitters from those areas. Los Angeles County had the highest number of submitted bobcats who died of conditions related to or secondary to mange (n=11).

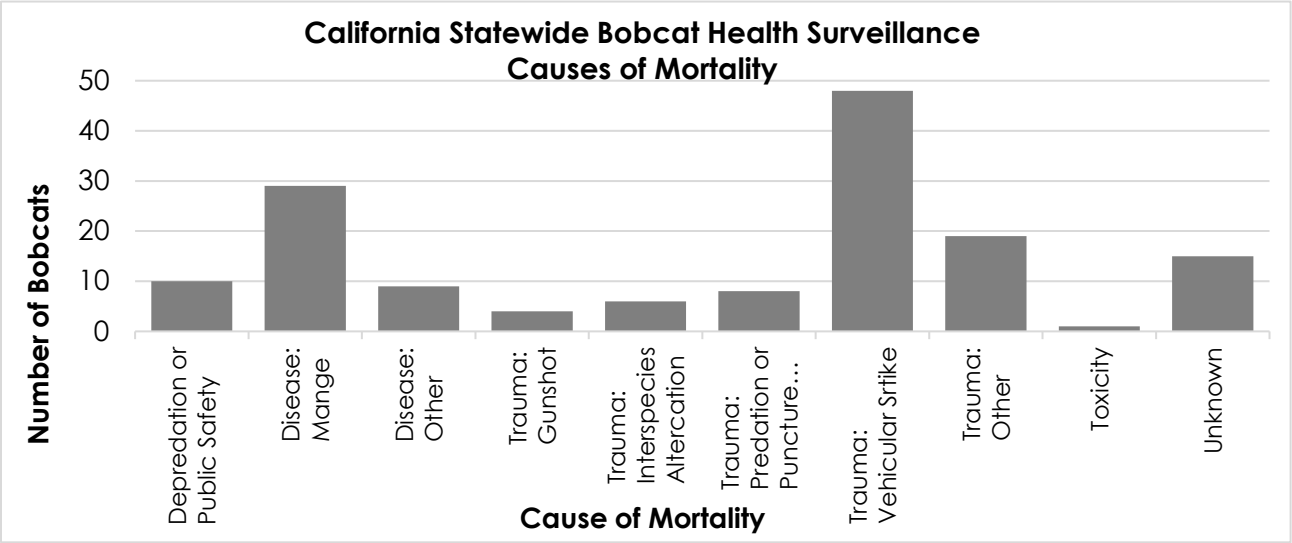

Figure 15. Causes of bobcat mortality based on the necropsy results (n=149) of the statewide bobcat health surveillance study. This does not include mortalities of collared bobcats.

Additional disease diagnoses responsible for mortality included hydrocephalus from feline panleukopenia virus infection (n=1), cardiopulmonary disease from heartworm infection (n=2), chronic kidney disease (n=1), acute severe kidney disease (n=1), highly pathogenic avian influenza virus infection (HPAI, H5N1; n=1), fungal pneumonia (n=1), streptococcus bacteria associated pleuritis (n=1), organ failure complications from emaciation and heavy parasite loads (n = 4), and one case (n=1) with mild verminous (parasitic) pneumonia but no other disease process identified as severe enough to cause death. The single HPAI case was a collared bobcat (BUT-M1) that died in Butte County in December 2022 from viral encephalitis and liver necrosis. Confirmatory testing at the USDA National Veterinary Services Laboratory (Ames, Iowa) determined the bobcat was infected with same emergent strain of HPAI virus (EA/AM reassortment of H5 goose and Guangdong and North American wild bird lineage 2.3.4.4) circulating in wild birds. No bird remains were found in the bobcat's stomach at necropsy.

Eight bobcat carcasses (two adult females and six adult males) submitted to the WHL had been dispatched under depredation permits, all of which were reported to have been killing domestic chickens, ducks, or geese. Two reportedly sick bobcats were dispatched for public safety reasons, one of which was a bobcat from Trinity County who tested positive for rabies virus infection and was the only rabies case diagnosed in our study. The other public safety case was a bobcat that scratched and possibly bit a person and did not leave the area for many hours after the incident, despite having easy access to natural habitat nearby. This bobcat was humanely dispatched by law

enforcement, and the carcass was taken for rabies testing. Anticoagulant rodenticide toxicosis was determined to be the cause of death for one deceased bobcat from Los Angeles County. The bobcat had hemorrhage in the thoracic cavity, pericardium, liver, and kidneys that were not trauma or disease related; no significant histological findings in tissues or tests indicating other disease; and five ARs detected in liver tissue. The cause of death for the other 15 cases was listed as unknown or undetermined.

Viral disease surveillance. Blood from the heart or chest cavity from 94 deceased bobcats were tested for FeLV antigen and FIV antibodies (Table 7). Infection with FeLV and exposure to FIV were rare in our study: one bobcat from Riverside County that died from emaciation and fungal pneumonia had an inconclusive FeLV test result and one bobcat from Los Angeles County that died from trauma was exposed to FIV. After the detection of fatal HPAI infection in a bobcat in 2022, we tested seven bobcats that had brain tissue collected for HPAI infection via RT-PCR at the CAHFS lab. Viral DNA was not detected in these seven bobcats. Bobcats that died prior to the emergence of HPAI in 2022 in wild birds in California were not tested.

Rodenticide Exposure. Anticoagulant rodenticides were detected in the livers of 100 of the 129 (77.5%) bobcats tested, with 83 (64.3%) of these having two or more ARs detected and 60 (46.5%) having three or more ARs detected (Figure 16 & Figure 17). Deceased bobcats tested for ARs were collected in 32 of the 58 counties in California (Figure 18 & Table 27). The single bobcat from Los Angeles County whose cause of death was AR toxicosis had been exposed to five different ARs (two FGARs and three SGARs). One bobcat from Orange County that died from chronic kidney disease had been exposed to six different ARs (three FGARs and three SGARs). Of the 29 bobcats whose deaths were attributed to mange, 28 had been exposed to ARs, and the one bobcat where ARs were not detected was the one case that was positive for sarcoptic mange. Of all bobcats positive for AR exposure 29% died from mange. Consistent with the spatial distribution of mange, AR-positive bobcats with mange were mainly confined to the Southern Coast, Southern Mountains and Valleys, and Central Coast ecoregions; whereas AR-positive bobcats with mortalities attributed to trauma-vehicular strike, trauma-other, and other diseases were relatively dispersed across the state (Figure 19).

Adipose or brain tissue from 106 bobcats across 31 counties was tested for exposure to the non-anticoagulant, neurotoxic rodenticide, bromethalin (Table 27). The bromethalin metabolite, DMB was detected in 13 of the tested bobcats (12.2%), but there were no confirmed or suspected mortalities due to bromethalin. Vitamin D3 (cholecalciferol) levels in kidney tissue were determined for a mature female bobcat from Sierra County after tubular mineralization was observed in the vessels of her lungs and kidneys to rule out cholecalciferol rodenticide toxicosis. Vitamin D3 levels were within normal limits and the mineralization observed is suspected to have been non-clinically significant.

Cause of death and rodenticide detections. Logistic regression revealed notoedric mange mortality was significantly associated with higher odds of AR exposure

compared to the reference group of trauma-hit by car (OR=17.1, 95% CI: 1.7-172.0, *p*=0.02). Trauma-other mortalities also showed a positive association with AR exposure but were not statistically significant (OR=6.0, 95% CI: 0.9-42.4, p=0.07). For a post-hoc assessment, we compared the AR exposure rates between mange cases (28/29) and trauma-other cases (14/18) using a Fisher's Exact Test. While the exposure rates in mange cases were higher than trauma-other cases, the difference was only marginally significant (OR=7.6, 95% CI: 0.7-406.6, p=0.06).

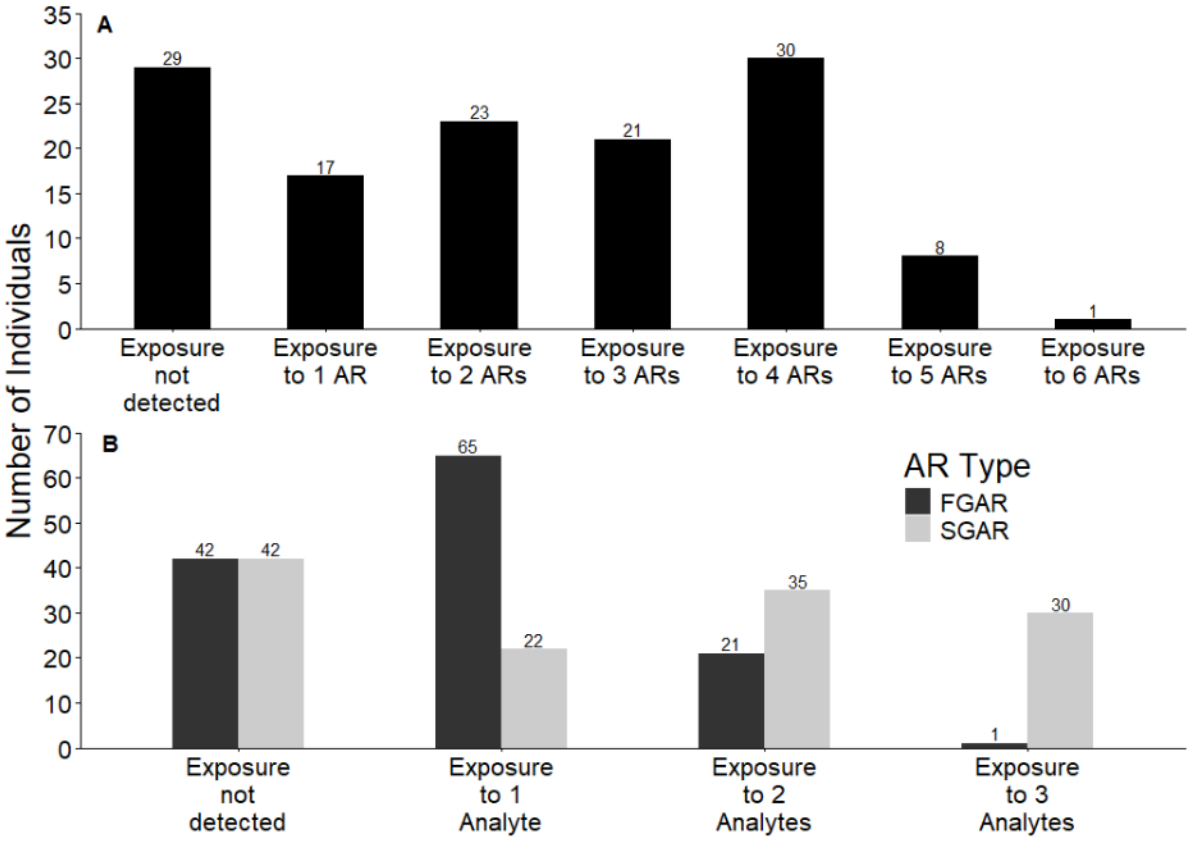

Figure 16. (A) Total number of bobcats with any anticoagulant rodenticides (ARs) detected in their liver out of 129 samples. (B) Number of bobcats with either first (FGAR) or second (SGAR) generation ARs detected in liver. "Exposure not detected" in graph A shows bobcats that had no ARs detected while graph B shows bobcats where a FGAR or SGAR were not detected but does not exclude all AR exposures. Samples were from deceased bobcats submitted to the Wildlife Health Laboratory for postmortem examination between 2020 and 2023. After the postmortem examination, livers were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

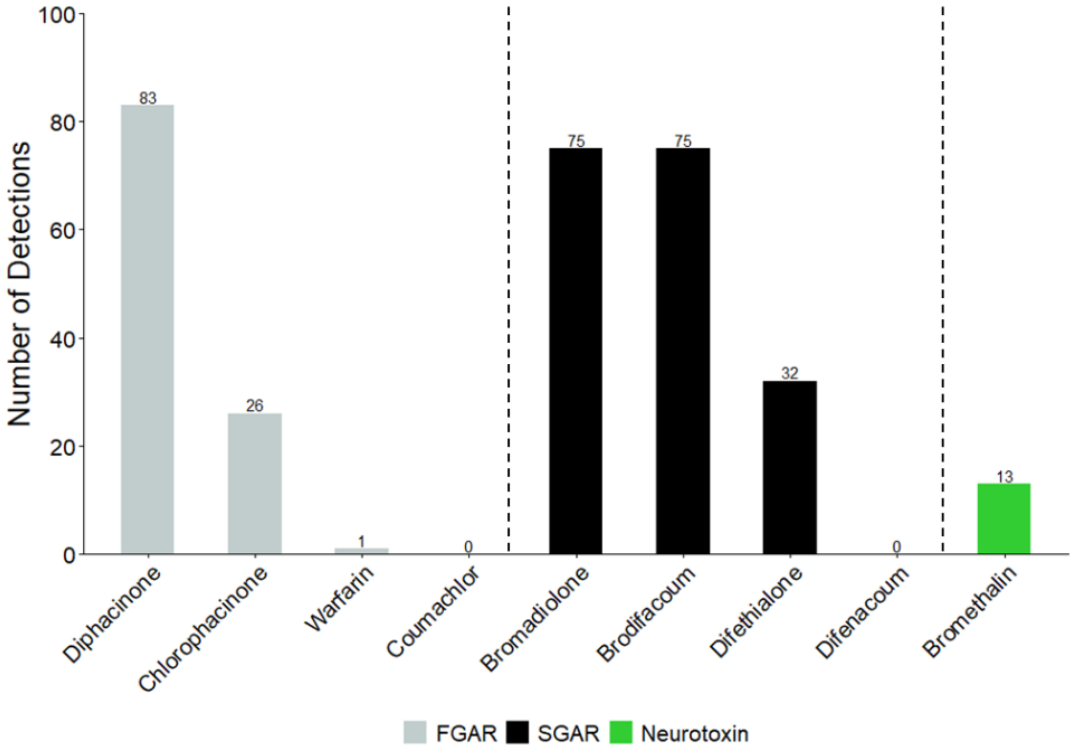

Figure 17. The number of anticoagulant rodenticide (AR) detections in the livers of 100 of the 129 bobcat livers tested, separated by first (FGAR) and second (SGAR) generation ARs. The right column is the number of Bromethalin, a neurotoxic rodenticide, detections in the tissues of 106 bobcats tested during the study period. Samples were from deceased bobcats submitted to the Wildlife Health Laboratory for postmortem examination between 2020 and 2023. After the postmortem examination, livers were submitted for toxicology to the California Animal Health and Food Safety Laboratory in Davis, CA.

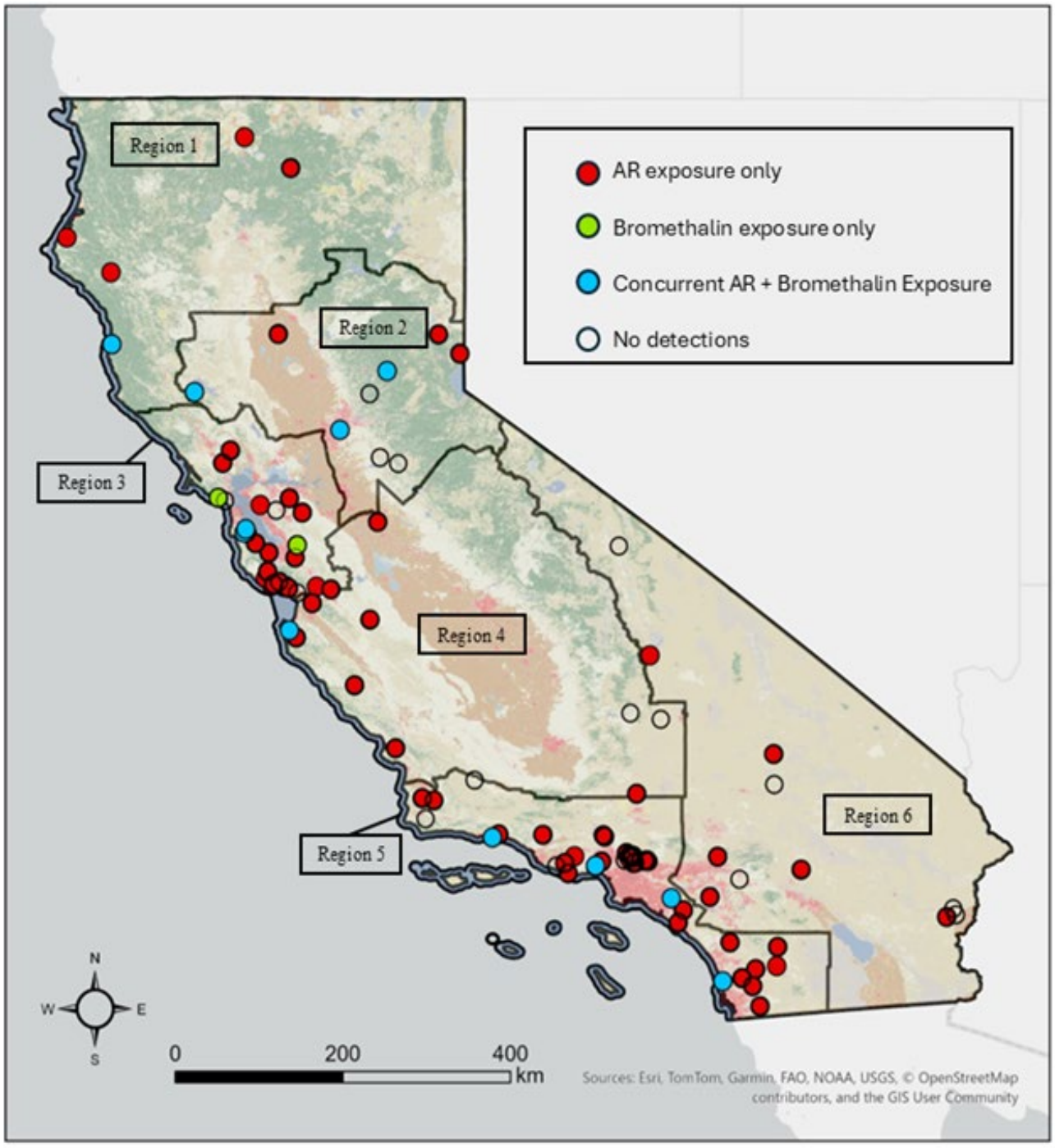

Figure 18. Locations of anticoagulant rodenticide and bromethalin exposures (for samples with known locations) in deceased bobcats submitted to the Wildlife Health Laboratory for postmortem examination between 2020 and 2023. After the postmortem examination between 2020 and 2023. After the postmortem examination, livers were submitted for toxicology to the California Animal Health and Food Safety Laboratory in Davis, CA.

Table 27. Exposure prevalence, and number of toxicosis cases of anticoagulant rodenticides (AR) and Bromethalin (Brom.) in the livers or tissue of 129 and 106 bobcat remains respectively, submitted to the WHL for postmortem examination from January 2020 to July 2023 by county. Samples were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA. We had one confirmed AR toxicosis case in Los Angeles County. See Section 2.5 for description of confirmed and suspected toxicosis. Some bobcat remains were not tested due to advanced decomposition or absence of necessary organs.

County	No. Bobcat Remains Submitted	No. Tested for ARS	AR Exposed	No. Tested for Brom.	Brom. Exposed	Concurrent AR & Brom. Exposure	No. Confirmed or Suspected Toxicosis
Alameda	3	3	2 (66.7%)	2	0 (0.0%)	0 (0.0%)	0
Amador	1	1	0 (0.0%)	1	0 (0.0%)	0 (0.0%)	0
Calaveras	1	1	0 (0.0%)	1	0 (0.0%)	0 (0.0%)	0
Contra Costa	1	1	1 (100.0%)	1	0 (0.0%)	0 (0.0%)	0
El Dorado	1	1	1 (100.0%)	1	0 (0.0%)	0 (0.0%)	0
Fresno	2	0	—	0	—	—	—
Humboldt	2	2	2 (100.0%)	0	—	0 (0.0%)	0
Imperial	1	1	1 (100.0%)	1	0 (0.0%)	0 (0.0%)	0
Inyo	3	2	1 (50.0%)	1	0 (0.0%)	0 (0.0%)	0
Kern	7	4	2 (50.0%)	4	0 (0.0%)	0 (0.0%)	0
Lake	1	1	1 (100.0%)	1	1 (100.0%)	1 (100.0%)	0
Los Angeles	23	22	20 (90.9%)	19	2 (10.5%)	2 (10.5%)	1
Marin	3	2	0 (0.0%)	2	1 (50.0%)	0 (0.0%)	0
Modoc	1	0	—	0	—	—	—
Monterey	6	6	4 (66.7%)	6	1 (16.7%)	1 (16.7%)	0
Napa	1	0	—	0	—	—	—
Nevada	1	0	—	0	—	—	—
Orange	3	3	3 (100.0%)	3	1 (33.3%)	1 (33.3%)	0
Placer	3	3	2 (66.7%)	3	1 (33.3%)	1 (33.3%)	0
Plumas	1	1	0 (0.0%)	0	—	0 (0.0%)	0
Riverside	7	6	3 (50.0%)	6	0 (0.0%)	0 (0.0%)	0

County	No. Bobcat Remains Submitted	No. Tested for ARS	AR Exposed	No. Tested for Brom.	Brom. Exposed	Concurrent AR & Brom. Exposure	No. Confirmed or Suspected Toxicosis
Sacramento	2	2	2 (100.0%)	1	1 (100.0%)	1 (100.0%)	0
San Benito	3	3	3 (100.0%)	2	0 (0.0%)	0 (0.0%)	0
San Bernardino	8	7	3 (42.8%)	5	0 (0.0%)	0 (0.0%)	0
San Diego	9	9	9 (100.0%)	8	1 (12.5%)	1 (12.5%)	0
San Luis Obispo	3	3	2 (66.7%)	2	0 (0.0%)	0 (0.0%)	0
San Mateo	12	7	7 (100.0%)	7	2 (28.6%)	2 (28.6%)	0
Santa Barbara	5	5	3 (60.0%)	5	0 (0.0%)	0 (0.0%)	0
Santa Clara	4	4	3 (75.0%)	4	1 (25.0%)	0 (0.0%)	0
Santa Cruz	11	11	11 (100.0%)	5	0 (0.0%)	0 (0.0%)	0
Siskiyou	2	1	1 (1000.0%)	0	—	—	—
Sonoma	3	3	3 (100.0%)	3	0 (0.0%)	0 (0.0%)	0
Tehama	1	0	—	0	—	—	—
Trinity	1	0	—	0	—	—	—
Ventura	7	4	3 (75.0%)	3	0 (0.0%)	.0	0
Not Specified	6	1	0 (0.0%)	0	—	0 (0.0%)	0
TOTAL	**159**	**129**	**100 (77.5%)**	**106**	**13 (12.3%)**	**11 (10.4%)**	**1**

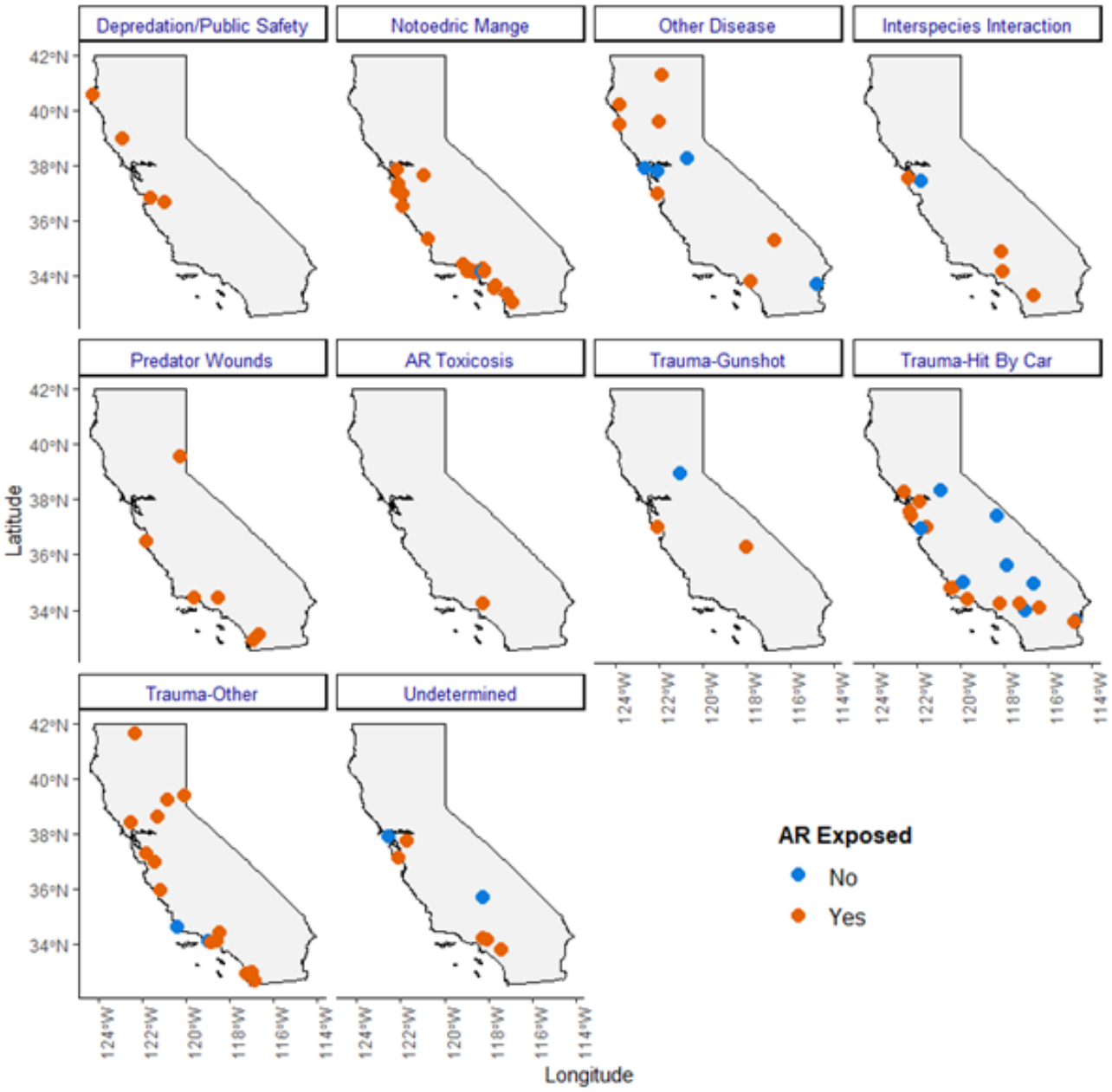

Figure 19. Locations within California of bobcat remains submitted to the WHL by primary cause of death and whether anticoagulant rodenticides were detected in their liver.

4.10 POPULATION MODELING AND SUSTAINABLE MORTALITY

In our Life Stage Simulation analysis (LSA), the average value of lambda (population growth) was significantly higher (df=19233, t=74.873, p<0.001) among unharvested populations ($\bar{x}$=1.05, SD=0.12; Figure 20) than harvested populations ($\bar{x}$=0.91, SD=0.15). Our results suggest that at the stable stage distribution, unharvested populations grew

by approximately 5% each year while on average, harvested populations decreased by approximately 9%. Further, the proportions of each age class were different between harvested and unharvested populations ($p<0.001$). Simulated harvested populations were composed of 38.6% kittens, 16.6% yearlings, and 44.8% adults while simulated unharvested populations were composed of 41.6% kittens, 12.6% yearlings, and 45.8% adults (Figure 21). These differences likely reflect the differences in survival rates among harvested and unharvested populations. In our literature review, average survival rates for yearlings and adults were higher in unharvested populations while limited information on kitten survival was higher in harvested populations. Similarly in harvested populations, a smaller proportion of the surviving female yearlings were reproducing, which could mean kitten rearing was limited to only the most fit or most risk-averse individuals. Lastly, the elasticity of each survival rate was significantly different ($p<0.001$) between harvested and unharvested populations, and importantly across all three age classes. Among all populations, a proportionally small change in adult survival would have roughly 3.5 times the impact on the population growth rate than that of the same change in yearling survival, and 6.3 times that of the same change in kitten survival (Figure 22). So, a decrease in adult survival, the main age class that is hunted, would have a larger impact on overall population growth than a decrease in yearling or kitten survival.

Our population models and LSA suggest that at the average survival values in North America from our literature search, (adult and yearling survival of 0.82, Table 9) unharvested bobcat populations grow. This suggests that if California bobcats have similar survival rates to other populations in North America, with no change in management (i.e., no authorized recreational harvest and other regulations remain the same), populations will be stable or increase in the short term. However, our models suggest that at adult and yearling survival of 0.78 or lower, populations would begin to decline. Based on the changes seen in other hunted bobcat populations, such as a shift to a larger proportion of yearlings and higher kitten survival and our LSA, harvested bobcat populations at the stable stage distribution could sustain a slightly reduced survival rate (0.75) for both yearlings and adults. The current annual adult survival rate for California bobcats, according to our research conducted for this report, was 0.66 (see Section 4.8 above). However, our sample size was relatively small and primarily focused in Northern California. The two other studies from California we considered in this analysis were both from Los Angeles and Ventura Counties and included some overlapping information for a portion of the bobcats studied. Riley et al. (2003) found a survival rate of 0.76 for the 50 bobcats from their study. Those 50 bobcats plus an additional 58 were included in a study from Moriarty (2007), who found an annual adult survival rate of 0.69, which further dropped drastically to 0.25 due to epizootic mange that lead to population decline (Moriarty et al. 2012). The results from these California studies and from our study show that additional GPS collaring, recruitment, and kitten survival studies would help improve estimates bobcat survival in California.

If a given population's current estimated survival rate is higher than the minimum value required for a stable population (0.78 in unharvested populations and 0.75 in harvested populations), the difference between the current survival and that minimum value suggests the proportion of individuals that can be sustainably lost to harvest mortality. If bobcat survival in California was sufficient, these proportions multiplied by the estimated abundance from our SCR analysis could be used to predict the maximum sustainable harvest among yearlings and adults for each ecoregion in California. Ultimately, more robust survival estimates specific to California bobcat populations would be needed for these calculations, but the estimates from the literature provide a good example of how it could be used. Since the stable stage distribution theoretically differs between harvested and unharvested populations, these values should be estimated for each population structure separately. Any potential change in population structure resulting from harvest would take time to develop after harvest begins for a previously unharvested population, and initial estimates of sustainable mortalities would need to be based on the unharvested population model.

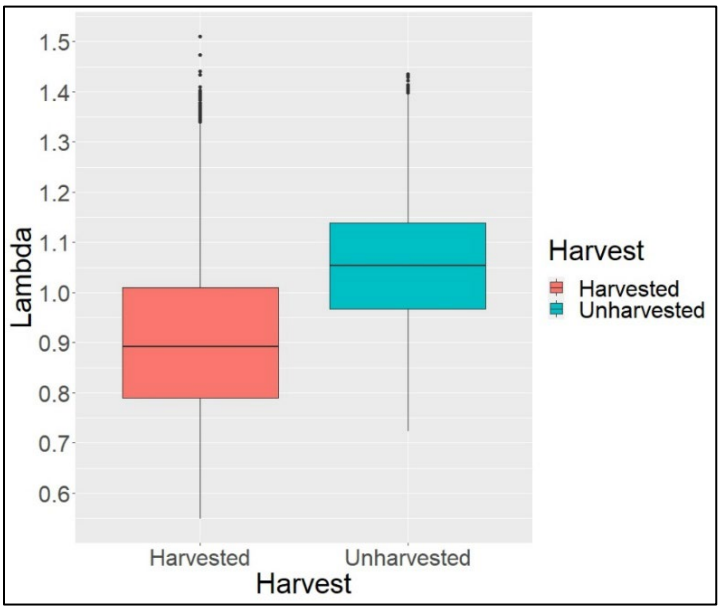

Figure 20. Boxplot of estimated lambda (i.e., population growth rate) values for harvested and unharvested populations. Each point is a simulated population with randomly selected vital rates from our Life Stage Simulation analysis based on values from scientific papers around the United States.

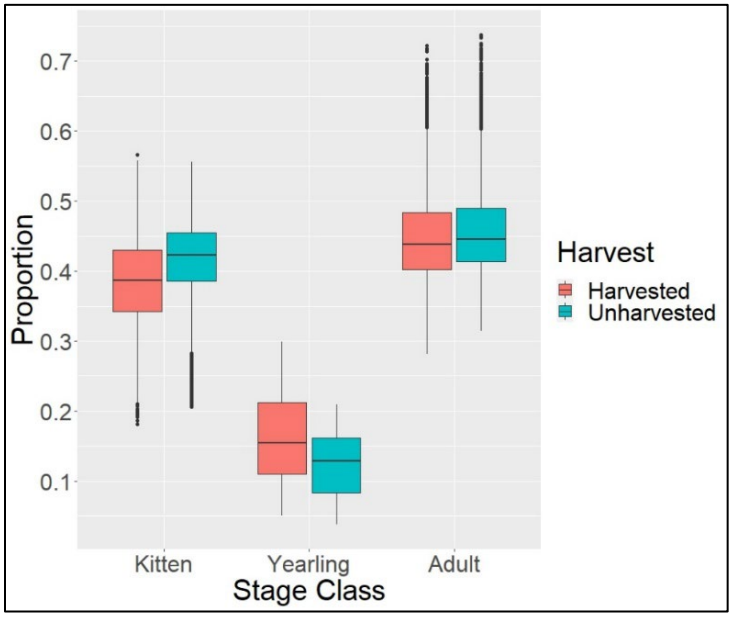

Figure 21. Boxplot of estimated population structure for harvested and unharvested populations at the stable stage distribution. Each point is a simulated population with randomly selected vital rates from our Life Stage Simulation analysis based on values from scientific papers around the United States.

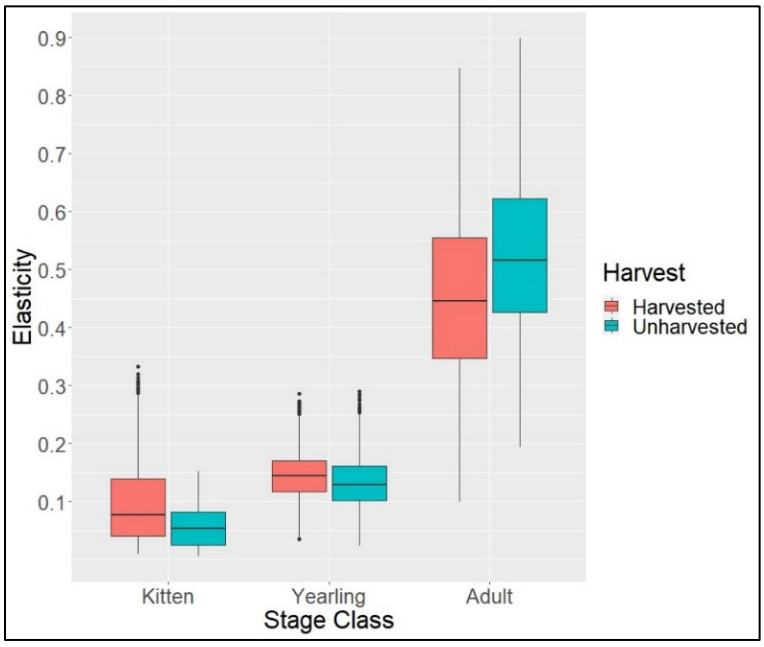

Figure 22. Boxplot of estimated elasticity values for each stage class of harvested and unharvested populations. Elasticity measures the proportional ability of a survival rate to alter the overall population growth rate. Each point is a simulated population with randomly selected vital rates from our Life Stage Simulation analysis based on values from scientific papers around the United States.

CHAPTER 5. DISCUSSION

5.1 SCAT COLLECTION AND FECAL DNA

The scat survey, collection, and analysis methods we used were successful and allowed for the development of a statewide bobcat population estimate and modeled density surface. While we envisioned collecting around 100 total scats from each study area based on the idea of how many animals could be present and the amount of effort we predicted for scat collection, we collected 33% fewer. This lesser amount could have been due to an early overestimation, but we also found that season, weather conditions, availability of suitable transects, timing and the experience of the field crew could have influenced the number of scats we were able to collect. The scat transect method is effective for bobcats as their use of paths and roads is consistent, but similar projects in the future could increase the distance of scat transects surveyed, or survey for longer periods. Projects could also consider the use of scat detection dogs that have been shown to be potentially 5 to 15 times more effective than humans at detecting bobcat scats (Long et al. 2007). However, the use of trained and experienced dogs and handlers can also increase survey costs.

We found that in some cases a two-week resurvey interval of scat transects did not give sufficient time for bobcats to return to the sites and deposit more scats. Conversely, in those areas with extremely hot, wet, or snowy weather, and areas highly traveled by the public, especially with vehicle and OHV use, two weeks may have been too long between visits. Additionally, we found that collecting scats opportunistically whenever or wherever they were encountered increased our detection probability by 7 % (n=31 scats), showing that some individuals did not travel the roads and trails that we used for transects and so were not accounted for in our model. Both scat preservation methods (in ethanol or dehydrated) were equally successful at producing a genotype as long as the samples were not degraded at the time of collection. For effective management of this large-scale project, collecting data electronically in the field (e.g., Survey123), consistently managing samples by assigning unique ID numbers soon after collection, long-term storage protocols, and delivering scat samples to the lab every few months for processing and analysis, were critical.

5.2 CAMERA SURVEYS AND PHOTO ANALYSIS

The camera model, camera settings, and camera placement protocols used for this study were effective in detecting bobcats and providing a broad understanding of the distribution and activity of other wildlife species within study areas. The spatial sampling unit grid of 40 km^2 with 1 km distance between camera stations was appropriate for detecting the presence of our target species and understanding facets of bobcat ecology such as abundance, occupancy, and temporal activity. The 6-week timeframe of camera deployment for our study was adequate and allowed for the assumption of a closed population, but having cameras deployed for 90 days should be considered

where possible to ensure all individuals have a chance to be detected and to capture seasonal changes. Due to logistical constraints and funding, study areas were surveyed sequentially throughout the year and thus, the seasonality of bobcat detection success by which movement rates change during mating season or when provisioning young (McNitt et al. 2020b), some study areas may not have been surveyed during the ideal time. Future long-term bobcat population monitoring should consider deploying cameras multiple times a year or for longer periods of time to parse out how seasonal changes affect detectability and occupancy.

Our bobcat detection success varied by study area, and one explanation for differences may involve surveyor ability in camera placement. We had different field teams in each CDFW administrative region, and some teams had more experience setting cameras than others. Careful consideration of camera placement, both at the micro-site level (e.g., placed in an ideal location pointing at a game trail where wildlife are moving through) and the macro-site level (e.g., placed pointing on the wildlife game trail versus in a random location with no evidence of wildlife moving through) is important, and field staff should be well trained in camera placement practices for best detection success.

In our study bobcat response to cameras in their environment seemed to vary depending on camera placement, use of scent lure, and population density of bobcats in the area. Cameras placed on roadsides or established hiking trails were often ignored by bobcats, where we captured the most photos of the animals walking by without seeming to acknowledge the camera. Cameras placed on natural features such as a rocky outcropping or a desert wash, captured more photos of bobcats looking at, sniffing, and spending time in front of the camera and exhibiting body language of being more interested. While we did not use scent lures at camera stations along roads and pathways, we did use them at stations set up away from typical wildlife use paths where it was beneficial in attracting bobcats and other species to the station. Lure often prompted visiting bobcats to spend time sniffing at the lure area and in many cases instigated a session of rolling around on the ground and sometimes returning to the camera station later. Although this behavior may be beneficial for some studies, we found that it was not well suited for photos to be used for pelage ID and for modeling effects where a "learned response" needed to be accounted for.

5.3 DENSITY MODELING

Our SCR model allowed us to build a statewide density map for bobcats in California (Figure 11) and develop a final bobcat population estimate of 62,292 (95% CI: 49,672 – 78,454) bobcats. The model and map suggest bobcat habitat preferences on a broad scale and highlight important areas for bobcat management in the state. Elevation, vegetation type, areas of drought, and wildfire scars were the main factors that were related to bobcat density in California on a broad scale (Table 13) in our modeling. The population density of bobcats was higher at the low and middle elevations in California,

where we also found that bobcats had smaller home range sizes. This trend of lower bobcat densities and larger home ranges at higher elevations has not been well defined throughout the bobcat range. The broad scope of our project, collaring bobcats throughout the state and at diverse elevations, is what allowed us to demonstrate this trend. It is well known that bobcats living at higher latitudes tend to have larger home ranges, attributed to the higher energetic costs and lower prey densities associated with living at higher latitudes (Anderson and Lovallo 2003) which is likely the cause at higher elevations as well. At both higher elevations and higher latitudes, resources are scarcer and weather conditions harsher, meaning animals must search larger areas for food, leading to lower population densities, while at low elevations or latitudes, the longer growing season means more prey which can support a larger bobcat population and higher densities.

We also found higher densities with increasing hardwood and shrub cover. Bobcats are found in a variety of vegetation types from dense conifer forests to deserts (Hall 1981, Sergeyev et al. 2023a). Yet no other vegetation type influenced bobcat densities in our study, and other studies have similarly found a preference for hardwood forests and shrublands (Riley et al. 2003, Ordeñana et al. 2010, Ruell et al. 2012). This suggests that while bobcats are highly adaptable and able to survive in many vegetation types, some are of higher quality and could be good areas of focus for conservation and priorities for preservation, especially in critical linkage and connectivity areas.

Bobcat densities were lower in areas that have experienced higher rates of drought over the previous five years, as well as areas of more severe wildfires over the past two years (description in Table 4). In fact, the scars of many large, recent wildfires stand out on our density map as areas of low predicted bobcat density, in contrast to the predictions for surrounding areas. Other studies show mixed results for the effects of wildfires on bobcat habitat use, but most agree that more severe and frequent fires are detrimental and lead to bobcats avoiding burned areas (Borchert 2012; Schuette 2014; Geary 2020). Bobcats may also take longer than other species to return to burn scars (Cunningham et al. 2006). It is possible that small, low to moderate severity fires benefit bobcats by creating openings in the forest and edge habitat which they use for hunting (Little et al. 2018, McNitt et al. 2020a). As a result of climate change, droughts are becoming more frequent in California which contributes to an increase in the number, size, and severity of wildfires (Littell et al. 2009, Steel et al 2018, Safford et al. 2022). This trend is unlikely to change soon, meaning reduced available habitat for bobcats and potential effects on local, and even statewide, populations. Future research should focus on bobcats' responses immediately post fire and on the effects of larger, more severe wildfires. Forest management practices that focus on fire resiliency may benefit bobcat populations, as it does with other wildlife species.

Wildland habitats within the Southern California Coast ecoregion had the highest modeled bobcat densities of any ecoregion in California (Figure 1 & Figure 11). Portions of that area also have high human population densities and fragmented habitats

resulting from the substantial number of highways and roads and other human developments. Bobcats can adapt well to living near urban areas (Riley et al. 2006, Ordeñana et al. 2010, Young et al. 2019) but low gene flow between fragmented populations and high mortality associated with roads are concerns (Kozakiewicz et al. 2023, Riley et al. 2006, Ruell et al. 2012, Serieys et al. 2015b, Smith et al. 2020) and highlight the need for a focus on habitat connectivity and safe wildlife road crossings throughout southern California, and the state more broadly. Due to our small number of surveys in urban areas, we could not model bobcat density response to human populations. However, other studies have found that while bobcats do live near urban development, their space use focuses more on natural areas within the urban environment, with use decreasing as development increases (Riley et al. 2003, Young et al. 2019). Urban sprawl and development have produced a fragmented landscape particularly in southern California, and since this area supports a significant bobcat population, the existing natural spaces and movement corridors should be the focus of management and conservation. Continuation of the research being done on bobcat populations in southern California, including population monitoring, gathering and interpreting genetic data, understanding challenges to bobcat survival, disease monitoring, movement studies and conservation of habitat connectivity, and human-wildlife conflict mitigation solutions should be supported by state and agency partners and incorporate citizen science. Our future bobcat population monitoring will focus in part on urban areas to improve our density model, help us understand the interaction between mange, ARs, and urbanization, and allow us to better understand the effects urbanization may have on bobcat populations.

During this study, we also developed a preliminary statewide population estimate based on pelage ID at camera stations. That estimate of 35,790 individuals (Section 4.3) was nearly half of the estimate based on the fecal DNA results (62,292 individuals). For the reasons explained below we believe that the pelage ID model underestimated the population, and we continue to view those results as preliminary as we work to improve the photo-based model. Throughout the pelage ID process, we used a conservative approach to identifying individual bobcats so as not to falsely add individuals that did not exist. For example, if there was not sufficient photographic evidence to fully identify two individuals from different trapping occasions, then both trapping occasions were marked as the same individual or one was mark as "unknown". Further, the large number of photos and bobcats in some study areas made it time consuming and difficult to identify individuals. Some of our study areas had over 35 individual bobcats, based on fecal DNA results, and one study area yielded 14,530 bobcat photos. These issues have led other authors to express the need for using pattern recognition software to aid in individual ID (Bolger et al. 2012, Tuia et al. 2022). Such challenges likely lead to misidentification or underestimation of the number of individuals which hampered our model and produced an erroneously low population estimate. Additionally, we have not yet formulated the model to account for the large number of bobcat detections labeled as unknown. We intend to carry this pelage ID part of the project forward by

reformatting the model using a spatial partial identity model (SPIM) as described in Augustine et al. (2018) that allows for unknown individuals to be accounted for. We also intend to make use of Machine Learning and Artificial Intelligence tools to further test and refine our pelage ID-based population estimate.

Previous statewide estimates of 61,000 bobcats from 1977 and 74,700 bobcats from 1981 were based on observations of bobcats and their sign, trapper catch rates, scent station census methods, and demographic information obtained from harvested bobcat jaws returned to the Department for investigation of age using cementum annuli analysis of their canine teeth. The data presented here with a current statewide bobcat population estimate of 62,292 individuals (95% CI: 49,672 – 78,454) is based on the best available science and the most robust analysis in California to date. Roberts and Crimmins (2010) produced a comprehensive list of bobcat population statuses for each state that reported population trends. Their study revealed that only six states at that time had used some form of population modeling for their estimates and that the amount of variability in survey methods across different states made it difficult to compare population estimates from state to state (Roberts and Crimmins 2010). Although our methods are comprehensive, it is important to remember that these density and abundance estimates were derived from field work conducted in 2021-2022 and only represent a snapshot in time. Due to ongoing landscape and habitat changes (e.g., human development and land use changes, climate change, wildfire, etc.), we expect that these populations will change over time. Ongoing population monitoring will be needed to support an accurate understanding of bobcat populations over time, across the state and within ecoregions.

5.4 OCCUPANCY

From our occupancy analysis (Table 17 & Figure 12), it does not seem like bobcats avoid larger carnivores even though larger carnivores have been known to kill bobcats (Fedriani et al. 2000, Hass 2009) and pose a threat across their range. Bobcats were more likely to occupy an area if competitor species (mountain lion, coyote, and gray fox) were also present. It is unlikely that these results are due to larger carnivores being attracted to bobcats as a prey item, since most antagonistic killings are opportunistic or occur over food (Prugh and Sivy 2020). It is more likely that the co-occurrence of bobcats and other carnivores is due to overlapping habitat and prey preferences (Santos et al. 2019, Dyck et al. 2021). Bobcats and coyotes both commonly occupy edge habitat (Dyck et al. 2021) and prey on many of the same species (Santos et al. 2019), which leads to them occupying the same areas. However, that does not mean that their fine scale habitat use is the same. Nielsen et al. (2017) found that while bobcats and coyotes used the same areas, bobcats spent more time in cover and coyotes spent more time in open habitat, reducing the likelihood of interaction and conflict. As obligate carnivores, the need for bobcats to access prey may outweigh the risk of intraguild conflict or predation (Fedriani et al. 2000, Hass 2009). Bobcats may also rely on temporal partitioning (as discussed in Section 5.5 below) to avoid competition.

Bobcats occupying the same spaces as mountain lions may further be a way for bobcats to avoid competition with other sympatric carnivores such as coyotes. Wang et al. (2015) found that bobcats were more likely to be found at sites with mountain lions while coyotes were less likely and suggested that bobcats may benefit from the suppression of coyote activity by mountain lions. Coyotes are known prey of mountain lions (Ackerman et al. 1984, Karandikar et al. 2022, Wilckens et al. 2016), especially when scavenging on a mountain lion's kill (Ruprecht et al. 2021). It is also possible bobcats are attracted to other carnivores as a food source, scavenging off their kills (Prugh and Sivy 2020), although this is less common in bobcats than other species (Ruprecht et al. 2021). Other studies have similarly found that bobcats do not spatially avoid larger carnivores (Fedriani et al. 2000, Santos et al. 2019, Dyck et al. 2021, Avrin et al. 2023). While we did not find a significant change in bobcat occupancy when black bears were present, Moll et al. (2021) did show an increase in site use by bobcats when black bears were hibernating compared to when they were awake, suggesting some avoidance. It is possible our data was from too broad of an area to tease out this relationship fully and that varying effects of habitat muddied the results. Our overall results could also be an artifact of camera placement. Most of our cameras were placed on trails to increase bobcat detections, but this is likely also increased other carnivore detections as many select for trails and roads for easier movement.

Bobcat occupancy was also positively associated with disturbance species (humans, cows, and wild pigs) although by a smaller amount than with other species. This could be because cattle are generally in the open pastures that many bobcat prey species, such as ground squirrels, voles, and rabbits are also found in. Further, these pastures often have long stretches of edge habitat that consist of denser cover which bobcats select for. Similarly, wild pigs occupy a wide range of habitats and prey on small mammals (Frederick 1998), likely leading to overlap with bobcats. Bobcats have also been known to prey on wild piglets (Mayer 2009). It is important to note that wild pigs were only at 3% of camera sites, so the biological relevance of these results is lower and may not be applicable for much of California. Bobcats and humans may frequently be detected in the same places because bobcats use the rural roads and trails that humans travel on. Many of our study areas occur on public lands which are open to, and often favored by, humans for various recreational pursuits.

The spatial distributions of many carnivores and particularly felids are at least partially dependent on prey availability (Logan and Sweanor 2001, Sanos et al. 2019, Khosravi et al. 2021), which our findings are consistent with. While our data does not directly measure prey availability with abundance, increased use of an area by a prey species and thus higher occupancy suggests more availability. Our results highlight bobcats' ability to take advantage of a wide range of prey. Bobcat occupancy increased with the presence of all prey species except small mustelids, although some had stronger effects than others. The presence of wild turkeys was associated with the highest bobcat occupancy while the presence of squirrels was associated with the smallest increase in

occupancy. Our results could suggest the relative importance of different prey species on a range-wide scale in California, but local prey diversity and abundance likely play an important role on regional or population level bobcat preferences. For example, in a study near San Diego, California, rodents made up the majority of bobcat diets (Larson et al. 2015), while studies in the northern United States found both rabbits and squirrels to be the most common prey (Nussbaum and Maser 1975, Newbury and Hodges 2018). Prey availability plays a critical role in bobcat habitat selection; the effects of prey species were stronger than any habitat variables on bobcat occupancy in our study. We should note that our camera methods are focused on detecting bobcats so our data may underrepresent prey species, despite high detection rates. Bobcats effectively exploit a wide variety of prey (Hansen 2007, Hass 2009, Newbury and Hodges 2018) and are likely not solely influenced by any one species in an area. Conversely, bobcats were less likely to occupy a site if small mustelids (see Table 5 for species included) were present. As occupancy does not assume dominance, this could be the result of mustelids such as fishers and martens avoiding bobcats due to the risk of intraguild predation (Wengert et al. 2014, Slauson et al. 2019, U.S. Fish and Wildlife Service 2020, Anderson 2023). Small mustelid occupancy in our study doubled when bobcats were not present at a site compared to when bobcats were present. It is also possible that this is an artifact of differing preferences in habitat selection.

5.5 TEMPORAL ACTIVITY

We found that bobcats are primarily nocturnal or crepuscular, although a portion of their activity does happen during the day. This matches what others have found across bobcat's range (Lesmeister et al. 2015, Wang et al. 2015, Sergeyev et al. 2023b). Our analysis of bobcat daytime activity—the deviation from their norm—suggests bobcats may shift their activity times to increase chances of catching available prey and to avoid competition with other carnivores. Similarly, Hubbard et al. (2022) found that bobcats had more flexibility in their temporal activity than any other carnivore in their study. In our study bobcats were less active during the day when coyote activity was high (based on relative abundance), consistent with a similar study (Lesmeister et al. 2015). While this effect was not significant in our analysis, it was included in the top model and is a common interaction due to large overlap in habitat, so we feel it calls for discussion. Coyotes are active during the day and night (Botts et al. 2020, Sergeyev et al. 2023a), and while bobcats may be using temporal partitioning to reduce conflict with coyotes, it is unlikely they avoid them completely. In fact, our analysis found a higher temporal overlap between bobcats and coyotes than with any other species. Bobcats had a similarly high degree of temporal overlap with mountain lions. It is possible that bobcats shift when they use different habitats within their home range to avoid coyotes or other larger carnivores, rather than fully shifting their activity. Thus, they would still be detected at the same cameras as our occupancy analysis showed, but not at the same times. Sergeyev et al. (2023a) found that while both bobcats and coyotes selected for dense cover as well as open areas across behavioral states, bobcats used

denser cover more for resting and hunting, while coyotes often rested in open areas and hunted closer to dense cover. Unlike coyotes, the relative abundance of gray fox in an area had minimal effects on bobcat daytime activity in areas with lower bobcat density. However, in areas with higher bobcat density, small increases in gray fox relative abundance were associated with an increase in daytime activity among bobcats. In other words, bobcats seem more sensitive to gray fox presence when they already must compete among a larger bobcat population. Other studies have not found a difference in bobcat or gray fox activity due to the abundance of the other (Lesmeister et al. 2015), although they did not consider the abundance of the affected species in their analysis. In our temporal analysis, gray foxes were strongly nocturnal so a shift by bobcats to more daytime activity could be an effective way to reduce interactions and prey overlap since different prey species are active day and night (Figure 13).

No other carnivore species' relative abundance had a significant effect on bobcat daytime activity. Large carnivores may also indirectly affect bobcat temporal activity through coyote temporal activity. Coyotes may shift to more diurnal activity to avoid the large carnivores and thus cause bobcats to become more nocturnal to avoid the coyotes (Wang et al. 2015, Shores et al. 2019). Bobcats may not need to shift activity to avoid some large carnivores such as black bears as their activity patterns naturally do not overlap. Black bears were strongly diurnal in our study (Figure 13). As our analysis spans all of California, some of the nuance in species temporal activity related to habitat or local climate is likely lost. Further, as with many felids, bobcat temporal activity is likely highly influenced by when their prey is active.

Bobcat daytime activity was greater in areas where squirrels were abundant, which were highly diurnal in our analysis, and less in areas where the typically nocturnal rabbits were abundant. Bobcat activity overlapped greatly with rabbits across their range, and rabbits are known to be an important food source for bobcats (Nussbaum and Maser 1975, Anderson and Lovallo 2003, Newbury and Hodges 2018). Chamberlain et al. (2003) similarly found that bobcat activity patterns could shift based on prey activity. Being able to find and catch prey is crucial to any carnivore's survival (Hansen 2007) so it is unsurprising that they would mirror the activity of important and available prey species. Bobcat daytime activity was also significantly higher in evergreen forests, where we detected more squirrel activity than in either herbaceous or shrub and scrub habitats, where we detected more rabbits and other rodent species. Non-squirrel rodents were abundant in all habitats and as a result, their relative abundance may not be as influential on bobcat activity as those of the more variable squirrel and rabbit populations. Rodents were highly nocturnal in our analysis and had moderately high overlap with bobcat activity which would provide plenty of opportunities for hunting. Rodents are a common food source across the bobcat's range (Nussbaum and Maser 1975, Anderson and Lovallo 2003, Newbury and Hodges 2018). Our results highlight the adaptability of bobcats. Not only are they able to take advantage of a wide range of prey, but they can also shift their activity to match the most abundant prey source

where they are. This is likely one reason they are able to survive in such a wide range of habitats throughout California.

Bobcats had low temporal overlap with both humans and domestic cattle. Humans are highly diurnal, and many studies have shown that bobcats, and other carnivores shift their activity more to night in areas of high human densities (Tigas et al. 2002, Wang et al. 2015, Hubbard et al. 2022). So, while bobcats spatially overlap with humans, using many of the same roads and trails, they temporally avoid interactions. The limited temporal overlap with cattle is likely one reason they do not avoid them spatially as shown in our occupancy analysis. Wild pigs on the other hand had moderate temporal overlap with bobcats. This could be because wild pigs and bobcats utilize some of the same resources such as prey as discussed in the occupancy section.

5.6 GPS COLLAR DEPLOYMENT, MOVEMENTS, AND HOME RANGE

GPS Collar Deployment. Our effort to capture bobcats and deploy GPS collars lasted three years and were logistically complicated and labor-intensive. We utilized multiple capture teams who were active across much of the state simultaneously and successfully deployed collars on 41 bobcats.

We used specially trained hounds for bobcat captures in 2021, and cage traps in 2022. While hounds are one of the most common methods used to radio-collar larger felids in North America (Germaine et al. 2000, Russell et al. 2012, Proffitt et al. 2015, Beausoleil et al. 2016, McBride et al. 2016, Murphy et al. 2019) there is not much data on the use of hounds to capture bobcats for research (McBride et al. 2016). However, bobcats are hunted with hounds in some states. The use of specially trained hounds for this project proved to be efficient and successful in most habitats except for those with large trees, such as redwoods, where bobcats could climb to unreachable heights, and in rocky areas where the bobcat could hide in deep rock dens. Hounds track and pursue bobcats by scent and then hold them at bay until a capture team arrives. Captures required highly trained and specialized staff, including a dog handler and an experienced tree climber (McBride et al. 2016) who may need to retrieve a sedated bobcat from entangling tree limbs or vines. The challenges of having limited specialized staff, concern for bobcats becoming physically exhausted and potentially injured (Powell and Proulx 2003), and concern over post-capture survival through harsh winter conditions were the impetus for the shift to cage traps.

Efficiently trapping bobcats in cage traps also requires specialized knowledge and experienced capture staff. For our study, trapping was easier in study areas with higher bobcat population densities, where a higher number of animals moving around on the landscape made it more likely for them to encounter a trap set and become trapped. Most successful trapping was also achieved in areas such as the desert, where natural land features (e.g., a sandy wash between large boulders) funneled a bobcat into a trap set. Fall and winter months were the most successful trapping seasons, partly

because traps can be left open during the day when daily temperature highs will not be dangerous for entrapped wildlife, but also because bobcats are searching for mates through these later seasons and bolder and more curious.

Trap setting methods, such as location of trap and type of lure used were dictated by site-specific conditions. Anecdotally from the efforts in this study, olfactory attractants such as catnip, bobcat glad lures, bobcat urine, and if possible, bobcat scat from the same location were most effective at attracting bobcats to the trap area and visual attractants, such as feathers, and CDs with googly eyes attached were the most successful tools for enticing bobcats into traps. We had less success trapping bobcats in traps that had been baited with meat (deer, rabbit, or rodents), but this could have been due to these traps often catching nontarget species such as fox and skunk, who would enter that trap before the target bobcat could have a chance to investigate and potentially be trapped.

Cage traps can pose health risks when an enclosed animal becomes agitated and rubs their face and head on the bars, causing abrasions, especially around the eyes. Teeth can also be broken if the animal bites at the cage and gets their mouth stuck between the narrow cage bars. Modifications to add smaller gauge wire or smooth plexiglass to the front of the cage can minimize facial damage from rubbing. Similarly, adding something softer for the animal to bite, such as a piece of rubber hose attached to the inside of the cage can focus the animal's attention and reduce the likelihood of injury. Capture staff needed to be ready to process the caged bobcat as soon as possible and care for any wounds that may have happened in the process.

Home Range. Consistent with other studies of felids, male bobcats from this project had larger home range sizes than females (Table 20; Litvaitis et al. 1987, Lovallo and Anderson 1996, Cochrane et al. 2006, Hansen 2007, Ferguson et al. 2009) and the average home ranges sizes from each sex reported here fall within the range those from other studies across their geographic range (Miller and Speake 1979, Major and Sherburne 1987, Knick 1990, Anderson and Lovallo 2003, Ferguson et al. 2009). We also did not find evidence of seasonal changes in home range size which is consistent with other studies (McNitt 2020b). Rather, this study found differences in movement patterns within bobcats' home ranges between seasons, likely due to reproductive behaviors such as mate seeking or provisioning for young. While we did not directly test for seasonality in our movement data, most of the long-distance travel done by males in our study was during the wet-winter/mating season when bobcats are typically looking for mates.

The bobcats with the largest home range sizes, for both sexes, were from Sierra County in the Tahoe National Forest (SIE-F1=36.6 km^2 and SIE-M5=93.4 km^2). Six GPS collars were deployed on bobcats from Sierra County, one female and five males, all of which were among the largest home ranges from the study and lived at an average elevation of 1,870 m (6,135 ft). The bobcat who lived at the highest elevation (2,226 meters or 7,303

feet) was a female from Mono County whose home range size was well above average (MNO-F1=17 km^2). Individuals with two of the smallest home ranges (BUT-F3=3.5 km^2 & GLE-F1=4.1 km^2) were recorded at some of the lowest elevations (32 meters; 105 feet) in Sacramento River Wildlife Area in Butte and Glen counties.

The relationships between elevation, bobcat population density, and home range size have not been well documented. Our results (Section 4.6) indicate that with a gain in elevation, bobcat population density decreased, and home range sizes increased. Therefore, in the lower elevations of California, bobcat populations are denser with smaller individual home ranges. The ecoregions and habitat types within these lower elevations likely provide more resources to support larger bobcat populations.

Latitude has been reported (Anderson and Lovallo 2003) as a factor in home range size, with bobcats at higher latitudes having larger home ranges. The three bobcats (two females and a male) collared in Modoc County were living at the highest latitudes represented in our dataset, with one female home range slightly above the average (MOD-F1=16.8 km^2), and the other female and the male had lower than average home range sizes for their respective sexes (MOD-F2=7.9 km^2 and MOD-M1=20.8 km^2). Tehama County was the second highest latitude, and the home range size of the one male bobcat collared (THE-M2=11.5 km^2) there was well below the male average. Conversely, the female and male bobcats collared in San Bernardino County, at the lowest latitude from our study both had above average home ranges sizes for their sex (SBD-F1=22.4 km^2 and SBD-M1=32 km^2). It is possible that the range of latitudes from the Modoc County bobcats at a latitude of approximately 40.86700 in northern California, to the San Bernardino bobcats at approximately 35.15500 in southern California, do not represent a wide enough spread to capture latitude influences on bobcat home range size. Comparisons of home range size with respect to latitudes also may be confounded by our small sample size of collared bobcats and the different habitat types and ecoregions that our study was designed to incorporate; we made no effort to sample similar habitat types at different latitudes.

There was limited evidence of intersexual home range overlap from the GPS collar data from our study. This may be because we collared half as many females as male bobcats, and small number of individuals collared in some of the study areas. For those study areas where multiple individuals were collared, female bobcat home ranges overlapped with multiple males, but there were no other females collared in the area to provide sufficient information about intrasexual overlap amongst females. Male bobcat home ranges overlapped with multiple other males and females. In Kern County, a male and a female had the same home range size, that overlapped nearly entirely.

Movements. The average minimum daily travel distance for bobcats was 2.9 km for female bobcats and 3.8 km for male bobcats (Table 21). The longest 24-hour path distance was 14.4 km for a female and 21.5 km for a male. Although males from our

study fell within the range of those reported by others, female bobcats from our study had a longer daily movements than those reported in the literature (*females average 1.2 km per day*; Bailey 1974, Kitchings and Story 1984, Anderson and Lovallo 2003). However, daily travel distance estimates from early studies were based on VHF radiotelemetry locations and could have been less precise than estimates based on GPS locations depending on how many locations are taken each day. Additionally, both methods of calculating daily travel distances cannot account for the movements made between locations, and the wandering animal likely travels farther than estimated based on the straight-line distance between locations. The long travel distances by females in our study may be due to the fact that 6 of the 10 females lived above 1,000 meters in elevation with larger home ranges, less habitat fragmentation, few road barriers, and the need to travel farther for resources.

Seven male bobcats from our study exhibited long distance exploratory movements beyond their normal home ranges. In most cases these bobcats eventually returned to their home range, and we surmise that the movements might have involved searching for mating opportunities or resources. In two cases (SBD-M1 and SIE-M2) the collars dropped when the bobcats were outside of their typical home range. In an additional case, a male from Siskiyou County (SIS-M2), was collared in November before a winter storm and he was collared for 17 days before he traveled more than 90 km over the next month before returning to the original location. This cat was collared in the winter, and his movements were recorded throughout the mating season.

5.7 RESOURCE SELECTION FUNCTIONS

Our top model suggests that bobcats select for hardwood, shrub, and herbaceous landcovers (Table 23 & Figure 14) at the small scale (within their home range). Other studies have found bobcats utilize a variety of habitats in California including woodlands, chaparral, and herbaceous grasslands (Ordeñana et al. 2010, Ruell et al. 2012, Wengert 2013, Dunagan et al. 2019), and our density modeling showed higher bobcat densities in hardwood and shrub cover at the large scale (within California), which supports these RSF results. Interestingly, in our study, females selected more strongly for shrub cover and avoided hardwood forests. Shrub commonly provides more dense cover and better denning habitat for kitten rearing (Sergeyev et al. 2023a, Morrison et al. 2024). Male bobcats selected for hardwood cover and showed little avoidance or attraction to shrub cover, although there was a lot of error around this trend likely due to regional differences in available habitats (Table 24). Males may be more likely to spend time in a wider range of habitats than females due to their larger home ranges and may be willing to accept higher risk to find mates and increase reproductive success (Conner et al. 1999, Riley et al. 2003). Both sexes strongly selected for herbaceous cover which is the typical habitat of many rodents and other prey species (Kaminski et al. 2007, McNitt et al. 2020a, Sergeyev et al. 2023a). This selection for multiple habitat types within a distance-based model may suggest the use of edge habitat which bobcats are known to prefer as it provides a variety of covers for resting,

denning, and hunting (Ruell et al. 2012, Wengert 2013, Dunagan et al. 2019). While anecdotal, a visual inspection of collar locations supports this, with many individuals spending time along the edge of herbaceous or riparian areas. Herbaceous areas provide opportunities for hunting while the nearby shrubland or hardwood forest provide cover and protection. Similarly, we found that bobcats weakly selected for riparian areas along streams and rivers which may also provide good hunting opportunities and serve as movement corridors often used by a variety of carnivores (Young et al. 2019).

Conversely, bobcats in our study avoided urban areas (Figure 14). While bobcats are known to live near urban areas in California and elsewhere (Riley et al. 2003, Ordeñana et al. 2010, Young et al. 2019), they generally utilize nearby natural areas that provide sufficient cover (Crooks 2002, Lombardi et al. 2017, Schmidt et al. 2023). Our results support this as we measured habitat selection within already established home ranges, suggesting that even bobcats living near urban areas avoid them to the extent possible. However, we did not collar any bobcats in truly urban areas so our results may not be as relevant as those from more urban studies such as those done in Southern California. Urban areas may provide benefits to carnivores such as bobcats because they often have dense prey populations of rodents and birds (Young et al. 2019). However, urban areas also have decreased gene flow (Ruell et al. 2012), higher incidents of rodenticide exposure, higher mortality rates due to roads (Riley et al. 2003, Anderson 2023), and increased competition due to higher densities of other carnivores in the small available natural habitats (Parsons et al. 2019). Riley et al. (2003) found bobcat habitat use decreased as development increased. Urbanization and habitat fragmentation in California are major threats to carnivore conservation and habitat connectivity should be a top priority when planning new developments and road systems.

We also found that bobcats selected lower elevations within their home range, south facing slopes, and moderate elevation change (ruggedness). Bobcats exist at a range of elevations in California, and we recorded detections from as low as 13 meters and as high as 2,774 meters. However, several of our analyses show that lower elevations may be preferable for bobcats on a large and small scale. Our density model showed higher population densities at lower elevations (large scale) and our resource selection model showed selection for lower elevations within home ranges (small scale). While some of our collared bobcats had little elevation change within their home range—those in Butte and Glen counties had 10 or fewer meters between the highest and lowest point—most home ranges included between 200 meters and >1000 meters in elevation change. At the large-scale higher elevations have scarcer food resources and harsher winters making survival more difficult (Chamberlain et al. 2003, Sergeyev et al. 2023b). At the small scale, movement may be easier at lower elevations such as in valleys, versus on ridgetops due to ruggedness and environmental conditions such as wind. Similarly, in the northern hemisphere south facing slopes are sunnier so bobcats, or their prey, may be selecting for warmer and drier areas. Bobcat's choice of aspect and elevation likely vary based on local climate, season, and snow depth (Larivière and Walton 1997). It is

no surprise that we found bobcats selected moderate ruggedness in their environment as other studies have found that they prefer habitat with high structural diversity and specifically rocky outcroppings (Hansen 2007, Abouelezz et al. 2018, Sergeyev et al. 2023a). Rocky outcroppings are important as they provide cover from other predators and natal den sites for females (Hansen 2007, Abouelezz et al. 2018). Rugged areas require a high energy expenditure to move within which may outweigh the benefits of cover, while flat areas are less likely to provide the preferred structural diversity.

We measured and modeled bobcat habitat selection across the varied landscape of California. However, it is also important to understand the nuances of that varied landscape. While broad habitat preferences of bobcats may be similar across the state, fine scale selection likely varies between populations and individuals based on local conditions. Thus, the conservation and management of different bobcat populations across California may be best tailored to those local or regional conditions. For example, protecting hardwood forests may be more important for bobcats in the foothills, while conifer forests may be more important for bobcats in the Sierra Nevadas. It is also possible that our data reflects populations in Northern California better than other parts of the state due to the uneven distribution of our collared bobcats. Looking forward, we hope to continue monitoring and assessing bobcat habitat selection and use, as well as long-term population trends and drivers throughout the state.

5.8 SURVIVAL AND FACTORS AFFECTING SURVIVAL

During the study, nine bobcats died within four months of being collared. One male from Sacramento County (SAC-M1) who had been collared in a suburban community was illegally shot and killed 22 days after he was collared. The animal had been preying on free range chickens on a private residence, and a depredation permit had not been sought after by the landowner. One bobcat from Monterey County (MON-F2) was killed by a collared mountain lion 17 days after her capture. Five bobcats from one study area in Siskiyou County (SIS-F1, SIS-F2, SIS-F3, SIS-M1, and SIS-M2) were captured using specially trained hounds in November of 2021. Three of these cats died within four months of capture and the collars of the other two were found later as discussed below. These bobcats were captured days before the first major winter storm of the winter. The weight of two of the female bobcats were close to the project's minimum threshold for collaring and they died 67 (SIS-F1) and 19 days (SIS-F2) after capture. Due to weather and access conditions, SIS-F1 and SIS-F3's mortality locations could not be investigated promptly and only the collars were found the following spring. SIS-F2 and SIS-M2's necropsies attributed their deaths to emaciation and SIS-M1's death occurred when he appeared to have died in an altercation with a wild turkey where both animals were found together with mortal injuries. Bobcats SIE-F1 and SIE-M4 died 104 and 120 days after capture, and necropsies attributed their deaths to predation. The loss of animals that died soon after capture resulted in a careful assessment of project capture methods, capture timing, and collar weight and out of an abundance of caution hound capture

efforts were ceased and the minimum weight for a bobcat to be collared was increased from 6 kg to 7 kg.

The adult annual survival rate of 77% for collared bobcats from the California Bobcat Project falls within the reported range of 49% to 88% survival rates for adult bobcats across their range (Knick 1990, Roberts 2007). However, most of the bobcat-years (34 out of 63) came from northern California (Figure 5). Thus, we caution inferring that this estimate is representative of the entire state. More collared individuals, monitored for multiple years, from central and southern California could provide us with a more representative survival estimate for bobcats statewide.

Additionally, we collared almost twice as many males as females and male bobcat-years made up the majority (41 out of 63 bobcat-years) of the dataset. This is likely in part due to their larger size making males more likely to be over the weight threshold for a collar, while females are often too small. Understanding female bobcat survival is essential to understanding bobcat population health in California, as it is the females that give birth to new individuals which are recruited into the population. This current annual adult survival estimate is more representative of male bobcat survival than the survival of both sexes. Collaring more female bobcats will be vital to accurately understanding bobcat population health in California. We will continue to work with manufacturers to produce smaller GPS collars for bobcats that are more suitable for females to help with this goal.

Kittens, juvenile bobcats, and bobcats weighing under six kilograms were not collared as part of this study (see Section 2.4) and were not considered in the survival analysis, which limited our results to adults only. In conclusion, we suggest that more bobcat collaring occurs, with a focus on providing a more representative statewide sample population; that collaring more female bobcats needs to be a stated objective; and that future research should include studying the survival of all bobcat life stages.

5.9 STATEWIDE BOBCAT HEALTH SURVEILLANCE

CDFW received support from many organizations in response to its request for bobcat carcasses for health surveillance and the scale of the data gathered for statewide bobcat health surveillance was unprecedented. The two leading causes of death for bobcats (Figure 15) from this effort were vehicular collisions (30%) and mange (18%), which is consistent with prior studies from southern California (Riley et al, 2010, Serieys et al. 2015). However, these results are skewed because the animals that die under these conditions are highly visible and may be more likely to be collected, reported, or taken into a wildlife center or rehabilitation facility by a person who finds them. Similarly, bobcats that are infested with mange tend to become less wary of humans and in an advanced state of the disease, can be more easily caught by experienced animal handling personnel. The bobcats not represented in our results are those that live in remote locations away from the human eye and die of natural causes such as disease

and predation. For comparison, of the 14 collared bobcat mortalities in our study, which may better represent those remote populations, 43% died from suspected predation or prey related trauma, 29% died from disease, and 14% died from each emaciation and gunshots. This could highlight the different threats facing bobcat populations near higher human density areas vs more natural areas.

Notoedric mange is highly infectious and has been suspected to be the cause of mortalities in bobcats as far back as the 1950s when wildlife managers were concerned that it could result in high mortality rates because it was fatal in cats (Penner and Parke 1954). Notoedric mange can have population-level affects and has the potential to significantly reduce effective population size, causing genetic bottlenecks in small and isolated populations (Riley et al. 2007, Riley et al. 2010, Serieys et al. 2015, Serieys et al. 2018). The link between AR exposure and notoedric mange mortality in bobcats is well documented, yet not fully understood (Riley et al. 2007, Moriarty 2012, Serieys et al. 2013, 2015, 2018) and a causative association between the two has not been proven (Kopanke et al. 2018). Repeated exposure to ARs is associated with immune dysfunction that can explain increased susceptibility to mange and bobcats with chronic exposure may be more susceptible to falling ill and dying from this disease (Serieys et al. 2018). However, Kopanke et al. (2018) whose study found no immunological response to chronic low-level brodifacoum exposure in domestic cats, argues that wildlife living near urban areas are exposed to many different stressors and contaminants that affect immune function which should be considered when looking at mange cases and related mortalities.

Mange was the most commonly diagnosed disease in bobcats from our study, but this could be due to a few special interest groups from urban areas who pay close attention to sick animals in their community and bring in carcasses for testing. The spatial clustering of mange mortalities confined to the Central and South Coast ecoregions (Figure 19) may indicate other contributing and interacting factors in the area, such as bobcat and other animal host densities, urbanization, and the geographic range of the Neotropical mite species. Furthermore, there were high rates of AR use for rodent control in these two regions according to state pesticide use reporting data, which makes it difficult to determine whether the link between mange and AR exposure is coincidental or causal. In our study, 96.5% (n=28) of the bobcats that died from notoedric mange also had two or more ARs detected in their livers; whereas 63.0% (n=54) of bobcats that died from trauma (hit by car, gunshot, other) tested positive for two or more ARs in liver tissue. The persistence of ARs in liver tissue complicates interpretation of an association between ARs and mange or other causes of death. Exposure to ARs may predispose wildlife to excessive hemorrhage following an otherwise non-lethal traumatic injury or increase sensitivity to additional exposure(s) (Erickson and Urban, 2004). Bobcats can experience multiple exposure events over long time periods, as can be seen by the number of animals exposed to multiple compounds in our study. They are also likely exposed to the same compound multiple times, but we cannot measure that. Further if mange-infested

or compromised bobcats change their space use and prey selection towards human inhabited areas and commensal rodents, risk of AR exposure could increase.

Rodenticide exposure in the absence of toxicosis should not be ignored (Brink et al. 2018). The uncertainties about the magnitude and drivers of chronic exposure and sub-lethal levels of rodenticide exposure demonstrate the need for continued monitoring. Given the circumstances, the high prevalence of AR exposure and the emerging presence of bromethalin in our large sample of bobcats is cause for concern and strong rationale for continued surveillance for non-target exposures and toxicities in this species.

The collared adult male bobcat from our study that died from highly pathogenic avian influenza virus infection (H5N1), was the first confirmed case of H5N1 HPAI in a wild mammal in California. While waterfowl and domestic poultry are especially vulnerable, the current strain of H5N1 circulating in the U.S. and Canada has been causing illness and death in a greater diversity of wild bird species than previous avian influenza outbreaks, and infecting mammals (Harvey et al. 2023). Mammalian and avian predators and scavengers may be exposed to avian influenza viruses when feeding on infected birds (Gunther et al. 2024, EnetWild Consortium, 2024). Although this bobcat had no stomach contents present at the time of necropsy, bird feathers and bone fragments were a common finding in the stomach contents of bobcats that were necropsied in this study.

The rabid bobcat from Trinity County in 2022 represented the first reported rabies virus infection in a California bobcat since 1990 (CDPH 2023). The virus was traced back to the *Myotis californicus* bat variant through genotype sequencing by the California Department of Public Health (CDPH). Rabies in incidental hosts such as bobcats and other wild felids is rare because there are no known rabies variants that are adapted to live in these species (Krebs et al. 2003, CDPH 2023). However, bobcats can transmit rabies to humans and other animals, as was recorded from one known case in San Diego County in 1969 (Emmons et al. 1973, CDPH 2023).

Infection with FeLV and exposure to FIV was rare in deceased bobcats that we tested. Both are retroviruses that can contribute to immunosuppression in felids. FeLV is of heightened interest as it can be transmitted from infected domestic cats to wild felids and spillover infections have been documented to cause progressive disease in mountain lions (Petch et al. 2022). Although FeLV infection appears less prevalent in bobcats, its immunosuppressive effects warrant continued surveillance for possible associations with other health conditions, and to understand potential role for bobcats in transmission among domestic cats and mountain lions.

5.10 ECOREGIONAL DENSITY AND RECOMMENDATIONS FOR SUSTAINABLE MORTALITY

Based on our analyses we have estimated the bobcat population across California as well as at the ecoregional scale. We also better understand the different habitats within ecoregions that support higher bobcat densities (Table 16). From our population and survival estimates and life stage analysis, we can estimate the level of mortality that bobcat populations within each ecoregion may be able to withstand before declining. However, improved estimates of California-specific survival rates would make these estimates more robust. If CDFW is asked to develop hunting recommendations in California, we could use those estimates of sustainable mortality as a starting point.

We would estimate sustainable mortality based on the best available California bobcat population and survival data. Our current population estimate is based on results from only two years of data collection (2021-2022). It provides a snapshot in time of the number and status of bobcats in California, and populations will likely change due to natural cycles and conditions altered by climate change. Further, different bobcat populations in California face additional and inconsistent stressors such as drought, wildfire, and human development and habitat fragmentation (Riley et al. 2003, Ruell et al. 2012, Schuette 2014, Geary 2020) that can result in population changes. These factors should all be considered and local populations monitored before and during any population management changes.

Photo by Jack Clark

CHAPTER 6. RESEARCH IMPLICATIONS

The California Bobcat Population Monitoring Project, encompassing 48 study areas across the state, to our knowledge is the most extensive bobcat survey ever done. Prior to this study, bobcat population estimates in California were based on observations of the species and their sign, trapper catch rates, scent station census methods, demographic information obtained from bobcat jaws returned to the Department, and various field studies conducted in several areas of the state (Gould 1978, Lembeck 1978, Zezulak 1978, Zezulak and Schwab 1980, Gould 1980). As such, the need for more information about bobcats in California and the goals of the project outlined in Chapter 1 have been achieved as follows:

GOAL 1: To determine statewide bobcat population density and abundance.

Field methods for this study were replicated across the state, resulting in multiple data streams including camera data, fecal DNA, and GPS telemetry data that were used to determine the final statewide population estimate of 62,292 (95% CI: 49,672 – 78,454) bobcats across California.

GOAL 2: Assess the overall health of the bobcat population in California.

The results of this study have shown that, while the overall health of bobcat populations in California currently look stable, localized populations could face stressors such as disease that would result in population level declines, and that more information is needed to estimate bobcat survival rates across the state and within local populations.

GOAL 3: Develop an adaptive conservation and management framework to address stressors on bobcat populations in California.

This study measured multispecies occupancy, bobcat home range and movement patterns, resource selection, and survival rates; and developed methods for determining population size; and estimated ecoregional population densities to inform future management decisions.

GOAL 4: Understand the efficacy of nonlethal solutions to mitigate bobcat depredation on domestic animals.

To address human-wildlife conflict issues specific to bobcats and to explore nonlethal solutions to these conflicts, we used a multifaceted approach as described in Chapter 5 of the Bobcat Conservation and Management Plan. These include: 1) an analysis of statewide CDFW Wildlife Incident Reports (WIR), 2) coordination with California Department of Food and Agriculture (CDFA) on domestic animals at risk of bobcat predation, and 3) identification and description of common HWC mitigation methods.

GOAL 5: Outline guiding principles, strategies, and adaptive management recommendations for the long-term monitoring and conservation of bobcats in California.

Although much is now known about bobcats in California due to research efforts by scientists throughout the state, numerous research needs still remain. We suggest that current, on-going, and future research should focus on:

- Improved survival estimates for all bobcat life stages, including ecoregion-specific estimates in areas of the state where data is lacking or where increased management actions may be warranted.
- Additional studies of bobcat habitat use, ecology, and survival in wildland-urban interfaces.
- Continued evaluations of human-bobcat conflict and measures people can take to ensure their domestic and livestock animals are protected, and the most effective methods for coexistence.
- Spatio-temporal interactions of bobcats with co-occurring large carnivores and ungulates.
- Continued monitoring of non-target rodenticide exposure and toxicity in bobcats to determine if legislation to reduce ARs is having an effect and to monitor all impacts of changing rodenticide use patterns on wildlife.
- Continued monitoring of mortality causes and disease surveillance to 1) understand the impact of both current and emerging pathogens (e.g., HPAI) that may spillover from other species and domestic animals, and 2) examine potential interactions with non-target rodenticide exposure.
- Conducting studies on bobcat diet using DNA metabarcoding techniques in rural, suburban, and urban areas to study interactions with non-target rodenticide exposure, pest management practices and the interaction between bobcats and rodent control.
- Identifying or studying known areas of the state where habitat loss and connectivity will impact bobcat populations, especially as it pertains to roadways and wildlife-vehicular collisions.
- Continued studies on bobcat genetic populations across the state, identifying areas where genetic diversity is lacking and where this lack could lead to bottleneck or population level declines.
- Further studying the impacts that climate change variables such as drought and wildfire have on diseases, resource availability, and bobcat populations and how management practices can positively or negatively contribute to bobcat survival in an ever-changing environment.

- Interactions between bobcats and their prey and the impacts that bobcat can have on special-status species.
- Engaging California's Native American Tribes to cultivate connectedness and research into bobcat populations on their lands, and empowering youth programs with the resources and knowledge they may use to carry bobcat research on into the future.

Data from this project can be accessed for further analysis through an established data sharing agreement; please contact the CDFW Bobcat Project staff for inquiry. This project was undertaken by the Department to build the current scientific knowledge and background to inform the development of the statewide Bobcat Conservation and Management Plan.

California's wealth of wildlife diversity, variety of ecoregions and habitats, the conservation mindedness of its citizens and their desire for the protection of wild spaces, ensures that bobcats will persist and possibly thrive in the state long into the future. These spotted felines, sometimes considered to be elusive, have become more familiar to Californians as we build closer to their habitats, hike, bike, hunt, and fish in their home ranges, try to protect our chickens from their pesky claws, and become enamored by their presence on our home security cameras and in our neighborhoods. Bobcats are a critical part of the California ecosystem, and it is the aim of the CDFW Bobcat Project to continue to work collaboratively for their conservation and management in the state.

Photo by Jack Clark

LITERATURE CITED

Abouelezz, H. G., Donovan, T. M., Mickey, R. M., Murdoch, J. D., Freeman, M., & Royar, K. (2018). Landscape composition mediates movement and habitat selection in bobcats (Lynx rufus): implications for conservation planning. *Landscape Ecology*, *33*, 1301-1318.

Ackerman, B. B., Lindzey, F. G., & Hemker, T. P. (1984). Cougar Food Habits in Southern Utah. *Journal of Wildlife Management*, *48*(1), 147-155. https://doi.org/10.2307/3808462

Ahrens, K. D., Sacks, B. N., Preckler-Quisquater, S., & Buchalski, M. R. (2024). Development of a 96 SNP panel for fecal genotyping and individual identification of bobcats (Lynx rufus) in California. *Conservation Genetics Resources*, 1-4.

Allen, M. L., Roberts, N., & Bauder, J. (2020). Estimating bobcat (Lynx rufus) abundance in Wisconsin during 1981-2015. *bioRxiv*, https://doi.org/10.1101/2020.03.23.004044.

Alonso, R. S., McClintock, B. T., Lyren, L. M., Boydston, E. E., & Crooks, K. R. (2015). Mark-recapture and mark-resight methods for estimating abundance with remote cameras: a carnivore case study. *PloS one*, *10*(3), e0123032.

Anderson, E., & Lovallo, M. (2003). Bobcat and lynx. In: Wild mammals of North America: biology, management, and economics. Feldhamer, G.A., Thompson, B.C., and Chapman, J.A. (Eds) Baltimore: Johns Hopkins Press.

Anderson, E. L. (2023). Sympatric carnivores and vegetation structure influence the distribution and abundance of Humboldt martens in Northern California. Cal Poly Humboldt theses and projects. 689. https://digitalcommons.humboldt.edu/etd/689

Augustine, B. C., Royle, J. A., Kelly, M. J., Satter, C. B., Alonso, R. S., Boydston, E. E., & Crooks, K. R. (2018). Spatial capture–recapture with partial identity: An application to camera traps.

Avrin, A. C., Pekins, C. E., Wilmers, C. C., Sperry, J. H., & Allen, M. L. (2023). Can a mesocarnivore fill the functional role of an apex predator? *Ecosphere*, *14*(1), e4383.

Bailey, R. G. (2016). Bailey's ecoregions and subregions of the United States, Puerto Rico, and the US Virgin Islands. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2016-0003

Bailey, T. N. (1974). Social organization in a bobcat population. *The Journal of Wildlife Management*, 435-446.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, *67*(1), 1 - 48. https://doi.org/10.18637/jss.v067.i01

Bautista, A. C., Woods, L. W., Filigenzi, M. S., & Puschner, B. (2014). Bromethalin poisoning in a raccoon (*Procyon lotor*): diagnostic considerations and relevance to nontarget wildlife. *Journal of Veterinary Diagnostic Investigation*, *26*(1), 154-157.

Beausoleil, R. A., Clark, J. D., & Maletzke, B. T. (2016). A long-term evaluation of biopsy darts and DNA to estimate cougar density: an agency-citizen science collaboration. *Wildlife Society Bulletin*, *40*(3), 583-592.

Berger-Wolf, T. Y., Rubenstein, D. I., Stewart, C. V., Holmberg, J. A., Parham, J., Menon, S., Crall, J., Van Oast, J., Kiciman, E., & Joppa, L. (2017). Wildbook: Crowdsourcing, computer vision, and data science for conservation. *arXiv preprint arXiv:1710.08880*.

Berny, P., Esther, A., Jacob, J., & Prescott, C. (2018). Development of resistance to anticoagulant rodenticides in rodents. In N. W. van den Brink, J. E. Elliot, R. F. Shore, & B. A. Rattner (Eds.), *Anticoagulant rodenticides and wildlife* (pp. 259-286). Springer.

Bidder, O. R., Connor, T., Morales, J. M., Rickbeil, G. J., Merkle, J. A., Fuda, R. K., Rogerson, J. D., Scurlock, B. M., Edwards, W. H., & Cole, E. K. (2023). Forage senescence and disease influence elk pregnancy across the Greater Yellowstone Ecosystem. *Ecosphere*, *14*(12), e4694.

Blankenship, T. L., Haines, A. M., Tewes, M. E., & Silvy, N. J. (2006). Comparing survival and cause-specific mortality between resident and transient bobcats Lynx rufus. *Wildlife Biology*, *12*(3), 297-303.

Bolger, D. T., Morrison, T. A., Vance, B., Lee, D., & Farid, H. (2012). A computer-assisted system for photographic mark–recapture analysis. *Methods in Ecology and Evolution*, *3*(5), 813-822.

Bolze, G. J., Tirelli, F. P., Queirolo, D., & Ramos Pereira, M. J. (2021). Living on the edge: density and activity patterns of the ocelot, Leopardus pardalis, in the austral limit of the Atlantic Forest. *Studies on Neotropical Fauna and Environment*, 1-14.

Borchers, D. L., & Efford, M. G. (2008). Spatially explicit maximum likelihood methods for capture–recapture studies. *Biometrics*, *64*(2), 377-385.

Borchert, M. I. (2012). Mammalian carnivore use of a high-severity burn in conifer forests in the San Bernardino Mountains of southern California, USA. *Hystrix*, *23*(2), 51.

Botts, R. T., Eppert, A. A., Wiegman, T. J., Rodriguez, A., Blankenship, S. R., Asselin, E. M., Garley, W. M., Wagner, A. P., Ullrich, S. E., Allen, G. R., & Mooring, M. S. (2020). Circadian activity patterns of mammalian predators and prey in Costa Rica. *Journal of Mammalogy*, *101*(5), 1313-1331.

Brink, N. W., Elliott, J. E., Shore, R. F., & Rattner, B. A. (2018). Anticoagulant rodenticides and wildlife. In: van den Brink, N., Elliott, J., Shore, R., Rattner, B. (eds) Emerging Topics in Ecotoxicology, vol 5. Springer, Cham.

Brooks, M. E., Kristensen, K., Van Benthem, K. J., Magnusson, A., Berg, C. W., Nielsen, A., Skaug, H. J., Mächler, M., & Bolker, B. M. (2017). glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. The R Journal. 10.32614/RJ-2017-066

Brown, M. (2021). Monitoring Populations and Movement of Bobcats (Lynx rufus) on the Eastern Slope of the Sierra Nevada Mountains of California. All Graduate Theses and Dissertations. 8071. https://digitalcommons.usu.edu/etd/8071

Burnham, K. P., & Anderson, D. R. (1998). *Practical use of the information-theoretic approach*. Springer.

Calenge, C. (2024). *adehabitatHR: Home Range Estimation*. R package version 0.4.22, https://github.com/clementcalenge/adehabitathr

California Department of Fish and Wildlife. (2021). Annual Report on Pesticide Exposures & Mortalities in Non-target Wildlife 2020. Report prepared by the California Department of Fish and Wildlife, Wildlife Health Laboratory, Rancho Cordova, California.

California Department of Fish and Wildlife (2022). The 2021 Summary of Pesticide Exposures & Mortalities in Non-target Wildlife. Report prepared by the California Department of Fish and Wildlife, Wildlife Health Laboratory, Rancho Cordova, California.

California Department of Fish and Wildlife (2023). The 2022 Summary of Pesticide Exposures & Mortalities in Non-target Wildlife. Report prepared by the California Department of Fish and Wildlife, Wildlife Health Laboratory, Rancho Cordova, California.

California Department of Fish and Wildlife (2024). The 2023 Summary of Pesticide Exposures & Mortalities in Non-target Wildlife. Report prepared by the California Department of Fish and Wildlife, Wildlife Health Laboratory, Rancho Cordova, California.

California Department of Fish and Wildlife (2025). California State Wildlife Action Plan, 2025 Update: A Conservation Legacy for Californians.

California Department of Public Health, Veterinary Public Health Section. (2023). Rabies Surveillance in California, Annual Report 2022. https://www.cdph.ca.gov/Programs/CID/DCDC/pages/reportedanimalrabies.aspx

Chamberlain, M. J., Leopold, B. D., Burger Jr, L. W., Plowman, B. W., & Conner, L. M. (1999). Survival and cause-specific mortality of adult bobcats in central Mississippi. *The Journal of Wildlife Management*, 613-620.

Chamberlain, M. J., Leopold, B. D., & Conner, L. M. (2003). Space use, movements and habitat selection of adult bobcats (Lynx rufus) in central Mississippi. *The American Midland Naturalist*, *149*(2), 395-405.

Chirima, G. J., & Owen-Smith, N. (2017). Comparison of kernel density and local convex hull methods for assessing distribution ranges of large mammalian herbivores. *Transactions in GIS*, *21*(2), 359-375.

Cochrane, J. C., Kirby, J. D., Jones, I. G., Conner, L. M., & Warren, R. J. (2006). Spatial organization of adult bobcats in a longleaf pine-wiregrass ecosystem in southwestern Georgia. *Southeastern Naturalist*, *5*(4), 711-724.

Conner, M., Plowman, B., Leopold, B. D., & Lovell, C. (1999). Influence of time-in-residence on home range and habitat use of bobcats. *The Journal of Wildlife Management*, 261-269.

Conner, M., Smith, M.D., & Burger Jr., L.W. (2005). A comparison of distance-based and classification-based analysis of habitat use: reply. Ecological Society of America. 86(11), 3125-3129. https://www.jstor.org/stable/3450826

Coppock, R. (2013). Advisory: Bromethalin rodenticide—No known antidote. *The Canadian Veterinary Journal*, *54*(6), *557*.

Cox, S. L., Stevens, B., & Reggeti, F. (2022). Bromethalin exposure in a free ranging American black bear (*Ursus americanus*). *Journal of Wildlife Disease*, *58*, 235-237.

Crall, J. P., Stewart, C. V., Berger-Wolf, T. Y., Rubenstein, D. I., & Sundaresan, S. R. (2013). Hotspotter—patterned species instance recognition. 2013 IEEE workshop on applications of computer vision (WACV), Clearwater Beach, FL, USA, 2013, pp. 230-237, doi: 10.1109/WACV.2013.6475023.

Crooks, K. R. (2002). Relative sensitivities of mammalian carnivores to habitat fragmentation. *Conservation Biology*, *16*(2), 488-502.

Crowe, D. M. (1975a). Aspects of ageing, growth, and reproduction of bobcats from Wyoming. *Journal of Mammalogy*, *56*(1), 177-198.

Crowe, D. M. (1975b). A model for exploited bobcat populations in Wyoming. *The Journal of Wildlife Management*, 408-415.

Cunningham, S. C., Kirkendall, L., & Ballard, W. (2006). Gray fox and coyote abundance and diet responses after a wildfire in central Arizona. *Western North American Naturalist*, 169-180.

Dewitz, J. (2021). *National land cover database (NLCD) 2019 products*. *US Geological Survey*. https://doi.org/10.5066/P9KZCM54

Dunagan, S. P., Karels, T. J., Moriarty, J. G., Brown, J. L., & Riley, S. P. D. (2019). Bobcat and rabbit habitat use in an urban landscape. *Journal of Mammalogy,* 100(2), 401–409. https://doi.org/10.1093/jmammal/gyz062

Dyck, M. A., Wyza, E., & Popescu, V. D. (2021). When carnivores collide: a review of studies exploring the competitive interactions between bobcats *Lynx rufus* and coyotes *Canis latrans*. *Mammal Review*, *52*(1), 52-66.

Efford, M. (2023). *secr: Spatially explicit capture-recapture models*. R package version 4.6.10. https://CRAN.R-project.org/package=secr

Efford, M. (2025). Habitat masks in secr 5.2. University of Otago, Auckland, New Zealand.

Emmons, R. W., Leonard, L. L., De Genaro, J., Frank, Protas, E. S., Bazeley, P. L., Giammona, S. T., & Sturckow, K. (1973). A case of human rabies with prolonged survival. *Intervirology*, *1*(1), 60-72.

Erickson, W., & Urban, D. (2004). *Potential risks of nine rodenticides to birds and nontarget mammals: a comparative approach*. US Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances.

ENETwild Consortium (2024). Highly pathogenic avian influenza in wild mammals: critical appraisal of spill-over events and of strategies for prevention, surveillance and preparedness. External Scientific Report. https://doi.org/10.5281/zenodo.13885775

ESRI. (2011a). *ArcGIS Desktop*. Version 10.8.2. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

ESRI. (2011b). *Survey123*. Version Release 3.11. Environmental Systems Research Institute. Redlands, CA: Environmental Systems Research Institute.

Fedriani, J. M., Fuller, T. K., Sauvajot, R. M., & York, E. C. (2000). Competition and intraguild predation among three sympatric carnivores. *Oecologia*, *125*, 258-270.

Ferguson, A. W., Currit, N. A., & Weckerly, F. W. (2009). Isometric scaling in home-range size of male and female bobcats (Lynx rufus). *Canadian Journal of Zoology*, *87*(11), 1052-1060.

Filigenzi, M. S., Bautista, A. C., Aston, L. S., & Poppenga, R. H. (2015). Method for the detection of desmethylbromethalin in animal tissue samples for the determination of bromethalin exposure. *Journal of Agricultural and Food Chemistry*, *63*, 5146–5151.

Fisher, P., O'Connor, C., Wright, G., & Eason, C. T. (2003). Persistence of four anticoagulant rodenticides in the livers of laboratory rats. *DOC Science Internal Series*, *139*, 1-19.

Fiske, I., & Chandler, R. (2011). unmarked: An R Package for Fitting Hierarchical Models of Wildlife Occurrence and Abundance. *Journal of Statistical Software*, *43*(10), 1-23. https://doi.org/doi.org/10.18637/jss.v043.i10

Fox, L. B. (1990). *Ecology and population biology of the bobcat, Felis rufus in New York* State University of New York College of Environmental Science and Forestry.

Fraser, D., Mouton, A., Serieys, L. E., Cole, S., Carver, S., Vandewoude, S., ... & Wayne, R. (2018). Genome-wide expression reveals multiple systemic effects associated with detection of anticoagulant poisons in bobcats (Lynx rufus). *Molecular ecology*, *27*(5), 1170-1187.

Fritts, S. H., & Sealander, J. A. (1978). Reproductive biology and population characteristics of bobcats (Lynx rufus) in Arkansas. *Journal of Mammalogy*, *59*(2), 347-353.

Frederick, J.M. (1998). Overview of wild pig damage in California. Proceeding 18th Vertebrate Pest Conference. Published at University of California Davis. 82-86

Fuller, T. K., Berendzen, S. L., Decker, T. A., & Cardoza, J. E. (1995). Survival and cause-specific mortality rates of adult bobcats (Lynx rufus). *American Midland Naturalist*, 404-408.

Fuller, T. K., Berg, W. E., & Kuehn, D. W. (1985). Survival rates and mortality factors of adult bobcats in north-central Minnesota. *The Journal of Wildlife Management*, *49*(2), 292-296.

Gashwiler, J. S., Robinette, W. L., & Morris, O. W. (1961). Breeding habits of bobcats in Utah. *Journal of Mammalogy*, *42*(1), 76-84.

Geary, W. L., Doherty, T. S., Nimmo, D. G., Tulloch, A. I., & Ritchie, E. G. (2020). Predator responses to fire: A global systematic review and meta-analysis. *Journal of Animal Ecology*, *89*(4), 955-971.

Germaine, S. S., Bristow, K. D., & Haynes, L. A. (2000). Distribution and population status of mountain lions in southwestern Arizona. *The Southwestern Naturalist*, *45*(3), 333-338.

Getz, W. M., Fortmann-Roe, S., Cross, P. C., Lyons, A. J., Ryan, S. J., & Wilmers, C. C. (2007). LoCoH: nonparameteric kernel methods for constructing home ranges and utilization distributions. *PloS one*, *2*(2), e207.

Gillies, C. S., Hebblewhite, M., Nielsen, S. E., Krawchuk, M. A., Aldridge, C. L., Frair, J. L., Saher, D. J., Stevens, C. E., & Jerde, C. L. (2006). Application of random effects to the study of resource selection by animals. *Journal of Animal Ecology*, *75*(4), 887-898.

Gonzales, A. G., & Hoshi, J. (2015). *California state wildlife action plan, 2015 update: a conservation legacy for Californians*. California Department of Fish and Wildlife.

Gould, G. I., Jr. (1978). Furbearer study, Sierra County, California. California Department of Fish and Game. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=18545

Gould G. I., Jr. (1980). *Bobcat Study, San Diego County, California*. Gould, G. I., Jr. Bobcat study, San Diego County, California. California Department of Fish and Game. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=169329

Günther, A., Krone, O., Globig, A., Pohlmann, A., King, J., Fast, C., Grund, C., Hennig, C., Herrmann, C., & Piro, S. (2024). Avian raptors are indicator species and victims of high pathogenicity avian influenza virus HPAIV H5N1 (clade 2.3. 4.4 b) in Germany. *Scientific reports*, *14*(1), 28779.

Hall, E. R. (1981). The Mammals of North America, second edition. Vols. I & II. John Wiley & Sons, New York, New York. 1181 pp.

Hansen, K. (2007). *Bobcat: master of survival*. Oxford University Press.

Hartig, F. (2024). DHARMa: residual diagnostics for hierarchical (multi-level/mixed) regression models. *CRAN: Contributed Packages*.

Harvey, J. A., Mullinax, J. M., Runge, M. C., & Prosser, D. J. (2023). The changing dynamics of highly pathogenic avian influenza H5N1: Next steps for management & science in North America. *Biological Conservation, 282*. https://doi.org/10.1016/j.biocon.2023.110041

Hass, C. (2009). Competition and coexistence in sympatric bobcats and pumas. *Journal of Zoology*, *278*(3), 174-180.

Heilbrun, R. D., Silvy, N. J., Tewes, M. E., & Peterson, M. J. (2003). Using automatically triggered cameras to individually identify bobcats. *Wildlife Society Bulletin*, 748-755.

Hijmans, R. J. (2023). *raster: Geographic Data Analysis and Modeling*. *R package* (Version 3.6-21) https://CRAN.R-project.org/package=raster

Hubbard, T., Cove, M. V., Green, A. M., Iannarilli, F., Allen, M. L., LaRose, S. H., Nagy, C., Compton, J. A., & Lafferty, D. J. R. (2022). Human presence drives bobcat interactions among the U.S. carnivore guild. *Biodiversity and conservation*, *31*, 2607-2624. https://doi.org/https://doi.org/10.1007/s10531-022-02445-2

Jackson, W. B., Spaulding, S. R., Van Lier, R. B. L., & Dreikorn, B. A. (1982). *Bromethalin--a promising new rodenticide*. Proceedings of the Vertebrate Pest Conference: 10th. 2-24

Jacques, C. N., Klaver, R. W., Swearingen, T. C., Davis, E. D., Anderson, C. R., Jenks, J. A., Deperno, C. S., & Bluett, R. D. (2019). Estimating density and detection of bobcats in fragmented midwestern landscapes using spatial capture–recapture data from camera traps. *Wildlife Society Bulletin*, *43*(2), 256-264.

Jennings, M. K. (2012). Landscape dynamics in Southern California: Understanding mammalian carnivore response to fire and human development (Doctoral dissertation). San Diego State University & University of California, Davis.

Johnson, D. H. (1980). The comparison of usage and availability measurements for evaluating resource preference. *Ecology*, *61*(1), 65-71.

Johnson, N. F., & Holloran, D. J. (1985). Reproductive activity of Kansas bobcats. *The Journal of Wildlife Management*, *49*(1), 42-46.

Jones, L. R., Zollner, P. A., Swihart, R. K., Godollei, E., Hudson, C. M., & Johnson, S. A. (2020). Survival and mortality sources in a recovering population of bobcats (Lynx rufus) in south-central Indiana. *The American Midland Naturalist*, *184*(2), 222-232.

Kaminski, J. A., Davis, M. L., Kelly, M., & Keyser, P. D. (2007). Disturbance effects on small mammal species in a managed Appalachian forest. *The American Midland Naturalist*, *157*(2), 285-397. https://doi.org/10.1674/0003-0031(2007)157[385:DEOSMS]2.0.CO;2

Kamler, J. F., & Gipson, P. S. (2000). Home range, habitat selection, and survival of bobcats, Lynx rufus, in a prairie ecosystem in Kansas. *Canadian Field-Naturalist*, *114*(3), 388-394.

Karandikar, H., Serota, M. W., Sherman, W. C., Green, J. R., Verta, G., Kremen, C., & Middleton, A. D. (2022). Dietary patterns of a versatile large carnivore, the puma (Puma concolor). *Ecology and evolution*, *12*(6), e9002.

Khosravi, R., Hemami, M.-R., Malakoutikhah, S., Ashrafzadeh, M. R., & Cushman, S. A. (2021). Prey availability modulates predicted range contraction of two large felids in response to changing climate. *Biological Conservation*, *255*, 109018.

Kitchings, J. T., & Story, J. D. (1984). Movements and dispersal of bobcats in east Tennessee. *The Journal of Wildlife Management*, *48*(3), 957-961.

Knick, S. T. (1990). Ecology of bobcats relative to exploitation and a prey decline in southeastern Idaho. *Wildlife Monographs*, 3-42.

Knick, S. T., Brittell, J. D., & Sweeney, S. J. (1985). Population characteristics of bobcats in Washington State. *The Journal of Wildlife Management*, 721-728.

Koehler, S. A. (2006). *Habitat selection and demography of bobcats (Lynx rufus) in Iowa* Iowa State University Ames, USA.

Kopanke, J. H., Horak, K. E., Musselman, E., Miller, C. A., Bennett, K., Olver, C. S., Volker, S. F., Vandewoude, S., & Bevins, S. N. (2018). Effects of Low-level Brodifacoum Exposure on the Feline Immune Response. *Scientific Reports*, 8(1). https://doi.org/10.1038/s41598-018-26558-3

Kozakiewicz, C. P., Burridge, C. P., Lee, J. S., Kraberger, S. J., Fountain-Jones, N. M., Fisher, R. N., ... & Carver, S. (2023). Habitat connectivity and host relatedness influence virus spread across an urbanising landscape in a fragmentation-sensitive carnivore. *Virus Evolution*, *9*(1), veac122.

Krebs, J. W., Williams, S. M., Smith, J. S., Rupprecht, C. E., & Childs, J. E. (2003). Rabies among infrequently reported mammalian carnivores in the United States, 1960–2000. *Journal of wildlife diseases*, *39*(2), 253-261.

Landry, S. M. (2017). Bobcat population ecology in West Virginia. Graduate Theses, Dissertations, and Problem Reports. 6033. https://researchrepository.wvu.edu/etd/6033

Larivière, S., & Walton, L. R. (1997). Lynx rufus. *Mammalian species* (563), 1-8.

Larson, R. N., Morin, D. J., Wierzbowska, I. A., & Crooks, K. R. (2015). Food habits of coyotes, gray foxes, and bobcats in a coastal southern California urban landscape. *Western North American Naturalist*, 339-347.

Lembeck, M. (1978). *Bobcat study, San Diego County, California*. State of California, the Resources Agency, Department of Fish and Game.

Lesmeister, D. B., Nielsen, C. K., Schauber, E. M., & Hellgren, E. C. (2015). Spatial and temporal structure of a mesocarnivore guild in midwestern North America. *Wildlife Monographs*, *191*, 1-61. https://doi.org/10.1002/wmon.1015

Lewis, J. S., Rachlow, J. L., Garton, E. O., & Vierling, L. A. (2007). Effects of habitat on GPS collar performance: using data screening to reduce location error. *Journal of applied ecology*, *44*(3), 663-671.

Lichti, N. I., & Swihart, R. K. (2011). Estimating utilization distributions with kernel versus local convex hull methods. *The Journal of Wildlife Management*, *75*(2), 413-422.

Littell, J. S., McKenzie, D., Peterson, D. L., & Westerling, A. L. (2009). Climate and wildfire area burned in western US ecoprovinces, 1916–2003. *Ecological Applications*, *19*(4), 1003-1021.

Littell, J. S., McKenzie, D., Wan, H. Y., & Cushman, S. A. (2018). Climate change and future wildfire in the western United States: An ecological approach to nonstationarity. *Earth's Future*, *6*(8), 1097-1111.

Litvaitis, J. A., Major, J. T., & Sherburne, J. A. (1987). Influence of season and human-induced mortality on spatial organization of bobcats (Felis rufus) in Maine. *Journal of Mammalogy*, *68*(1), 100-106.

Logan, K. A., & Sweanor, L. L. (2001). *Desert puma: evolutionary ecology and conservation of an enduring carnivore*. Island press.

Lombardi, J. V., Comer, C. E., Scognamillo, D. G., & Conway, W. C. (2017). Coyote, fox, and bobcat response to anthropogenic and natural landscape features in a small urban area. *Urban Ecosystems*, *20*, 1239-1248.

Lombardi, J. V., Haines, A. M., Watts III, G. W., Grassman Jr, L. I., Janečka, J. E., Caso, A., Carvajal, S., Wardle, Z. M., Yamashita, T. J., & Stasey, W. C. (2022). Status and distribution of jaguarundi in Texas and Northeastern México: Making the case for extirpation and initiation of recovery in the United States. *Ecology and Evolution*, *12*(3), e8642.

Lombardi, J. V., MacKenzie, D. I., Tewes, M. E., Perotto-Baldivieso, H. L., Mata, J. M., & Campbell, T. A. (2020). Co-occurrence of bobcats, coyotes, and ocelots in Texas. *Ecology and Evolution*, *10*(11), 4903-4917.

Long, R. A., Donovan, T. M., Mackay, P., Zielinski, W. J., & Buzas, J. S. (2007). Effectiveness of scat detection dogs for detecting forest carnivores. *The Journal of Wildlife Management*, *71*(6), 2007-2017.

Lovallo, M. J. (2000a). Bobcat habitat assessment and population density in Pennsylvania. *Pennsylvania Game Commission, The Pennsylvania Cooperative Fish and Wildlife Research Unit*.

Lovallo, M. J. (2000b). *Status and Management of the Bobcat (Lynx rufus) in Pennsylvania*. *Pennsylvania Game Commission, The Pennsylvania Cooperative Fish and Wildlife Research Unit*.

Lovallo, M. J., & Anderson, E. M. (1996). Bobcat (Lynx rufus) home range size and habitat use in northwest Wisconsin. *American Midland Naturalist*, 241-252.

MacKenzie, D. I., Nichols, J. D., Lachman, G. B., Droege, S., Andrew Royle, J., & Langtimm, C. A. (2002). Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, *83*(8), 2248-2255.

Major, J. T. & Sherburne J. A. (1987). Interspecific Relationships of Coyotes, Bobcats, and Red Foxes in Western Maine. *The Journal of Wildlife Management*, 51(3) 606–16. https://doi.org/10.2307/3801278

Mayer, J. J. (2009). Natural Predators of Wild Pigs in the United States. In. Wild Pigs: Biology, Damage, Control Techniques and Management, Savannah River National Laboratory, Aiken, South Carolina. pp.193-204

McBride, R., McBride, C., & McBride, C. (2016). Safe and Selective Capture of Bobcats (Lynx rufus) Using Trained Hounds in the Absence of Snow. *Southeastern Naturalist*, *15*(2), 291-298.

McMillin, S., Piazza, M. S., Woods, L. W., & Poppenga, R. H. (2016). New rodenticide on the block: diagnosing bromethalin intoxication in wildlife. *Proceedings of the Vertebrate Pest Conference*, *27*, 419-421.

McNitt, D. C., Alonso, R. S., Cherry, M. J., Fies, M. L., & Kelly, M. J. (2020a). Influence of forest disturbance on bobcat resource selection in the central Appalachians. *Forest Ecology and Management*, *465*, 118066.

McNitt, D. C., Alonso, R. S., Cherry, M. J., Fies, M. L., & Kelly, M. J. (2020b). Sex-specific effects of reproductive season on bobcat space use, movement, and resource selection in the Applalachian Mountains of Virgina. *PLOS One* 15(8): e0225355.

Miller, S., & Speake, D. (1979). Progress report: demography and home range of the bobcat in south Alabama. Bobcat Research Conference Proceedings, Front Royal, Va.

Mills, S., Whiteley, A. & Tourani, M. (2025). Conservation of Wildlife Populations. Oxford University Press.

Moll, R. J., Jackson, P. J., Wakeling, B. F., Lackey, C. W., Beckmann, J. P., Millspaugh, J. J., & Montgomery, R. A. (2021). An apex carnivore's life history mediates a predator cascade. *Oecologia*, *196*, 223-234. https://doi.org/10.1007/s00442-021-04927-6

Moreno-Sosa, A. M., Yacelga, M., Craighead, K. A., Kramer-Schadt, S., & Abrams, J. F. (2022). Can prey occupancy act as a surrogate for mesopredator occupancy? A case study of ocelot (Leopardus pardalis). *Mammalian Biology*, *102*(1), 163-175.

Moriarty, J. G. (2007). *Female bobcat reproductive behavior and kitten survival in an urban fragmented landscape*. Graduate Thesis: California State University, Northridge.

Moriarty, J. G., & Riley, S. P. (2011). Survival and dispersal of bobcat kittens in a fragmented urban landscape. *Final report. Western National Parks Association, Oro Valley*.

Moriarty, J. G., Riley, S. P., Serieys, L. E., Sikich, J. A., Schoonmaker, C. M., & Poppenga, R. H. (2012). Exposure of wildlife to anticoagulant rodenticides at Santa Monica Mountains National Recreation Area: from mountain lions to rodents. Proceedings of the Vertebrate Pest Conference.

Morin, D. J., Waits, L. P., McNitt, D. C., & Kelly, M. J. (2018). Efficient single-survey estimation of carnivore density using fecal DNA and spatial capture-recapture: a bobcat case study. *Population Ecology*, *60*, 197-209.

Morrison, E. E. (2022). *Reproductive Rates, Kitten Survival, and Den Site Selection of Bobcats (Lynx Rufus) in the Black Hills, South Dakota* West Virginia University.

Morrison, E. E., Lehman, C. P., Neiles, B., & Rota, C. T. (2024). Resource selection of den sites for bobcats (Lynx rufus) in the Northern Great Plains, United States. *Journal of Mammalogy*, *106*(3), 51-58. https://doi.org/10.1093/jmammal/gyae105

Murphy, S. M., Wilckens, D. T., Augustine, B. C., Peyton, M. A., & Harper, G. C. (2019). Improving estimation of puma (Puma concolor) population density: clustered camera-trapping, telemetry data, and generalized spatial mark-resight models. *Scientific reports*, *9*(1), 4590.

Murray, M., & Cox, E. C. (2023a). Active metabolite of the neurotoxic rodenticide bromethalin along with anticoagulant rodenticides detected in birds of prey in the northeastern United States. *Environmental Pollution*, *333*, e122076.

Murray, M., & Cox, E. C. (2023b). Bromethalin exposure and possible toxicosis in a bald eagle (*Haliaeetus leucocephalus*). *Journal of Wildlife Disease*, *59*, 815-817.

Neale, J. C., & Sacks, B. N. (2001). Resource utilization and interspecific relations of sympatric bobcats and coyotes. *Oikos*, *94*(2), 236-249.

Neale, J. C., Sacks, B. N., Jaeger, M. M., & McCullough, D. R. (1998). A comparison of bobcat and coyote predation on lambs in north-coastal California. *The Journal of Wildlife Management*, 700-706.

Negrões, N., Sarmento, P., Cruz, J., Eira, C., Revilla, E., Fonseca, C., Sollmann, R., TŐRRES, N. M., Furtado, M. M., & Jácomo, A. T. (2010). Use of camera-trapping to estimate puma density and influencing factors in central Brazil. *The Journal of Wildlife Management*, *74*(6), 1195-1203.

Newbury, R. K., & Hodges, K. E. (2018). Regional differences in winter diets of bobcats in their northern range. *Ecology and Evolution*, *8*(22), 11100-11110.

Nielsen, C. K., Bottom, C. R., Tebo, R. G., & Greenspan, E. (2017). Habitat overlap among bobcats (Lynx rufus), coyotes (Canis latrans), and wild turkeys (Meleagris gallopavo) in an agricultural landscape. *Canadian Journal of Zoology*, *96*(5), 486-496.

Ng, S. J., Dole, J. W., Sauvajot, R. M., Riley, S. P., & Valone, T. J. (2004). Use of highway undercrossings by wildlife in southern California. *Biological Conservation*, *115*(3), 499-507.

Nomsen, D. E. (1982). *Food habits and placental scar counts of bobcats in South Dakota*. South Dakota State University.

Nussbaum, R. A., & Maser, C. (1975). Food habits of the bobcat. *Lynx rufus* in the Coast and Cascade Ranges of Western Oregon in Relation to Present Management Policies. *Northwest Science, 49,* 261-266.

Ordeñana, M. A., Crooks, K. R., Boydston, E. E., Fisher, R. N., Lyren, L. M., Siudyla, S., Haas, C. D., Harris, S., Hathaway, S. A., & Turschak, G. M. (2010). Effects of urbanization on carnivore species distribution and richness. *Journal of Mammalogy*, *91*(6), 1322-1331.

Parker, G., & Smith, G. (1983). Sex-and age-specific reproductive and physical parameters of the bobcat (Lynx rufus) on Cape Breton Island, Nova Scotia. *Canadian Journal of Zoology*, *61*(8), 1771-1782.

Parsons, A. W., Rota, C. T., Forrester, T., Baker-Whatton, M. C., McShea, W. J., Schuttler, S. G., Millspaugh, J. J., & Kays, R. (2019). Urbanization focuses carnivore activity in remaining natural habitats, increasing species interactions. *Journal of applied ecology*, *56*(8), 1894-1904. https://doi.org/https://doi.org/10.1111/1365-2664.13385

Penner, L. R., & Parke, W. N. (1954). Notoedric mange in the bobcat, Lynx rufus. *Journal of Mammalogy*, *35*(3), 458-458.

Petch, R. J., Gagne, R. B., Chiu, E., Mankowski, C., Rudd, J., Roelke-Parker, M., Vickers, T. W., Logan, K. A., Alldredge, M., & Clifford, D. (2022). Feline leukemia virus frequently spills over from domestic cats to North American pumas. *Journal of Virology*, *96*(23), e01201-01222.

Powell, R. A., & Proulx, G. (2003). Trapping and marking terrestrial mammals for research: integrating ethics, performance criteria, techniques, and common sense. *ILAR journal*, *44*(4), 259-276.

Proffitt, K. M., Goldberg, J. F., Hebblewhite, M., Russell, R., Jimenez, B., Robinson, H. S., Pilgrim, K., & Schwartz, M. K. (2015). Integrating resource selection into spatial capture-recapture models for large carnivores. *Ecosphere*, *6*(11), 1-15.

Prugh, L. R., & Sivy, K. J. (2020). Enemies with benefits: integrating positive and negative interactions among terrestrial carnivores. *Ecology Letters*, *23*(5), 902-918.

R Core Team (2021). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna. https://www.R-project.org

Ridout, M. S., & Linkie, M. (2009). Estimating overlap of daily activity patterns from camera trap data. *Journal of Agricultural, Biological, and Environmental Statistics*, *14*, 322-337.

Riley, S. P. D. (2006b). Spatial ecology of bobcats and gray foxes in urban and rural zones of a national park. *The Journal of Wildlife Management*, *70*(5), 1425-1435.

Riley, S. P. D., Boydston E. E., Crooks K. R., & Lyren L. M. (2010) Bobcats (Lynx rufus). In: *Urban Carnivores: Ecology, Conflict and Conservation*. (eds Gehert D., Riley S. P. D., Cypher B. L.), pp. 121-140. The Johns Hopkins University Press, Baltimore.

Riley, S. P. D., Bromley, C., Poppenga, R. H., Uzal, F. A., Whited, L., & Sauvajot, R. M. (2007). Anticoagulant exposure and notoedric mange in bobcats and mountain lions in urban southern California. *The Journal of Wildlife Management*, *71*(6), 1874-1884.

Riley, S. P. D., Foley, J., & Chomel, B. (2004). Exposure to feline and canine pathogens in bobcats and gray foxes in urban and rural zones of a national park in California. *The Journal of Wildlife Diseases*, *40*(1), 11-22.

Riley, S. P. D., Pollinger, J. P., Sauvajot, R. M., York, E. C., Bromley, C., Fuller, T. K., & Wayne, R. K. (2006a). FAST-TRACK: A southern California freeway is a physical and social barrier to gene flow in carnivores. *Molecular ecology*, *15*(7), 1733-1741.

Riley, S. P. D., Sauvajot, R. M., Fuller, T. K., York, E. C., Kamradt, D. A., Bromley, C., & Wayne, R. K. (2003). Effects of urbanization and habitat fragmentation on bobcats and coyotes in southern California. *Conservation Biology*, *17*(2), 566-576.

Roberts, N. M., & Crimmins, S. M. (2010). Bobcat population status and management in North America: evidence of large-scale population increase. *Journal of Fish and Wildlife Management*, *1*(2), 169-174.

Rolley, R. E. (1985). Dynamics of a harvested bobcat population in Oklahoma. *The Journal of Wildlife Management*, 283-292.

Rota, C. T., Ferreira, M. A., Kays, R. W., Forrester, T. D., Kalies, E. L., McShea, W. J., Parsons, A. W., & Millspaugh, J. J. (2016). A multispecies occupancy model for two or more interacting species. *Methods in Ecology and Evolution*, *7*(10), 1164-1173.

Rowcliffe, M. (2021). Activity: Animal Activity Statistics. *CRAN*. https://doi.org/https://cran.r-project.org/web/packages/activity/activity.pdf

Royle, J. A., Chandler, R. B., Sun, C. C., & Fuller, A. K. (2013). Integrating resource selection information with spatial capture–recapture. *Methods in Ecology and Evolution*, *4*(6), 520-530.

Rudd, J. L., Poppenga, R. H., Woods, L. W., Riley, S. P., Sikich, J. A., Streitenberger, N., & Clifford, D. L. (2024). Detection of rodenticides in pregnant mountain lions (*Puma concolor*) and their fetuses in California. *Canadian Wildlife Biology & Management*, *13*(2).

Ruell, E., Riley, S., Douglas, M., Antolin, M., Pollinger, J., Tracey, J., Lyren, L., Boydston, E., Fisher, R. N., & Crooks, K. (2012). Urban habitat fragmentation and genetic population structure of bobcats in coastal southern California. *The American Midland Naturalist*, *168*(2), 265-280.

Ruell, E. W., Riley, S. P., Douglas, M. R., Pollinger, J. P., & Crooks, K. R. (2009). Estimating bobcat population sizes and densities in a fragmented urban landscape using noninvasive capture–recapture sampling. *Journal of Mammalogy*, *90*(1), 129-135.

Ruprecht, J., C.E. Eriksson, T.D. Forrester, D.B. Spitz, D.A. Clark, M.J. Wisdom, M. Bianco, M.M. Rowland, J.B. Smith, B.K. Johnson, & T. Levi (2021). Variable strategies to solve risk–reward tradeoffs in carnivore communities, *Proc. Natl. Acad. Sci. U.S.A. 118(35),* e2101614118, https://doi.org/10.1073/pnas.2101614118.

Russell, R. E., Royle, J. A., Desimone, R., Schwartz, M. K., Edwards, V. L., Pilgrim, K. P., & Mckelvey, K. S. (2012). Estimating abundance of mountain lions from unstructured spatial sampling. *The Journal of Wildlife Management*, *76*(8), 1551-1561.

Safford, H. D., Paulson, A. K., Steel, Z. L., Young, D. J., & Wayman, R. B. (2022). The 2020 California fire season: A year like no other, a return to the past or a harbinger of the future? *Global Ecology and Biogeography*, *31*(10), 2005-2025.

Santos, F., Carbone, C., Wearn, O. R., Rowcliffe, J. M., Espinosa, S., Lima, M. G. M., Ahumada, J. A., Gonçalves, A. L. S., Trevelin, L. C., & Alvarez-Loayza, P. (2019). Prey availability and temporal partitioning modulate felid coexistence in Neotropical forests. *PloS one*, *14*(3), e0213671.

Schmidt, G. M., Jennings, M. K., Smith, J. G., Boydston, E. E., Lyren, L. M., & Lewison, R. L. (2023). Bobcats in southern California respond to urbanization at multiple scales. *Biological Conservation*, *278*, 109849.

Schuette, P., Diffendorfer, J., Deutschman, D., Tremor, S., & Spencer, W. (2014). Carnivore distributions across chaparral habitats exposed to wildfire and rural housing in southern California. *International journal of wildland fire*, *23*(4), 591-600.

Section, C. D. o. P. H.-V. P. H. (2022). *Rabies Surveillance in California*.

Sergeyev, M., Crawford, D. A., Holbrook, J. D., Lombardi, J. V., Tewes, M. E., & Campbell, T. A. (2023a). Selection in the third dimension: Using LiDAR derived canopy metrics to assess individual and population-level habitat partitioning of ocelots, bobcats, and coyotes. *Remote Sensing in Ecology and Conservation*.

Sergeyev, M., Holbrook, J. D., Lombardi, J. V., Tewes, M. E., & Campbell, T. A. (2023b). Behaviorally mediated coexistence of ocelots, bobcats and coyotes using hidden Markov models. *Oikos*, *2023*(4), e09480. https://doi.org/10.1111/oik.09480

Serieys, L. E., Armenta, T. C., Moriarty, J. G., Boydston, E. E., Lyren, L. M., Poppenga, R. H., Crooks, K. R., Wayne, R. K., & Riley, S. P. (2015a). Anticoagulant rodenticides in urban bobcats: exposure, risk factors and potential effects based on a 16-year study. *Ecotoxicology*, *24*, 844-862.

Serieys, L. E., Foley, J., Owens, S., Woods, L., Boydston, E. E., Lyren, L. M., Poppenga, R. H., Clifford, D. L., Stephenson, N., & Rudd, J. (2013). Serum chemistry, hematologic, and post-mortem findings in free-ranging bobcats (Lynx rufus) with notoedric mange. *The Journal of Parasitology*, *99*(6), 989-996.

Serieys, L. E., Lea, A. J., Pollinger, J. P., Riley, S. P., & Wayne, R. K. (2015b). Disease and freeways drive genetic change in urban bobcat populations. *Evolutionary Applications*, *8*(1), 75-92.

Serieys, L. E., Lea, A. J., Epeldegui, M., Armenta, T. C., Moriarty, J., VandeWoude, S., Carver, S., Foley, J., Wayne, R. K., & Riley, S. P. (2018). Urbanization and anticoagulant poisons promote immune dysfunction in bobcats. *Proceedings of the Royal Society B: Biological Sciences*, *285*(1871), 20172533.

Shores, C. R., Dellinger, J. A., Newkirk, E. S., Kachel, S. M., & Wirsing, A. J. (2019). Mesopredators change temporal activity in response to a recolonizing apex predator. *Behavioral Ecology*, *30*(5), 13243-11335. https://doi.org/https://doi.org/10.1093/beheco/arz080

Slauson, K. M., Zielinski, W. J., Kirk, T. A., & LaPlante, D. W. (2019). A landscape habitat suitability model for the Humboldt Marten (Martes caurina humboldtensis) in Coastal California and Coastal Oregon. *Northwest Science*, *93*(1), 30-51.

Smith, L., Liang, B., Booth, M., Filigenzi, M., Tkachenko, A., & Gasskill, C. (2018). Development and validation of quantitative ultraperformance liquid chromatographytandem mass spectrometry assay for anticoagulant rodenticides in liver. *Journal of Agriculture and Food Chemistry*, *65*, 6682–6691.

Smith, J. G., Jennings, M. K., Boydston, E. E., Crooks, K. R., Ernest, H. B., Riley, S. P. D., Serieys, L. E. K., Sleater-Squires, S., & Lewison, R. L. (2020). Carnivore population structure across an urbanization gradient: a regional genetic analysis of bobcats in southern California. *Landscape Ecology, 35*(3), 659–674. https://doi.org/10.1007/s10980-020-00971-4

Stanley, T. R., & Burnham, K. P. (1998). Information-Theoretic Model Selection and Model Averaging for Closed-Population Capture-Recapture Studies. *Biometrical Journal*, *40*(4), 475-494. https://doi.org/10.1002/(SICI)1521-4036(199808)40:4<475::AID-BIMJ475>3.0.CO;2-#

Steel, Z. L., Koontz, M. J., & Safford, H. D. (2018). The changing landscape of wildfire: burn pattern trends and implications for California's yellow pine and mixed conifer forests. *Landscape Ecology*, *33*, 1159-1176.

Stevens Jr, D. L., & Olsen, A. R. (2004). Spatially balanced sampling of natural resources. *Journal of the American statistical Association*, *99*(465), 262-278.

Therneau, T. M. & Lumley, T. (2011). survival: Survival Analysis, Including Penalized Likelihood. *R Core Team*. http://CRAN.R-project.org/package=survival

Thornton, D. H., & Pekins, C. E. (2015). Spatially explicit capture–recapture analysis of bobcat (Lynx rufus) density: implications for mesocarnivore monitoring. *Wildlife Research*, *42*(5), 394-404.

Tigas, L. A., Van Vuren, D. H., & Sauvajot, R. M. (2002). Behavioral responses of bobcats and coyotes to habitat fragmentation and corridors in an urban environment. *Biological Conservation*, *108*(3), 299-306.

Tuia, D., Kellenberger, B., Beery, S., Costelloe, B. R., Zuffi, S., Risse, B., Mathis, A., Mathis, M. W., Van Langevelde, F., & Burghardt, T. (2022). Perspectives in machine learning for wildlife conservation. *Nature communications*, *13*(1), 1-15.

Tycz, B. M. (2016). *Evaluation of bobcat (Lynx rufus) survival, harvest, and population size in the west-central region of South Dakota* South Dakota State University.

U. S. Environmental Protection Agency (2024). Rodenticides: Final Biological Evaluation, Effects Determinations, and Mitigation Strategy for Federally Listed and Proposed Endangered and Threatened Species and Designated and Proposed Critical Habitats.

U.S. Fish & Wildlife Service. (2020). Endangered and Threatened Wildlife and Plants; Threatened species status for Coastal Distinct Population Segment of the Pacific marten with a Section 4 (d) rule. *Federal Register*, *85*, 63806-63831.

Van Lier, R. B., & Cherry, L. D. (1988). The toxicity and mechanism of action of bromethalin: a new single-feeding rodenticide. *Fundamental and Applied Toxicology*, *11*(4), 664-672.

von Thaden, A., Nowak, C., Tiesmeyer, A., Reiners, T. E., Alves, P. C., Lyons, L. A., Mattucci, F., Randi, E., Cragnolini, M., & Galián, J. (2020). Applying genomic data in wildlife monitoring: Development guidelines for genotyping degraded samples with reduced single nucleotide polymorphism panels. *Molecular Ecology Resources*, *20*(3), 662-680.

Wang, Y., Allen, M. L., & Wilmers, C. C. (2015). Mesopredator spatial and temporal responses to large predators and human development in the Santa Cruz Mountains of California. *Biological Conservation*, *190*, 23-33.

Wengert, G. M. (2013). *Ecology of intraguild predation on fishers (Martes pennanti) in California*. University of California, Davis.

Wengert, G. M., Gabriel, M. W., Matthews, S. M., Higley, J. M., Sweitzer, R. A., Thompson, C. M., Purcell, K. L., Barrett, R. H., Woods, L. W., & Green, R. E. (2014). Using DNA to describe and quantify interspecific killing of fishers in California. *The Journal of Wildlife Management*, *78*(4), 603-611.

Wilckens, D. T., Smith, J. B., Tucker, S. A., Thompson, D. J., & Jenks, J. A. (2016). Mountain lion (Puma concolor) feeding behavior in the Little Missouri Badlands of North Dakota. *Journal of Mammalogy*, *97*(2), 373-385.

Wisdom, M. J., Mills, L. S., & Doak, D. F. (2000). Life stage simulation analysis: estimating vital-rate effects on population growth for conservation. *Ecology*, *81*(3), 628-641.

Woolf, A., Nielsen, C. K., Weber, T., & Gibbs-Kieninger, T. J. (2002). Statewide modeling of bobcat, Lynx rufus, habitat in Illinois, USA. *Biological Conservation*, *104*(2), 191-198.

Young, J. K., Golla, J. M., Broman, D., Blankenship, T., & Heilbrun, R. (2019). Estimating density of an elusive carnivore in urban areas: use of spatially explicit capture-recapture models for city-dwelling bobcats. *Urban Ecosystems*, *22*, 507-512.

Zezulak, D. S. (1978). *Northeastern California bobcat study*. California Department of Fish and Game Report.

Zezulak, D. S., & Schwab, R. G. (1980). *Bobcat biology in a Mojave Desert community*. California Department of Fish and Game, and Bureau of Land Management: California Desert Planning Program Report.

APPENDIX A: BOBCAT CAPTURE PLAN

CDFW Bobcat Capture Plan (2020-2024)