



Nilgai Inventory at Palo Alto Battlefield National Historic Park

Final Report

Natural Resource Report NPS/NRSS/IMD/NRR—2023/2497



ON THE COVER

Camera trap photo example with two nilgai antelope standing in a tall grass field
(NPS)

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Contents

	Page
Figures.....	v
Tables.....	vi
Appendices.....	vi
Executive Summary	vii
1. Introduction.....	1
1.1 Study Area.....	1
1.2 Focal Species: Nilgai Antelope	2
1.3 Other Wildlife Species	4
2. Methods.....	5
2.1 Camera Traps and Time-to-Event Model.....	5
2.2 Equipment.....	5
2.3 Camera Trap Stations	6
2.3.1 Camera Trap Data Collection.....	8
2.4 Latrine Sites.....	8
2.5 Photo Analysis.....	9
2.6 Time-to-Event Model	9
2.7 Independent Detections	10
2.8 Site Covariates.....	11
2.8.1 Vegetation.....	11
2.8.2 Woody Plant Cover and Structure.....	13
2.8.3 Inundation.....	15
2.9 Regression Analysis	15
3. Results.....	16
3.1 Photo Analysis.....	16
3.2 Time-to-Event Model	17
3.3 Independent Detections	19

Contents (continued)

	Page
3.3.1 Camera Trap Stations	19
3.3.2 Latrine Site Stations	21
3.3.3 Nilgai Antelope: Time Series Analysis	23
3.3.4 Other Wildlife Species	25
3.4 Site Covariates.....	27
3.4.1 Vegetation.....	27
3.4.2 Regression Analysis	29
4. Discussion.....	31
4.1 Nilgai Antelope	31
4.2 Other Wildlife Species	33
5. Conclusions.....	35
6. References.....	36

Figures

	Page
Figure 1. Study Area within the western unit of Palo Alto Battlefield National Historical Park.	2
Figure 2. Young bull nilgai antelope.....	3
Figure 3. Bobcat documented at D4.....	4
Figure 4. Representative camera trap station site situated within an inundated resaca (E4).	6
Figure 5. Camera trap stations and latrine site stations across the western unit of Palo Alto Battlefield National Historical Park.....	7
Figure 6. A subadult nilgai antelope spooks a turkey vulture into flight at latrine site station LS_4.	8
Figure 7. Vegetation survey plot diagram.....	12
Figure 8. Representative site photos per cover type.	14
Figure 9. Woody plant cover and structure cover type delineation method.	15
Figure 10. Independent detections at camera trap stations.	20
Figure 11. Independent detection events at latrine site stations.....	22
Figure 12. Two subadult male nilgai antelope exhibit characteristic stances for mock-sparring.	23
Figure 13. Total independent detections per day of nilgai antelope.	24
Figure 14. Coyote passes in front of D5.	26
Figure 15. White-tailed deer buck at LS_8.	26
Figure 16. A subadult male nilgai antelope crosses an inundated resaca at camera trap station E4.	29
Figure 17. Nursing nilgai antelope calf.....	32
Figure 18. A group of feral hogs at camera trap station D4.....	34

Tables

	Page
Table 1. Other wildlife species: Total independent detection events (camera trap stations and latrine site stations).	16
Table 2. TTE model results.	18

Appendices

	Page
Appendix A—Supplemental Methods	A-1
Appendix B—Maps	B-1
Appendix C—Independent Detection Event Analysis Results.....	C-1
Appendix D—Site Covariate Results	D-1
Appendix E—Regression Analysis Results	E-1

Executive Summary

Keywords: nilgai antelope, invasive species, camera trapping, vegetation, abundance, distribution

Nilgai antelope (*Boselaphus tragocamelus*) are invasive ungulates introduced to southern Texas, where they have since established free-ranging populations. One such population has been consistently observed within the western unit of Palo Alto Battlefield National Historical Park. Park managers are concerned about potential impacts to native vegetation resulting from nilgai antelope grazing and alteration of the historic character of the park. To provide Palo Alto Battlefield National Historical Park with the ability to make informed management decisions, baseline information regarding abundance, occupancy, and distribution of nilgai antelope was collected and analyzed by DJ&A, P.C. with support from the Caesar Kleberg Wildlife Research Institute at Texas A&M University, Kingsville. Using remote camera traps and population modelling techniques for estimating abundance of unmarked populations, 20 active camera trap stations were installed for one year, with two additional stations rotated through a subset of eight identified latrine sites to capture spatiotemporal patterns of use and group demographics. Captured images of nilgai antelope were analyzed to estimate abundance, occupancy, and predicted distribution of nilgai antelope in the park. Other wildlife species detected were also analyzed as data permitted.

Total abundance of nilgai antelope within the study area was estimated to be 58 individuals (SE=1.8), with some seasonal variation in response to births, deaths, emigration, immigration, and potential changes in group size and behavior stemming from biological activities such as parturition and breeding. Independent detection event analyses resulted in 2,333 discrete events, with 2,190 of those containing nilgai antelope. Relative to nilgai antelope, 26 other wildlife species were detected including feral hog, collared peccary, raccoon, bobcat, coyote, and white-tailed deer in order of decreasing independent detection events. Of nilgai antelope, adult females were most commonly detected and subsequently were the primary drivers behind observed patterns of use across the study area. Detections occurred at all sites, indicating use of the entire study area, with central and northwestern portions maintaining the highest overall activity for all sex and age classes. Southeastern portions had notably low detections, indicating a lack of suitable habitat. Time series analysis of nilgai antelope activity showed minimal fluctuations in activity with three primary peaks in May, September, and January. Adult males exhibited relatively heightened activity in the fall leading into the breeding season.

Nilgai antelope detections increased significantly with increasing cover of invasive grasses and grazed species and decreased as cover of native species and gulf cordgrass increased. This pattern indicates that habitats with increased prevalence of invasive graminoids may offer more suitable habitat than habitats with intact native vegetation such as coastal prairie within the study area. Continued restoration of native vegetation communities could result in reduced habitat suitability and overall carrying capacity for nilgai antelope within the western unit of Palo Alto Battlefield National Historical Park.

1. Introduction

The nilgai antelope (*Boselaphus tragocamelus*) is an invasive ungulate species endemic to South Asia and introduced to South Texas, where it has now established free-ranging populations. One such population has been documented in apparently increasing numbers within the boundaries of Palo Alto Battlefield National Historical Park (PAAL). The enabling legislation of PAAL, Palo Alto Battlefield National Historic Site Act of 1991 Public Law 102-304, charges the National Park Service (NPS) with restoring and maintaining the historic character of the site, and vegetation resources form an integral component of such character (National Park Service 2010b). The presence of a large, nonnative ungulate such as nilgai antelope may have adverse impacts upon the vegetation resource of PAAL and its historic character. Of particular interest is the native open prairie vegetation community that is representative of the dominant vegetation community present at the time of the battle.

Nilgai antelope may also exclude native white-tailed deer (*Odocoileus virginianus*) from the park, as they tend to inhabit similar habitats (Sheffield 1983a). Nilgai antelope are also known vectors of the cattle fever tick (CFT, *Rhipicephalus (Boophilus) microplus*, *R. (B.) annulatus*), which transmits the deadly tick-borne disease bovine babesiosis to domestic cattle, posing a significant threat to working cattle ranches, such as those directly adjacent to PAAL (Foley, Goolsby, Ortega-S, et al. 2017). To provide PAAL with the ability to make informed management decisions, baseline information regarding abundance, occupancy, and predicted distribution of nilgai antelope was collected and analyzed by DJ&A, P.C. with support from Dr. Jeremy Baumgardt and the Caesar Kleberg Wildlife Research Institute at Texas A&M University, Kingsville. Incidental detections of other wildlife species were analyzed contingent upon sample size to provide additional information regarding general wildlife occupancy and use throughout the study area.

1.1 Study Area

The study area encompasses the western unit of PAAL and is 531.88 hectares in total (Figure 1). The western unit is defined as the region of the park west of a private inholding, which functionally bisects the park into western and eastern units. Park managers have consistently observed a population of nilgai antelope within the larger western unit of the park. This population may be attracted to the study area as a result of pressure from yearlong hunting practices on adjacent private lands as well as availability of prime habitat for nilgai antelope within the study area. Previous land use throughout the study area includes construction and maintenance of water control features, intermittent cultivation, cattle ranching, and construction of livestock-related infrastructure such as dip tanks and stock ponds (Ramsey III, Nelson, and Yan 2004).

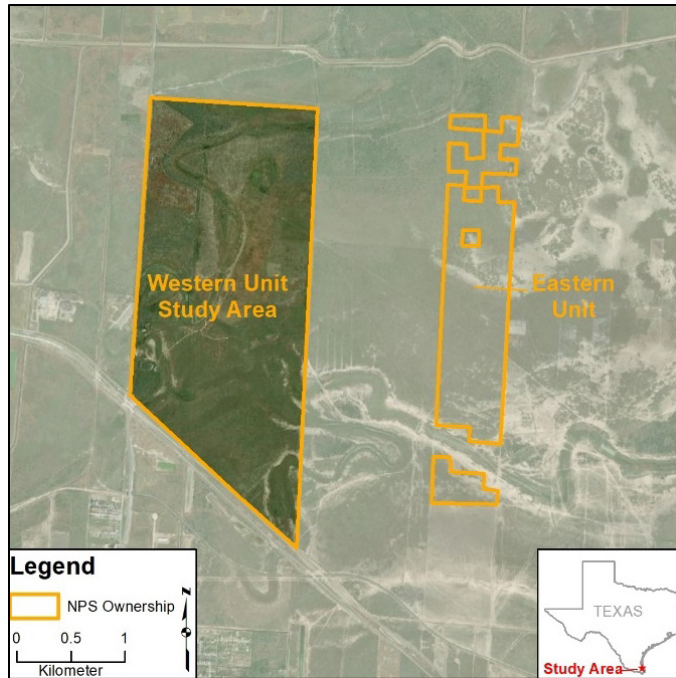


Figure 1. Study Area within the western unit of Palo Alto Battlefield National Historical Park.

Aside from developed areas represented by infrastructure and roads, habitat types within PAAL can be generalized into three categories: salt prairies, brushlands, and wetlands, with salt prairie habitat comprising up to 75% of the park's total area (Cooper, Cederbaum, and Gannon 2004). Salt prairie communities occur in low-lying areas with saline soils and are dominated by gulf cordgrass (*Spartina spartinae*) and sea ox eye or borrichia (*Borrichia frutescens*) (National Park Service 2010a). Tamaulipan brushland is also common throughout areas of higher elevation with less saline soils and is dominated by honey mesquite (*Prosopis glandulosa*), spiny hackberry (*Celtis pallida*), Texas ebony (*Pithecellobium flexicaule*), Texas prickly pear (*Opuntia engelmannii*), Spanish dagger (*Yucca treculeana*), and lotebush (*Ziziphus obtusifolia*), forming characteristically dense walls of shrub-dominated vegetation (National Park Service 2010b). Invading nonnative species such as invasive graminoids, have increased throughout the park, and active management of certain species is ongoing (National Park Service 2010b). The study area is topographically flat with minor differences in elevational profile with lower points found in resacas, former channels of the Rio Grande, which often fill with water from precipitation events and overland flow and sustain wetland habitat and associated plant communities (Ramsey III, Nelson, and Yan 2004). Higher points throughout the study are referred to as “lomas” and are a vestige of sediment deposition by the Rio Grande over time.

1.2 Focal Species: Nilgai Antelope

The nilgai antelope is an invasive antelope species introduced to southern Texas between 1924–1949 (Leslie 2008). Endemic to India, Pakistan, and Nepal, the nilgai antelope has established exotic free-ranging populations throughout southern Texas and Mexico, where environmental conditions are comparable to its native range. Within southern Texas, nilgai antelope are primarily grazers, though

they can subsist upon browse if preferred grasses and forbs are unavailable (Sheffield 1983b; Hines 2016).

Nilgai antelope are large Asian antelopes, standing between 1.2–1.4 meters at the shoulder, with an average body length between 1.7–2.1 meters and weight between 212–241 kilograms (Leslie 2008). Adults are sexually dimorphic, with males displaying a blue-grey coloration, two black, curved horns, a conspicuous white “bib” across the throat and a “pennant” of hair extending from the throat (Figure 2). Females are a tawny brown and often have a smaller pennant compared to males. Both sexes have striking white spots across the face and black spots on each ear. Calves are a pale brown, and subadults often maintain this brown coloration until males begin to develop darker pelage as they transition to the blue-grey coat of a mature bull.



Figure 2. Young bull nilgai antelope.

A notable behavior of nilgai antelope is their habitual use of communal latrine sites, where multiple nilgai repeatedly defecate at discrete locations. These sites are likely utilized by nilgai antelope to convey social information such as reproductive status and territoriality through scent-marking, though the functions of nilgai latrine use remain largely unknown (Zoromski 2019). Nilgai have been observed to build latrine sites in response to scents such as rotting carcasses, nilgai offal, and screwworm lure (Sheffield 1983b; Foley, Goolsby, Ortega-S, et al. 2017). A recent study on nilgai latrines in South Texas revealed dynamic use, with shifting patterns possibly attributed to changing resource availability, though this hypothesis remains to be evaluated (Zoromski 2019). Latrine usage differed according to sex and age classes, with bulls contributing the majority of visits and defecations, indicating that territorial bulls use these latrines as communication tools, though females also utilize the sites, likely to convey reproductive receptivity (Zoromski 2019).

Nilgai movement in southern Texas is likely influenced primarily by biologically significant seasons such as parturition during mid-summer, pre-breeding in late fall for males, and breeding in winter and spring for both sexes (Sheffield 1983b; Foley, Goolsby, Ortega-S, et al. 2017). Nilgai antelope

typically occur in smaller, sexually segregated groups for the majority of the year, forming larger mixed-sex groups during the active breeding season (Leslie 2008). Females typically separate from larger groups prior to parturition and conceal young calves for up to one month following birth, at which point they tend to reestablish larger female groups consisting of cows, calves, and subadults. Males maintain larger groups of adults and subadults, with increased movement leading into the primary breeding season. Home ranges for both sexes have not been found to differ significantly, with males maintaining mean ranges of 9,366 hectares and females of 8,355 hectares, with varying range sizes likely a result of varied habitat quality and availability (Moczygemba et al. 2012; Foley, Goolsby, Ortega-S, et al. 2017).

1.3 Other Wildlife Species

Despite its small size, PAAL is host to a variety of wildlife species and is particularly rich in avian species. The NPS species list for PAAL includes 145 birds, 22 reptiles, 18 mammals, 10 fish, and 9 amphibians (National Park Service 2022; eBird 2022; Hays 2004). Birds are numerous throughout the park and range from waterfowl such as Blue-winged Teal (*Spatula discors*) to raptors such as the White-tailed Hawk (*Geranoaetus albicaudatus*). Reptiles present include Texas tortoise (*Gopherus berlandieri*), Texas horned lizard (*Phrynosoma cornutum*), western diamondback (*Crotalus atrox*), and Texas indigo snake (*Drymarchon corais*). Mammals within the park are less numerous, including feral hog (*Sus scrofa*), southern plains woodrat (*Neotoma micropus*), coyote (*Canis latrans*), collared peccary/javelina (*Tayassu [Pecari] tajacu*), and bobcat (*Lynx rufus*) (Figure 3). Fish species had been previously documented within PAAL but were not observed during a 2004 inventory at which time a prolonged drought had completely desiccated or reduced water levels to the extent fish could not survive (Hays 2004). Several unique amphibian species also occur including Couch's spadefoot toad (*Scaphiopus couchii*), black-spotted newts (*Notophthalmus meridionalis*), and common Mexican treefrogs (*Smilisca baudinii*).



Figure 3. Bobcat documented at D4.

2. Methods

2.1 Camera Traps and Time-to-Event Model

Most methods for estimating abundance, occupancy, and predicted distribution of wildlife using camera traps have relied upon the conventional capture-recapture framework, which requires individuals to be identifiable and is ill-suited for use for species without readily identifiable markings, such as nilgai antelope. Various models have been developed to address this issue, but they often have assumptions and limitations that reduce applicability to certain systems and are sensitive to violations of model assumptions (Moeller, Lukacs, and Horne 2018a; Moeller 2017). This study utilized the Time-to-Event model (TTE) (Moeller 2017; Moeller, Lukacs, and Horne 2018a), which estimates abundance from trapping rate and is designed for use on unmarked populations such as elk (*Cervus canadensis*) and other large ungulates. The model is built upon the premise that for randomly placed cameras or “traps” located in areas of varying animal density, trapping rate increases as animal density increases. This model utilizes observations in both time and space to account for heterogeneity of animal density across a given study area, measuring a single trap across several consecutive periods of time or sampling periods, which, combined, constitute a discrete sampling occasion. Each sampling period is defined as the length of time estimated for an individual of the focal species to move across the detection viewshed of the camera; this ensures spatial independence of detection for a given trap and sampling occasion (Moeller 2017). The TTE model is based upon a random sampling of a given study area in relation to the target species’ movement and increases photo analysis efficiency by depending solely upon the first detection of an individual of the target species within a given sampling period, reducing total photo processing time. Assumptions for the TTE model include: random camera placement relative to animal movement, population closure, animals distribution according to the Poisson process, accurate estimation of movement speed, perfect detection, and that animal detection is independent in space and time (Moeller, Lukacs, and Horne 2018a; Loonam et al. 2021). The TTE model has been shown to be robust to violations of these assumptions, which often occur in wild populations, given random camera placement and accurate estimation of movement rates (Loonam et al. 2021).

2.2 Equipment

All data collection sites were outfitted with RECONYX HP2X Hyperfire 2 Professional Covert IR Cameras (hereafter referred to as camera trap units) mounted on t-posts using anodized fencing wire (Figure 4). Each camera trap unit included a steel security enclosure and padlock to reduce weather and potential tampering. All units were installed parallel to the ground at 1.25 meters, to maximize detectability of the target species, nilgai antelope, while also ensuring detection of smaller, nontarget species. All units were oriented to the north to reduce reductions in image quality associated with sun position at sunrise and sunset. Appendix A provides detailed specifications for the camera trap units utilized throughout this study. Default settings were modified to fit the objective of the study and to increase detectability; settings were identical for all camera trap units. Captured images were recorded on two alternating SDHC memory cards (32 GB), and all camera trap units were powered by AA Lithium batteries. Camera traps were placed within a 10-meter radius centered around a pre-selected location. Slight modifications to surrounding vegetation were made as needed to reduce false triggers and maximize detectability of wildlife species.



Figure 4. Representative camera trap station site situated within an inundated resaca (E4).

2.3 Camera Trap Stations

Camera Trap Station (CTS) sites represent the 20 discrete locations where camera trap units were deployed for the duration of the study's sampling period (Figure 5). In order to satisfy requirements for population modeling and estimates of animal distribution, locations were selected randomly and were situated a minimum distance from one another to facilitate independence among sampling locations based on a combination of estimated movement rates of nilgai antelope and values used in similar studies for large ungulates (Baumgardt 2022; Foley, Goolsby, Ortega-S Jr., et al. 2017; Moczygemba et al. 2012; Moeller 2017; Moeller, Lukacs, and Horne 2018b; Sliwa 2021). Locations for CTS sites were selected randomly using ArcGIS. A 300 x 300-meter grid was superimposed over the study area, and potential CTS locations were identified as any grid intersection that fell within the study area (n=55). After random selection, site locations were reviewed by PAAL personnel and randomly reselected as needed to reduce risk of theft or tampering, incidental detections of NPS staff and visitors, impacts to user experience, and impacts to ongoing surveys and studies or management actions. The determined grid size maintains independence between CTS sites by incorporating documented movement rates of nilgai antelope, ensures minimum site quantity requirements for the chosen model, and provides adequate distribution of sites across the study area. Each CTS site and associated equipment was identified by its unique location within the established grid (e.g., B3) (Figure 5). All sites were approved by NPS prior to installation. No sites were removed or rotated throughout the duration of the sampling period.



Figure 5. Camera trap stations and latrine site stations across the western unit of Palo Alto Battlefield National Historical Park.

2.3.1 Camera Trap Data Collection

Camera traps were checked by a trained field technician every two weeks, at which time all SDHC cards containing data from the previous two weeks were collected, and the alternate SDHC card was inserted, which collected data up to the next biweekly check. During each biweekly check, each site was assessed for proper camera trap orientation, position, angle, stability, battery status, and general functionality; adjustments were made as needed.

2.4 Latrine Sites

Latrine Site (LS) stations are defined as the eight discrete locations where camera trap units were deployed for the duration of the specified sampling period. Using the existing 300 x 300-meter grid, six line transects were established along alternating horizontal grid lines “B”, “D”, “F”, “H”, “J”, and “L”. Line transect surveys were conducted in February 2021 to identify a subset of latrine sites across the study area. A field biologist walked each of the six defined transects, maintaining consistent speed between detections, and recorded the perpendicular distance of each observed latrine site from the transect. At each latrine site, a GPS location, photos, and unique ID was recorded along with relevant site descriptions and measurements. Of all observed latrine sites, a subset of eight sites were randomly selected as the final latrine site station locations.

Latrine site stations were deployed in temporal pairs in February 2021, June 2021, August 2021, and December 2021 to facilitate the detection of nilgai antelope throughout the course of one year (Figure 6). Each latrine site station collected images for a minimum of 14 consecutive days. The same covariates and photo-related data collected for all other camera trap stations were recorded at these latrine sites. The objective of the latrine site survey was to identify patterns in use and demographics of nilgai antelope detected in close proximity to latrine sites. Data gathered from LS stations was not utilized for population modeling or regression analysis.



Figure 6. A subadult nilgai antelope spooks a turkey vulture into flight at latrine site station LS_4.

2.5 Photo Analysis

Throughout the duration of the study, collected images were processed and organized utilizing the Colorado Parks and Wildlife's CPW Photo Warehouse 4.3 (v.4.3.0.6.), an Access database designed to streamline the collection and management of high-volume camera trapping studies (Ivan and Newkirk 2016). Each image was reviewed by a trained wildlife biologist and assigned a number of detected individuals per each sex and age class represented. Nilgai antelope could be assigned the following sex and age classes: Mature (Adult) Male/Female, Yearling (Subadult) Male/Female/Not Specified, Calf (Juvenile) Male/Female/Not Specified, and Unknown Sex Age for individuals positively identified as a nilgai antelope but sex and age could not be determined. Calves and subadults were rarely assigned sex class due to a lack of confirming characteristics, particularly in young individuals. When possible, sex and age class data was recorded for other wildlife species. At a minimum, number of individuals of other wildlife species was recorded. False positives, or images determined to have no species present, were assigned "None". Images determined to have an unknown wildlife species present were assigned "Unknown".

A random selection of 5–10 percent of all analyzed photos per check period was assessed by a second reviewer to ensure quality data collection and analysis. Quality control checks occurring after February 11, 2022 were comprised of a five-percent subset of photos due to low error rates in previous quality control reviews.

2.6 Time-to-Event Model

The TTE Model was utilized to estimate abundance and occupancy of nilgai antelope within the study area. For the TTE model, average movement rate for nilgai antelope was assigned utilizing data from 40 nilgai antelope (13 male, 27 female) radio-collared for up to 19 months collected for a separate study located 10 kilometers north of the study area conducted between 2019–2020 (Baumgardt 2022). Given that males and females have differing space use and movement, median hourly step lengths were calculated per each sex and the average of this was used for the TTE analysis (62 m/hr.) (Baumgardt 2022; Sliwa 2021). Median movement rates per sex and the average of the two rates were also calculated per three-month subsets spanning March 1, 2021–February 27, 2022 to account for potential seasonal changes in abundance. Detection viewshed was estimated by analysis of a representative set of photos per site. Photos included periods of defoliation versus full foliage that were then evaluated using ImageJ software, a program that facilitates accurate relative measurements within a photo using pixels (Rasband 1997–2018). Within a given photo, the total detectable area was measured, excluding any vegetation that would conceal an individual nilgai antelope. The proportion of area obstructed was then applied to the theoretical detection viewshed of the camera trap, resulting in the modified total detection viewshed, accounting for obstructions.

After accounting for obstructions, the resultant estimated average time for a nilgai antelope to pass through the detection viewshed was calculated to be 15.5 minutes. Sampling period length was assigned this value, with six sampling periods per occasions, with each occasion separated by 1.5 hours to ensure independence. This resulted in 2,865 sampling occasions per camera throughout the 12-month study. Sampling period length per three-month subsets was calculated in the same manner

using movement rates specific to a given three-month subset. Variance in sampling effort among data collection sites was accounted for within the TTE model and analyzed accordingly.

This population cannot be assumed to be closed to births, death, immigration, or emigration, and some variation in population can be attributed to changes in any of those categories, but the TTE model is robust to violations of the closed population assumption and has been shown to result in unbiased estimates of population (Loonam et al. 2021).

2.7 Independent Detections

Independent detections are defined as a discrete detection event comprised of one or multiple individuals, unique to particular location and time to which a collection of photos are assigned. An independent detection event has been determined not to influence previous or subsequent independent detection events and as such, is considered independent. Independence between detection events is evaluated by assessing the detected animals represented within the respective collection of photos. For events with more than one individual, if animals appeared to be moving together or otherwise influenced by one another's presence, they were grouped together under the same independent detection event. If multiple solitary individuals were detected within a 30-minute interval, they were evaluated for potential influence upon one another and either assigned separate independent detection events, if no relationship was observed, or under the same independent detection event if they appeared to influence one another's behavior. Analyzing observed abundance per discrete sex and age class categories in relation to a given independent detection events minimizes duplicate counts of the same individual. Individuals within the same independent detection event would not be duplicated or counted twice, but the same individual could appear within a subsequent, independent detection event, and so values conferred from these analyses should not be interpreted as indicators of population size or abundance. Rather, estimates derived from these data are useful for evaluating group demographics, size, behavior, and patterns of activity and use across the study area.

Independent detection events were identified using the "Individual ID/Detection Summary" function within the CPW Photo Warehouse Access database. The minimum number of minutes between independent detection events was set at 30 minutes, resulting in an initial set of independent detection events that were further refined based on evaluation by a wildlife biologist. Each independent detection event was evaluated to determine the total individuals per each sex and age class, as relevant and applicable to the species.

For all independent detection events, analysis was conducted separately for CTS sites and LS stations due to differing study objectives, sampling effort, and methodologies. For CTS sites, the study duration spans February 27, 2021 to February 27, 2022 (n=365 days), and for LS stations, all data collected was analyzed. For each species detected, summaries of relevant variables including total detection events, individuals, adults, subadults, juveniles, males, females, adult females (cows), and adult males (bulls) were calculated. Subadults and juveniles include all potential sex classes combined due to relatively low detections of these categories compared to adult males and females. These variables were summarized in total across all sites for values representative of the entire study area as well as per each location, including all data collected throughout the study duration. Daily

summaries were also calculated across all sites as well as per each location to illustrate patterns of change over time at the level of the study area as well as for each location. Relative proportions of these sex and age classes were also calculated to illustrate patterns of use in relation to other categories as well as to provide possible insight into social mechanisms driving such patterns. Daily summaries of these variables were evaluated for trends using a generalized additive model (GAM), which is a generalized linear model in which the linear response variable depends upon an unknown, smooth function of certain predictive variables in order to allow non-parametric fits to data, providing clearer visualization of trends when all contributing predictive variables for a given set of data are unknown (Wood 2006).

Analysis of other wildlife species was contingent upon sufficient independent detections, which for most species, were insufficient. Of the 26 other wildlife species detected, the top six according to total independent detections, were analyzed in detail. Species with high numbers of independent detection events constrained to one location during a short period of time were not considered commonly detected. Analyzed species include feral hog, collared peccary, raccoon, bobcat, coyote, and white-tailed deer in order of decreasing independent detection events. No other wildlife species was detected in sufficient quantities per specific sex and age classes to conduct detailed analyses. Time series analysis of total independent detections per day was conducted for these six species to illustrate patterns of activity throughout the study duration.

2.8 Site Covariates

Site covariates were collected for each site and consisted of variables characterizing vegetation, cover, and inundation. Collected covariates serve to provide supporting information for describing patterns of use and movement across data collection sites for nilgai antelope.

2.8.1 Vegetation

Vegetation surveys were designed to collect general information for each data collection site including key species cover and composition, general structure, basic age class, and representative photos. Surveys were conducted to coincide with the highest likelihood of the presence of identifying vegetative features such as inflorescences and foliage. Circular survey plots were centered at the t-post of each data collection site, with a radius of 30 meters, which represents the maximum detection distance for a given camera trap unit in order to collect vegetation data representative of the total detection viewshed as well as the immediate area (Figure 7). Key species were defined as any non-native species, including federally or state-listed (Texas) noxious weeds, or any species that comprised greater than ten percent by cover of the vegetation in the survey plot. This definition permitted efficient collection of dominant species and/or species relevant to managers to provide general vegetation information and does not provide a full inventory of all species present within the plot. Within each vegetation category (tree, shrub, graminoid, forb), the relative percent cover of the dominant two key species were collected for a maximum of eight species recorded per plot. If a non-native or noxious weed was present within the plot but not captured within the relative percent cover composition, it was documented as present within the site notes.

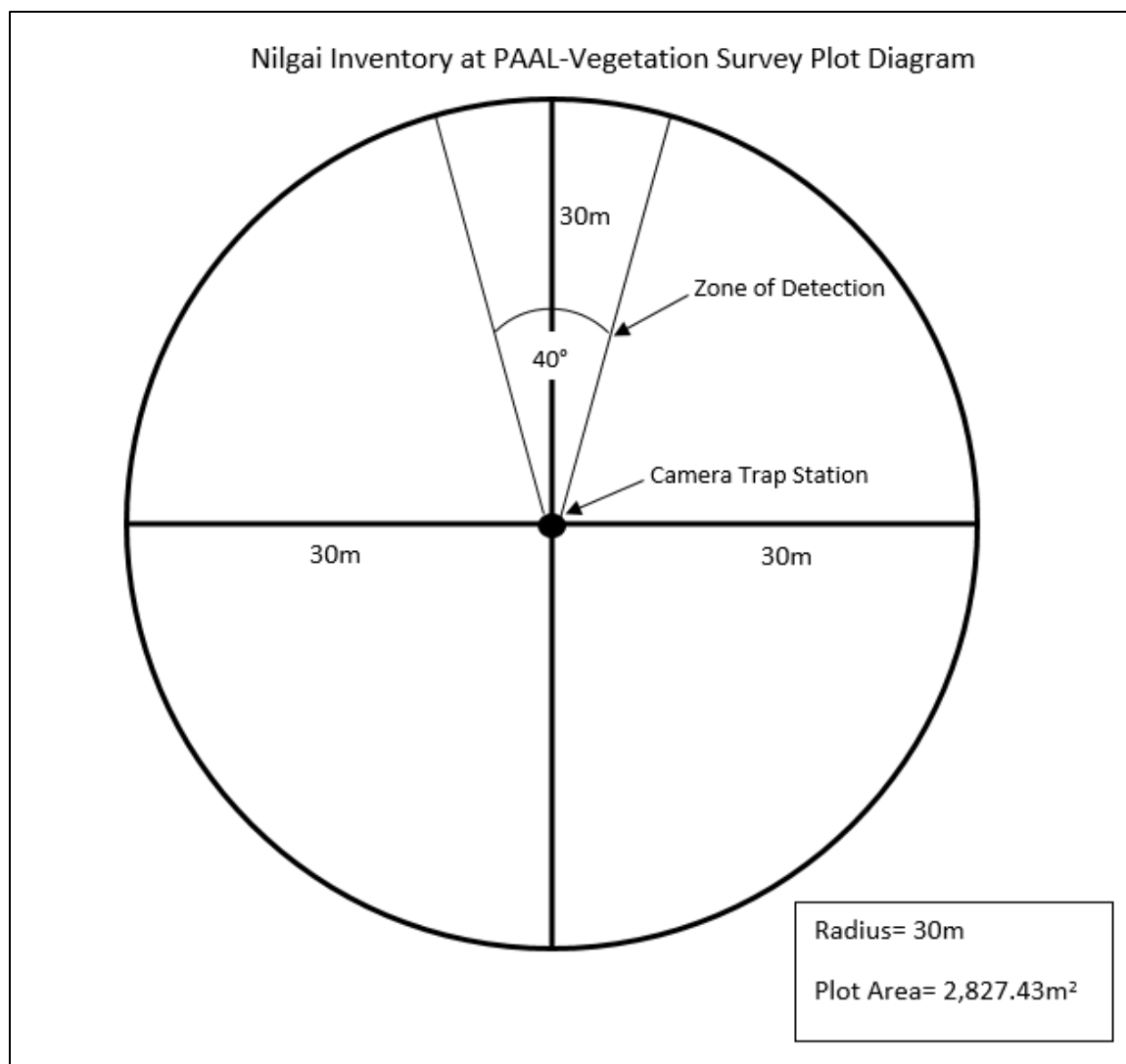


Figure 7. Vegetation survey plot diagram.

Each key species collected for relative species composition was then qualitatively assessed for evidence of grazing by large ungulates. Grazing intensity and potentially confounding factors was discussed within the notes per each survey plot (e.g., mowing, vegetation management treatments, etc.). Each recorded species was further evaluated for native status, using the USDA Plants Database¹ and corresponding designations per county of “Introduced”, “Introduced,Native (i.e., naturalized species)”, “Native”, or “Unknown” per species.

¹ <https://plants.usda.gov/home>

Ecological Site Descriptions (ESDs) were also identified per site using a Web Soil Survey report providing site-specific information regarding physiographic features, climate, soils, plant communities, (Web Soil Survey 2021).

2.8.2 Woody Plant Cover and Structure

Woody plant cover is an important habitat component for ungulates providing thermal refugia, security, forage, bedding, loafing, and parturition habitat (Mysterud and Ostbye 1999; Fulbright and Ortega-Santos 2013; Tomecek and Russell 2016). Woody plant cover varies in functionality for a given species based on vegetation height, density, and spacing. Understanding which habitat elements influence nilgai antelope occupancy facilitates relevant interpretation of the distribution of individuals within the study area. Though there is a paucity of data regarding the relationship between nilgai antelope and woody plant cover and structure, a 2021 study focused on nilgai antelope movement ecology found that nilgai antelope selected for woody and mixed cover, often with substantial brush components and typically avoid open, herbaceous areas (Sliwa 2021). For the 2021 study, pre-determined cover types were combined to comprise “woody cover”, including “woodland”, “forest”, and “shrubland”, with “mixed cover” represented by a combination of woody cover patches and open grasslands.

Within PAAL, woody plant cover and structure was identified as a covariate with potential to influence nilgai antelope movements and resultant detection quantity and patterns. Analyzing this covariate required specific definitions of cover types tailored to the species of interest, nilgai antelope, accounting for characteristics that may prohibit, influence, or hinder nilgai movement such as vegetation height and density at various strata. A 90-meter buffer was selected for analysis to capture effects of nearby cover classes that may not fall within the direct viewshed of the camera trap. Resultant cover types identified per each buffered data collection site represent areas with specific structural characteristics defined by height and density and do not necessarily indicate particular species assemblages. Cover type polygons were assigned to a 90-meter buffer surrounding each data collection site under the following assumptions:

Light detection and ranging (lidar) points represented spatially accurate locations of vegetation and/or natural features within the study area

Nilgai antelope movement would be constrained by vegetation shorter than the average shoulder height of an adult nilgai antelope (1.25 meters)

Thick vegetation between 0–1.25 meters would prohibit or hinder nilgai movement, resulting in reduced permeability through such features, thus influencing movements

Functional overstory cover was relatively contiguous such that solitary clusters of vegetation greater than 1.25 meters could not be defined as overstory for the focal species

Nilgai antelope were influenced by cover types adjacent to data collection sites (up to 90 meters).

Lidar discrete-return point cloud data was utilized to delineate four discrete cover types: Tall Overstory, Closed Understory (TOCU), Tall Overstory, Open Understory (TOOU), Mixed

Vegetation Height (MVH), and No Overstory (NO) (Figure 8, Figure 9). Height classes were derived from lidar data points by delineating areas with Tall Vegetation (>1.25 meters) and No Overstory (<1.25 meters) (U.S. Geological Survey 2019). The “Tall Vegetation” cover type was further assessed for continuity and size through ocular estimation. Solitary points or independent point clusters were evaluated individually to determine if such areas could provide functional cover for nilgai antelope, based on size and continuity. Areas including a mix of vegetation heights and understory densities were assigned a cover type of “Mixed Vegetation Height”. The “understory” was defined in reference to the focal species as the area between 0–1.25 meters from ground surface. Within areas of “Tall Overstory”, understory was defined as either “Closed” or “Open”, based on ocular estimation of the point density supplemented with field-based observations and imagery of each data collection site. Cover types with “closed” polygons were assumed to hinder and alter nilgai antelope movement, whereas “open” understory would permit movement. This assumption was verified by observations of little to no nilgai trails or access within “Closed” understory areas compared to “Open” understory areas, in which numerous trails and loafing evidence was observed. Cover type assignments were verified by cross-referencing satellite imagery (ESRI et al. 2021), and images collected during site installation for accuracy (Figure 8).

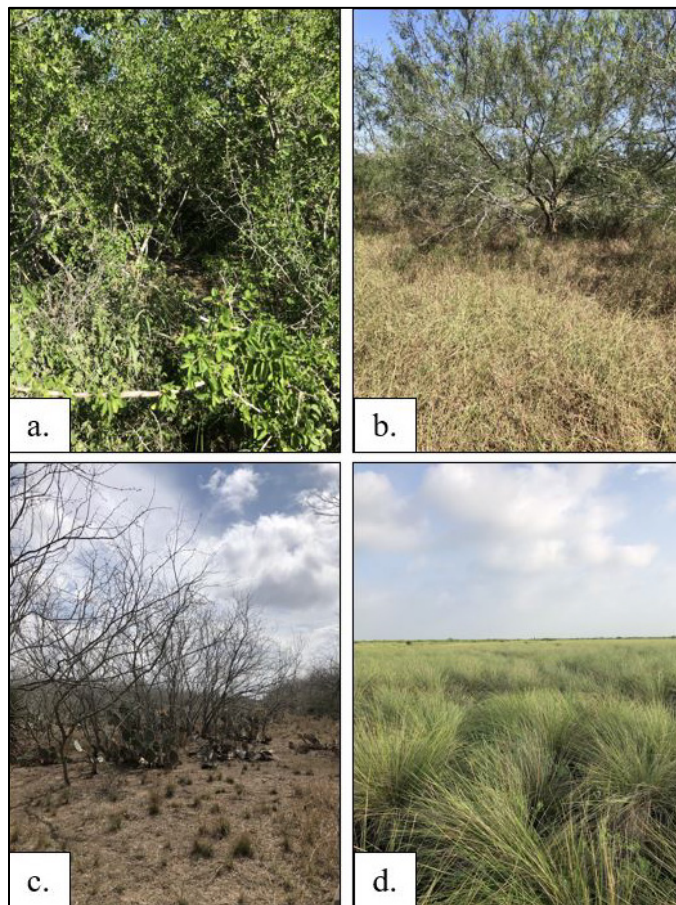


Figure 8. Representative site photos per cover type (a. Tall Vegetation/Closed Understory, b. Tall Vegetation/Open Understory, c. Mixed Vegetation Height, d. No Overstory).

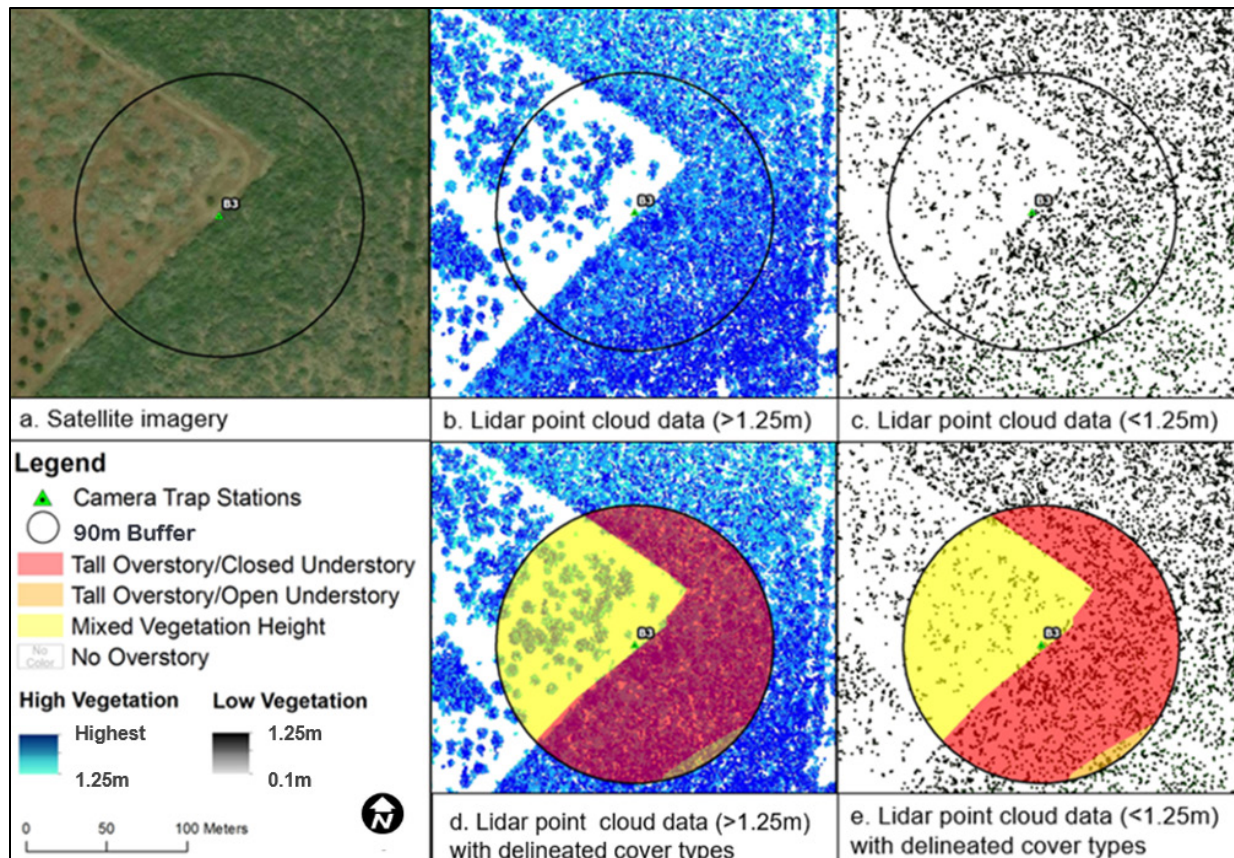


Figure 9. Woody plant cover and structure cover type delineation method.

2.8.3 Inundation

Throughout the duration of the study, the study area received higher-than-average precipitation, resulting in widespread flooding and inundation of low-lying areas beginning shortly after the initiation of the study in February of 2021. Characterizing this emergent site characteristic was important to account for potential impacts to nilgai antelope activity in relation to inundated sites and movement throughout the project area. Inundation was defined as any area that maintained some amount of standing water visible in satellite imagery. Inundation was delineated utilizing three-meter high-resolution multispectral satellite imagery from March 2021–March 2022 to digitize polygons of standing water at each snapshot in time (Planet Team 2022).

2.9 Regression Analysis

A simple linear regression analysis of all possible pairwise combinations of site covariates and total number of detections per each discrete sex and age class category for nilgai antelope was performed using R Statistical Software via the R stats package (R Core Team 2020). Appendix E provides a complete list of all variables analyzed including variables for woody plant cover and structure, species proportion per native and grazing categories, percent cover of vegetation categories and species, altitude, and all sex and age class categories of nilgai antelope. Regression analysis was only performed for camera trap stations.

3. Results

3.1 Photo Analysis

Throughout the duration of the study, CTS sites collected 56,683 individual photos and LS sites collected 8,258. Of all photos collected, 23,843 contained detections of wildlife species. Nilgai antelope were the most commonly detected species with 22,387 photos. Table 1 lists the 26 wildlife species captured throughout the study durations for both CTS sites and LS stations. Of these species, detections range from solitary Golden-fronted Woodpecker (*Melanerpes aurifrons*) to rogue domestic cow (*Bos taurus*), with 15 species being avian and 12 mammalian, indicating excellent detection probability for a range of wildlife species in addition to the focal species of this study.

Table 1. Other wildlife species: Total independent detection events (camera trap stations and latrine site stations). Common names for avian species are capitalized in accordance with standard ornithological practice and with guidelines for orthography set forth by the American Ornithological Society (American Ornithological Society 2020).

Common Name	Scientific Name	Number of Independent Detection Events
American Coot	<i>Fulica americana</i>	2
Black-bellied Whistling Duck	<i>Dendrocygna autumnalis</i>	4
Blue-winged Teal	<i>Spatula discors</i>	2
Common Gallinule	<i>Gallinula geleata</i>	1
Common Ground Dove	<i>Columbina passerina</i>	4
Curve-billed Thrasher	<i>Toxostoma curvirostre</i>	15
Eastern Meadowlark	<i>Sturnella magna</i>	1
Golden-fronted Woodpecker	<i>Melanerpes aurifrons</i>	1
Great-tailed Grackle	<i>Quiscalus mexicanus</i>	1
Groove-billed Ani	<i>Crotophaga sulcirostris</i>	1
Mottled Duck	<i>Anas fulvigula</i>	1
Mourning Dove	<i>Zenaida macroura</i>	14
Red-tailed Hawk	<i>Buteo jamaicensis</i>	1
Turkey Vulture	<i>Cathartes aura</i>	1
White-tailed Hawk	<i>Geranoaetus albicaudatus</i>	1
black-tailed jackrabbit	<i>Lepus californicus</i>	2
bobcat	<i>Lynx rufus</i>	14
collared peccary	<i>Tayassu [Pecari] tajacu</i>	17
coyote	<i>Canis latrans</i>	13
domestic cow	<i>Bos taurus</i>	4
feral hog	<i>Sus scrofa</i>	54
nilgai antelope	<i>Boselaphus tragocamelus</i>	2277
nine-banded armadillo	<i>Dasypus novemcinctus</i>	16
raccoon	<i>Procyon lotor</i>	17

Table 1 (continued). Other wildlife species: Total independent detection events (camera trap stations and latrine site stations). Common names for avian species are capitalized in accordance with standard ornithological practice and with guidelines for orthography set forth by the American Ornithological Society (American Ornithological Society 2020).

Common Name	Scientific Name	Number of Independent Detection Events
southern plains woodrat	<i>Neotoma micropus</i>	1
Virginia opossum	<i>Didelphis virginiana</i>	2
white-tailed deer	<i>Odocoileus virginianus</i>	8

3.2 Time-to-Event Model

Using the TTE model and provided computational code, the estimated population of nilgai antelope within the study area between March 1, 2021, and February 27, 2022 was 58 individuals (SE= 1.8). Table 2 details the results of the TTE model for the entire study duration as well as three-month seasonal estimates. Analysis of three-month seasonal estimates resulted in reduced precision and associated increases in standard error, though sample sizes remained sufficient to detect significant fluctuations in the density estimate. Seasonal population size fluctuated significantly between all three-month subsets, ranging from 49.5 estimated individuals within the June–August subset to 62.8 individuals within the December–February subset.

Table 2. TTE model results.

Time Period	Duration	Speed (meters/hour)	Sampling Period Length (minutes)	Estimated Population Size	Standard Error	Lower Confidence Interval	Upper Confidence Interval
12-month Estimate	March 1, 2021– February 27, 2022	62.0	15.5	58.3	1.8	55.0	61.9
Three-month Estimates	March 1, 2021– May 31, 2021	69.0	13.9	60.0	3.5	53.5	67.2
	June 1, 2021– August 31, 2021	58.0	16.6	49.5	3.3	43.4	56.3
	September 1, 2021– November 30, 2021	57.0	16.8	54.2	3.5	47.8	61.4
	December 1, 2021– February 27, 2022	76.0	12.6	62.8	3.5	56.3	70.0

3.3 Independent Detections

CTS sites captured 2,333 independent detection events across all species, with 2,190 of those events containing nilgai antelope. LS stations captured 132 independent detection events, with 87 containing nilgai antelope. Appendix B contains detailed maps illustrating the distribution and occupancy of nilgai antelope, including: total independent detections (Appendix B, Figures B-1 and B-2), total independent detections by sex class (Figure B-3, Appendix B), independent detections by age class (Appendix B, Figure B-4), and independent detections by combined sex and age classes (Appendix B, Figure B-5). Appendix C provides a detailed summary of all independent detection events by sex and age class per species at each location for CTS sites and LS stations. Per a given independent detection event, the following variables were analyzed: total independent detections, individuals, females, males, adults, adult females, adult males, subadults, and juveniles. These variables were interpreted in summary and through time series analysis of daily summaries throughout the duration of the study area.

3.3.1 Camera Trap Stations

When variables were summarized for each site, CTS sites had an average of 110 independent detections per site, with sites situated north of the visitor center in the middle of the study area (e.g., E5, F5, D4) having higher values than sites within the southeastern portion (e.g., I5, M6, K6) (Figure 10). Total individuals and adults were similarly higher and lower at these same locations, with an average of 248 total individuals and 168 total adults per site. Females and adult females were most common at sites towards the middle of the study area (e.g., E5, F5, F2) and less common at southeastern portions (e.g., I5, M6, K6), with an average of 97 total females and 87 total adult females per site. Juveniles had similar patterns as adult females and total females, though were also common at station D5, just north of the pipeline right-of-way access road towards the middle of the study area, with an average of 17 total juveniles per site. Males, adult males, and subadults were most common at a cluster of sites located in the middle of the study area near the pipeline right-of-way access road (e.g., F5, E5, G5, D4) and less common at southeastern sites (e.g., L5, M6, K6, L5), with an average of 74 total males, 54 total adult males, and 58 total subadults per site. Group sizes ranged widely, with the largest group of 19 individuals detected at D5. Most large groups were detected at sites located toward the middle of the study area near the pipeline right-of-way access road, though large groups were detected at sites outside of this area as well. Though large groupings did occur, the median value of total individuals detected was 1, contributing to an average of 2.2 individuals per detection.

Overall, adults represent the majority of individuals detected at all sites, followed by subadults and then juveniles. Total female individuals were higher than males at most locations, with the exception mainly located towards the center of the study area, though I5 and K6 in the southeastern portion also had higher proportions of males. Of adults, adult females were higher than adult males at a majority of sites with the exception of F5, G5, and I5. Adults outnumber subadults and juveniles at all sites, and subadults outnumber juveniles at all sites but one (M6).



Figure 10. Independent detections at camera trap stations.

Behavior observed at CTS sites varied widely and included grazing, browsing, breeding, nursing, sparring, grooming, dominance displays, defecation, urination, vocalization, scent investigation, and various social interactions between individuals. Breeding behavior such as chasing, mate-guarding, and receptivity assessment via scent was documented across many sites throughout the duration of the study. Larger groups composed of adult females, juveniles, and subadults were observed in addition to large bachelor groups consisting of adult and subadult males, consistent with documented grouping characteristics. When both sexes were observed within the same independent detection event, breeding behavior was often observed.

3.3.2 Latrine Site Stations

Combined, LS stations had an average of 11 independent detection events per site, with stations towards the middle of the study area near the pipeline right-of-way access road having higher detections than those located north of the road or in the southeastern portion (Figure 11). Total individuals and adults detected followed the same pattern, with an average of 20 total individuals and 11 total adults per site. Females, adult females, and subadults were most common at LS_2 and LS_4, both situated in the middle of the study area, just south of the pipeline right-of-way access road, with averages of 10 total females, 8 adult females, and 5 subadults per site. Juveniles were most common at LS_2, similar to adult females, females, and subadults but were less common at LS_4, with an average of 3 total juveniles per site. Males were likewise prevalent at LS_4 and LS_2, with an average of 5 total males per site. Adult males were common at LS_4, similar to other categories, but were also uniquely prevalent at LS_8, which is located in dense woody cover at the northeastern corner of the study area, with an average of 3 total adult males per site. The largest group detected at an LS station consisted of 10 individuals at LS_2, with the median for all sites being 1 and the average 1.8, slightly lower than averages for CTS sites.

Adults represent the majority of individuals detected across all LS stations, and subadults outnumber juveniles at most sites, with the exception of LS_1, LS_7, and LS_8, though differences were marginal. Females comprise the majority of individuals detected with the exception of LS_3 and LS_8, which were both dominated by adult males and located at opposite ends of the study area. Adult males made up a low proportion of individuals at LS_2, which had high numbers of all other sex and age classes and is located towards the middle of the study area, south of the pipeline right-of-way access road, whereas adult females were low at LS_8, located in the northeastern corner of the study area.

Behavior observed at LS stations included observations of both nilgai antelope and other wildlife species. Nilgai antelope were observed partaking in previously documented behavior common at latrine sites such as defecation, urination, flehmen responses, and mock sparring (Figure 12). LS_4, located just north of the pipeline right-of-way access road, received use by a variety of species additional to nilgai antelope, with avian species appearing to utilize the relatively scarce bare ground for reproductive displays, foraging, and potentially as a source of mineral dirt used for dust bathing.



Figure 11. Independent detection events at latrine site stations.



Figure 12. Two subadult male nilgai antelope exhibit characteristic stances for mock-sparring.

3.3.3 Nilgai Antelope: Time Series Analysis

Appendix C provides detailed time series graphs showing daily summaries of each variable and resultant patterns in use per each CTS site as well as summarized for all sites as a representation of the entire study area. Overall, activity remains consistent throughout the duration of the study, with moderate seasonal fluctuations. Distinct sex and age class categories show differing patterns in use throughout the duration of the study, likely influenced by fluctuating resources throughout the study area as well as biological seasons such as gestation and parturition, calf-rearing, pre-breeding, and breeding.

For all sites combined, total independent detection events per day had two primary peaks in May 2021 and January 2022, with another, smaller, peak in September 2021; the lowest daily detections occurred between July and August of 2021 (Figure 13). Smaller dips also occurred in March 2021 and 2022 as well as November 2021. Overall, activity appears to be highest during winter months (December–February) and late spring/early summer (April–June), with a small peak in September. Though periods of relatively low activity occur throughout the study duration, activity consistently

occurs, with differences in highs and lows being relatively marginal, indicating steady use of the study area by nilgai antelope throughout the year.

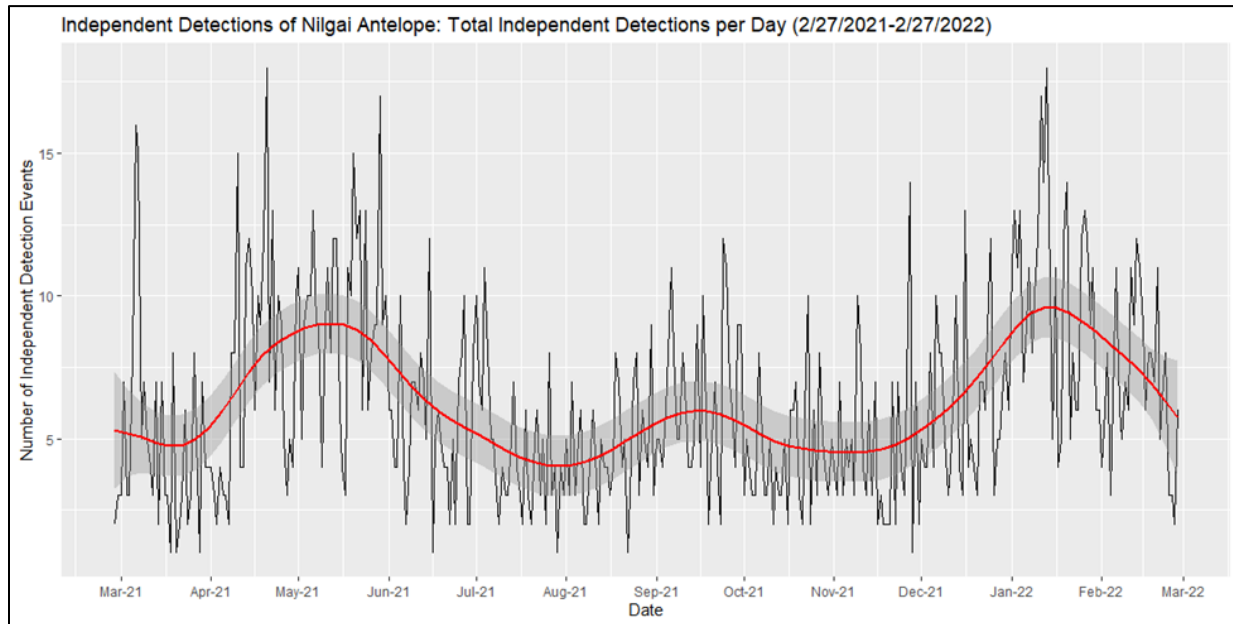


Figure 13. Total independent detections per day of nilgai antelope.

Total individuals and adults correspond to similar patterns as total independent detection events with slightly more fluctuation. Females and adult females have two primary peaks, in May 2021 and January 2022, and relatively flat activity through September 2021, contrary to patterns of total detections, individuals, and adults (Appendix C, Figures C-46 and C-47). Reduced activity of adult females beginning in June 2021 likely represents reduced grouping behavior of females, as individuals separate from larger groups to undergo gestation, parturition, and calf-rearing, up until the reestablishment of groups prior to the breeding season in late fall. Males and adult males have three distinct peaks which follow overall patterns for total detections, individuals, and adults, indicating that the September 2021 peak is primarily driven by increased activity by males and adult males, likely correlating to the pre-breeding biological season leading up to active breeding (Appendix C, Figures C-50 and C-51). Subadults have more fluctuation throughout the study period than other categories, with the three main peaks represented in addition to smaller peaks in July 2021 and March 2022 (Appendix C, Figure C-52). Subadults do exhibit a peak in September 2021 as well, likely driven by male subadult activity during the pre-breeding season. Juveniles deviate largely from all other sex and age classes, with two moderate peaks in March 2021 and March 2022 and a slight reduction heading into the summer, slowly increasing as time moves on into the fall (Appendix C, Figure C-53). Given the short temporal duration of the juvenile category, some of this decrease can likely be attributed to individuals entering the population in early fall and quickly aging into the yearling/subadult category as well as mortality.

3.3.4 Other Wildlife Species

Appendix C provides a summary per variable for all documented wildlife species in addition to time series graphs of the most detected species with sufficient data to provide meaningful time series analysis. Twenty-six additional wildlife species were detected at both CTS sites and LS stations throughout the duration of respective study periods. Of these species, two were not previously accounted for on documented species lists for PAAL; Common Gallinule (*Gallinula geleata*) and Virginia opossum (*Didelphis virginiana*) (Hays 2004; National Park Service 2022). Common Gallinule had been documented within the study area via the citizen science birding platform, eBird (eBird 2022). Six species had sufficient independent detection events to facilitate time series analysis, including feral hog, collared peccary (javelina), raccoon, bobcat, coyote, and white-tailed deer in order of decreasing independent detection events. This selection excludes species detected in high numbers at just one site within a short period of time and were not considered representative of the study area.

Including independent detection events at both camera trap stations and latrine site stations, feral hog were the second-most detected species, next to nilgai antelope, with 54 total detections and were broadly distributed, occurring at eight sites and detected throughout the duration of the study period, with decreased activity between February 2021 and August 2021 and a peak between August 2021 and January 2022. Feral hogs were detected both in multi-generational groups as well as solitarily and were often observed foraging or sniffing scent markers. Large, dominant males were repeatedly observed at site D4, where a prominent scent marking branch was located.

Collared peccary (javelina) were primarily detected between February 2021 and November 2021 at which point they were minimally detected until the end of the study, for a total of 17 detections. Detections occurred within the northwestern corner of the study area (e.g., F3, B3, E2, D4), and collared peccary were observed both solitarily and in groups with multiple age classes, and typically moved quickly through the area.

Raccoon also had 17 independent detections with a peak in January of 2022 and absence of detections between May 2021 and November 2021. Most detections consisted of individuals foraging in shallow inundated resacas or traveling along well-defined pathways throughout the northern half of the study area (e.g., D4, B6, F3, LS_7).

Bobcat were detected 14 times between February 2021 and May 2021 and September 2021 to February 2022 and appeared to favor the northwestern corner of the park (e.g., B3, D4, E2, LS_7). Bobcat were typically detected individually, though subadults were also detected, indicating active breeding and parturition within or adjacent to the study area.

Coyote detections were broadly distributed, with 13 total detections across 8 different sites spanning the length of the study area. Detections of coyote occurred throughout the study period, with a period of lower activity from June 2021–August 2021 as well as November 2021–January 2022. Coyote were observed traveling, marking territory through scat deposition, and hunting (Figure 14). Multiple unique individuals were observed, indicating that the study area contains or overlaps the home range of an active family group.

White-tailed deer were detected 8 times between March 2021 and April 2021 as well as November 2021 to December 2021. All detections of white-tailed deer consisted of solitary adult males that were primarily observed to be traveling through the area quickly and represented more than one unique individual, based on physical characteristics (Figure 15).



Figure 14. Coyote passes in front of D5.



Figure 15. White-tailed deer buck at LS_8.

3.4 Site Covariates

3.4.1 Vegetation

Appendix D provides detailed figures and tables displaying vegetation covariate data including plot composition, relative key species composition, species list, native status, grazing, woody plant cover and structure, and inundation. Appendix B also contains maps showing woody plant cover and structure cover types and inundation across the study area.

3.4.1.1 Plot Composition

Vegetation surveys collected relative compositions for key species as defined in section 2.8.1, documenting 30 species including 14 forbs, 10 graminoids, four shrubs, and two tree species. A full list of documented species is available in Appendix D. The majority of CTS sites and LS stations were dominated by graminoids, primarily gulf cordgrass (*Spartina spartinae*), guineagrass (*Urochloa maxima*), and Paraguayan windmill grass (*Chloris canterai*). A variable mix of trees, shrubs, and forbs was observed across all plots. Common forbs included bushy seaside tansy (*Borrchia frutescens*), Texas pricklypear (*Opuntia engelmannii*), and tornillo (*Prosopis reptans* var. *cinerascens*). Common trees and shrubs included honey mesquite (*Prosopis glandulosa*) and Mexican Palo Verde (*Parkinsonia aculeata*), lotebush (*Ziziphus obtusifolia*), and lime pricklyash (*Zanthoxylum fagara*).

Graminoids were the dominant vegetation component of most CTS sites, with gulf cordgrass dominant at sites throughout the southern portion of the park, giving way to invasive graminoids such as Paraguayan windmill grass and guineagrass moving north. Graminoids were less prevalent at sites with persistent inundation (e.g., D4, E4) or located within dense thornscrub habitat (e.g., B6). Forbs occurred across sites in appreciable numbers, with the exception of B2, which maintained a thick understory of invasive graminoids. Shrubs were typically minimal and scattered, typically occurring at sites at higher elevations across the study area. Trees were largely confined to northern portions of the study area, with honey mesquite (*Prosopis glandulosa*) dominant in drier locations and Mexican palo verde (*Parkinsonia aculeata*) most common within or adjacent to resacas and other inundated areas. CTS sites B6, D4, D5, E4, and F3 maintained inundation coverage, indicating partial to complete inundation at these sites at the time of survey in October 2021. Bare ground was minimal to nonexistent across all CTS sites.

Composition of LS stations varied considerably in comparison to CTS sites. Half of the sites maintained a dominant graminoid component, primarily composed of invasive graminoids, whereas the other half were comprised of a variable mix of dominant forbs, shrubs, or trees. No gulf cordgrass was documented at any LS station. Texas prickly pear (*Opuntia engelmannii*) was present at five of the eight sites, with lotebush (*Ziziphus obtusifolia*) and honey mesquite representing common shrubs and trees, respectively. Bare ground was relatively higher at three LS stations close to the pipeline right-of-way access road (e.g., LS_4, LS_5, LS_7), indicating more active visits to these sites due to fresh deposition of urine and feces, which inhibits vegetative growth. No LS stations were inundated at the time of survey in October 2021.

3.4.1.2 Grazing/Utilization and Native Status

Of 118 documented species occurrences across all sites, evidence of grazing by large ungulates was documented for five species: Paraguayan windmill grass (*Chloris canterai*), an unknown graminoid, buffelgrass (*Pennisetum ciliare*), honey mesquite (*Prosopis glandulosa*), and guineagrass (*Urochloa maxima*). Appendix D provides a summary of documented grazing and relative use. Of the species occurring at more than one site, guineagrass was grazed at the highest number of sites where it occurred at 60% (n=5) and honey mesquite the least at 14.30% (n=14). Four of five grazed species were introduced graminoids, whereas the only documented native species with evidence of grazing was honey mesquite. Due to the qualitative assessment of grazing, differentiation between grazing by nilgai antelope and other ungulates potentially present within the study area cannot be conclusively determined, though photo observations frequently captured nilgai antelope grazing or browsing across multiple sites. One observation of white-tailed deer at B6 captured foraging behavior. The majority of observed grazing can reasonably be interpreted as a relative metric of utilization by nilgai antelope.

3.4.1.3 Woody Plant Cover and Structure

Of the 20 camera trap station sites, all woody plant cover and structure was delineated per cover types assigned within 90-meter buffers surrounding each site, including Tall Overstory, Closed Understory (TOCU), Tall Overstory, Open Understory (TOOU), Mixed Vegetation Height (MVH), and No Overstory (NO). Sites with No Overstory were located throughout the southeast and middle portions of the study area, dominated by coastal plain habitat. Four sites had complete overstory coverage with varying understory components and were located towards the middle and northern extent of the study area. Other sites located in the northern and western portions of the study area had a mix of cover types, though Tall Overstory, Open Understory was the most prevalent. Tall Overstory, Closed Understory cover occurred infrequently, but was high at B6, in the northeastern portion of the study area. Mixed Vegetation Height cover was also infrequent, but evident at F3, located north of a large resaca at the center of the study area. Across all camera trap sites, the average total woody cover per site was 24.97%, with Tall Overstory, Open Understory being the most extensive at 29.40%. Tall Overstory, Closed Understory had the lowest average percent cover at 3.65%, and Mixed Vegetation Height was similarly low at 8.10%. No Overstory made up an average of 58.75%.

Most LS stations had appreciable amounts of woody cover, with Tall Overstory, Open Understory dominant across three sites and Tall Overstory, Closed Understory dominant at LS_8 but otherwise infrequent. Mixed Vegetation Height was a minor component or absent across all sites.

Comparatively, LS stations had nearly identical average total woody cover per each site at 24.97%, though these sites had higher average percent cover of all woody cover types at 13.12% for Tall Overstory, Closed Understory, 10.87% for Tall Overstory, Open Understory, and 35.25% for Mixed Vegetation Height. Average percent cover of No Overstory was lower at latrine sites at 40.62%, with a minority of the sites having no woody cover at all (e.g., LS_2, LS_3).

3.4.1.4 Inundation

Throughout the course of the study, above-average precipitation resulted in widespread overland flooding, inundating many low-lying areas of the study area with water (Figure 16). Seven CTS sites experienced an increase in inundation between March 2021–March 2022. No sites were observed to be inundated at the time of installation in February 2021. The inundated areas appeared approximately in March of 2021, according to camera trap imagery and field observations, and all inundated sites remained flooded until the end of the study in February 2022. Twelve CTS sites did not experience any increased inundation, and one site's total surface water coverage receded slightly (F3). Of the LS stations, three remained dry, and five increased, though none were inundated during their respective survey periods.



Figure 16. A subadult male nilgai antelope crosses an inundated resaca at camera trap station E4.

Average percent cover of inundation for camera trap stations increased from 1.88% in March 2021 to 11.78% in March 2022. Latrine sites increased from 5.75% to 12.40%.

3.4.2 Regression Analysis

Due to insufficient sample sizes for other wildlife species, regression analysis was performed only for nilgai antelope. Appendix E provides a detailed output summary of all significant ($\Pr(>|t|) \leq .1$) relationships.

Of all variables related to nilgai antelope, all sex and age class combinations showed significant relationships to one another, indicating strong social influence upon movement and activity as was expected for social ungulates. These correlations indicate that total detections and individuals were strongly driven by females, specifically adult females. Adult females and juveniles had intuitively strong correlations, whereas adult males and juveniles had the weakest relationship. Subadults correlations were more variable but had stronger relationships with adults, indicating that they likely overlap frequently in social groups with adults. Adult females and adult males had a relatively weaker relationship than with other sex and age classes, indicating minimal overlap for most of the

study period, as was expected given a tendency of nilgai antelope to sexually segregate for the majority of the year.

Site covariate variables showed a positive relationship of all sex and age classes to percent cover of Texas prickly pear percent cover (OPENL), Paraguayan windmill grass (CHCA6) and proportion of introduced and grazed species. All sex and age classes also showed an inverse relationship to percent cover of gulf cordgrass (SPSP). Most sex and age classes also had negative relationships to proportions of ungrazed and native species. Adult males had no significant correlation to proportion of ungrazed or native species. Sum of individuals had no relationship to proportion of native species. Adult females and juveniles had a positive relationship to percent cover of tornillo (PRREC), unlike any other sex and age class. No significant associations were found between nilgai antelope sex and age classes and any woody plant cover and structure cover type or percent cover of vegetation categories.

4. Discussion

4.1 Nilgai Antelope

Analysis of nilgai antelope detections for the duration of the study indicated that the study area is utilized year-round by a variety of sex and age classes, with some seasonal fluctuations likely in response to biological activities. The estimated population size of 58 individual nilgai antelope ($SE=1.8$) within the study area (531.88 hectares) equates to one nilgai antelope per every 9.17 hectares. Finer-scale estimates of population per three-month intervals further indicate that nilgai antelope consistently utilize the study area throughout the year and this population fluctuates due to births, deaths, emigration, and immigration as well as biological activities. Significant fluctuation within three-month seasonal subsets indicate that population size may also represent changes in behavior with impacts to group size and behavior such as parturition and breeding as well as environmental changes. Movement of nilgai antelope across study area boundaries is likely to continue to occur given the observed permeability of fencing surrounding the study area.

Overall, nilgai antelope are less likely to occur in southern regions of the study area, apparently preferring the middle portion of the study area, north of the boardwalk and interpretive trails and in close proximity to a pipeline right-of-way access road that bisects the western unit of PAAL. Adults were most numerous, followed by subadults and juveniles; a characteristic population structure that indicates active breeding and parturition within the study area. Adult females and juveniles were most commonly detected towards the middle and northwestern portions of the park, indicating likely presence of suitable habitat for calving and rearing young (Figure 17). Adult males also frequented middle portions of the park but were also observed in areas where adult females were less likely to occur, indicating that bulls are relatively more widespread than cows. Most detections consisted of solitary nilgai antelope or small groups compared to relatively few detections of larger groups. All documented behaviors of nilgai antelope were observed throughout the duration of the study, indicating that the study area provides sufficient habitat to fulfill all life cycle requirements for nilgai antelope, such as foraging, cover and security, breeding, and parturition. LS stations did not deviate significantly from patterns described for CTS sites, and no clear spatiotemporal patterns of activity emerged relative to LS stations, indicating sporadic and infrequent utilization of latrine sites by nilgai antelope throughout the study area. This lack of pattern is consistent with recent studies conducted to evaluate latrine site activity in southern Texas.



Figure 17. Nursing nilgai antelope calf.

Time series analysis of nilgai activity reveals three general peaks of activity that coincide with biological seasons in South Texas, including parturition and breeding, though these activities can occur at any time throughout a given year. Peaks in late fall and during winter months coincided with pre-breeding and breeding behavior and previously documented breeding periods for nilgai antelope in southern Texas. Peaks during late spring and early summer were likely a result of increased movement relative to increasing vegetation growth, increased grouping, and possibly late breeding behavior. Solely males experienced an increase in activity in September of 2021, indicating that male activity increases sharply prior to the initiation of the active breeding season. Reduced observations during summer months are likely indicative of decreased overall movement due to heat and decreased grouping behavior as cow nilgai approach calving season. Minimal overall fluctuations in activity are representative of a temperate environment in which resources do not fluctuate drastically but are also an indication of consistent presence of nilgai antelope within the study area throughout the duration of study.

Regression analyses performed for this study were general and exploratory in nature, given the paucity of data regarding nilgai antelope habitat selection. Results indicate associations between the tested variables, but they do not indicate direct causation. Significant results point to potential relationships that warrant further study beyond the scope of this project. Regression analyses returned significant positive relationships between total independent detection events of all nilgai antelope sex and age classes and percent cover of introduced species and grazed species as well as Texas prickly pear and Paraguayan windmill grass, specifically. All sex and age classes also had a significant negative relationship with percent cover of native species, ungrazed species, and gulf cordgrass, specifically. These significant associations indicate that nilgai antelope are more likely to occur in portions of the study area where introduced species dominate and gulf cordgrass is minimal or nonexistent. Associations between nilgai antelope detections and grazed introduced species also indicate that such areas are likely to provide foraging opportunities for large ungulates such as nilgai antelope as well. Areas with prevalent introduced species also overlap with areas of known historic

land use or disturbance that may have facilitated the spread of introduced species and/or native species associated with disturbance such as Texas prickly pear. Areas dominated by gulf cordgrass and representative of coastal prairie habitat also maintain high salinity and soil moisture content that likely precluded most historic land uses in such lower-lying areas. These same characteristics may also inhibit nilgai antelope use of such areas given a lack of suitable habitat for foraging, loafing, or parturition, though nilgai antelope were documented to travel through and breed in such areas, as evidenced by captured images. Continued restoration of coastal prairie habitat dominated by gulf cordgrass could result in decreased nilgai antelope occupancy in such areas, though further exploration of this relationship is required to clearly understand the relationship between this habitat type and nilgai antelope.

4.2 Other Wildlife Species

Other wildlife species were incidentally captured throughout the duration of the study and were often observed at the same locations. Camera trap station D4 emerged as a particular hotspot for species diversity, with overlapping detections of commonly detected species such as feral hog, collared peccary, raccoon, bobcat, and coyote. Station B3 also had high detections of other species, particularly bobcat, coyote, and collared peccary, which were likely taking advantage of easier movement via the mowed pipeline right-of-way access road that intersects the site. Detections were low to nonexistent in most coastal prairie habitat, similar to patterns observed for nilgai antelope. Detections of most wildlife species decreased dramatically after April 2021 and throughout the summer months, likely due to a rapid increase in overland flooding throughout the study area as well as intense heat, which likely resulted in decreased movement and potentially emigration from the area.

Feral hog were documented with the most frequency, and were most common at D4, where they were often observed in groups including young as well as solitary boars (Figure 18). White-tailed deer bucks were observed at sites situated in the northern extent of the park and exhibited “cruising” behavior when bucks efficiently traverse the landscape in search of receptive females. The lack of detections of female deer indicates that there are little to no deer occupying the study area and that the detected individuals were temporary visitors without an established home range overlapping the study area.



Figure 18. A group of feral hogs at camera trap station D4.

5. Conclusions

Within the study area, 58 nilgai antelope are estimated to occur, with significant seasonal variation that can be attributed to natural population changes such as to births, death, immigration, and emigration coupled with influential biological seasons such as parturition and breeding that influence nilgai antelope behavior and movements. Nilgai antelope were more frequently detected within the central and northwestern portions of the study area near a pipeline right-of-way access road compared to southern portions of the study area.

Activity throughout the study area had minimal overall fluctuations, with peaks in number of independent detection events corresponding to known biological seasons and associated behaviors (e.g., breeding, gestation, and parturition) and reduced activity during periods of intense heat overlapping known gestation and parturition periods that reduce adult female movement. Adult females were most commonly detected, influencing observed spatiotemporal patterns of use and activity. The presence of adult females is also strongly correlated with juveniles indicating the presence of habitat suitable for calving and rearing young. Grazing activity was highest for invasive graminoids and honey mesquite and was not documented for gulf cordgrass or other native species. Observed patterns of use and behavior indicate that the study area fulfills all life cycle requirements for nilgai antelope, and that nilgai antelope are more likely to occur in portions of the study area with increased prevalence of invasive graminoids, typically within central and northwest portions of the park, near the pipeline right-of-way access road. Continued restoration of coastal prairie habitat and associated reductions in invasive graminoids may result in reduced occupancy of nilgai antelope within habitat dominated by gulf cordgrass, as was observed for this study.

Twenty-six other wildlife species were also observed throughout the study area, with six detected in sufficient numbers to facilitate a detailed time series analysis: feral hog, collared peccary (javelina), raccoon, bobcat, coyote, and white-tailed deer. Detections of other wildlife species were most common in central and northwestern portions, similar to nilgai antelope. Feral hog were most frequently detected and were detected throughout the year, whereas most other species showed reductions or absence of activity throughout the summer months, potentially due to concurrent increases in overland flooding and intense heat.

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Appendix A—Supplemental Methods

Equipment Specifications

Tables A-1 and A-2 show the camera settings and specifications used for this study.

Table A-1. Modified camera trap settings specific to the Nilgai Inventory at PAAL project*.

Camera Attribute	Setting Used
Sensitivity	MEDIUM-HIGH
Pictures per trigger	2
Shutter	1/30 th
Max ISO	1600
Quiet Period	NO DELAY
Flash Output	HIGH
CodeLoc	YES-4976
PIR Type	LONG RANGE
Delay	2s
Time Format	24 hour

* All other settings remained consistent with Reconyx default factory settings (Table A-2)

Table A-2. Table of specifications for the RECONYX HP2X Hyperfire 2 Professional Covert IR camera.

Camera Attribute	Specifications Used
Primary Application	Wildlife Research?
Image Resolution	1080P HD Wide Screen or 3 Mega-pixel Standard Aspect Ratio
Video	720P HD Video with Audio
Video Length	Up to 90 Seconds
Product Warranty	5 years
Dimensions	~ 5.5 x 4.5 x 3 inches (14 x 11.5 x 7.5 cm)
Operating Temperature	-40° to +140° Fahrenheit (-40 to +60 °C)
Illumination	No-Glow™ High Output Covert IR
Illumination Range	Up to 150 feet (45 m)
Illumination On/Off Option	Included
Illumination Power Settings	Low/Med/High
Mapping & Image Management Software	MapView™ Professional & Configuration Software
User Defined Metadata in MapView™	Included
Metadata Export from MapView™	Included
Image Detail	Color by Day, Monochrome Infrared by Night
Trigger Speed	0.2 second
PIR Detect Range	Up to 100ft (30 m)
RapidFire™ Near-Video Speed	Up to 2 frames per second

Table A-2 (continued). Table of specifications for the RECONYX HP2X Hyperfire 2 Professional Covert IR camera.

Camera Attribute	Specifications Used
Frame Rate	RapidFire™ to 10 sec, 15 sec, 30 sec, 45 sec, 1 min between images
Photos per Trigger	1 to 90 images per trigger
Delay After Triggering	0,5,10,15,30 sec, 1,2,3,5,10,15,30,45 min, 1 hour
Delayed Start up to 1 Year	Included
Day/Night Options for Pics and Videos	Included
Night Time Shutter Speed	1/30, 1/60, 1/120, 1/240, 1/480
Max ISO Setting	800, 1600, 3200
Motion Sensor Scheduling	ON or OFF and Scheduled operation by day
Day of the Week Scheduling for Motion	Included
Time-Lapse Surveillance	1 or multiple Pics and/or Video
Time-Lapse Interval	[1,2,3,4] 5,6,10,12,15,20,30 sec, 1,2,3,4,5,6,10,12,15,20,30 min, 1,2,3,4,6,8,12, 24 Hour
Time-Lapse Scheduling	Up to 5 start and stop times (fixed and solar)
Day of the Week Scheduling for Time Lapse	Included
Loop Recording	Included
Memory Card Type	Secure Digital (SD® or SDHC®, SDXC®)
Memory Card Capacity	Up to 512GB
Image Data	Time, Date, Temperature, User Label and Moon Phase
Geo-Tagging of Pictures	Included
Battery Life	Up to 40,000 images or 2 years
Battery Requirements	NiMH Rechargeable or Energizer Ultimate Lithium
Battery Quantity / Size	12 AA
External Power Connection	Optional
Camera Settings	Available options are set on Camera or with the included Software
Camera Settings Export	Included
Customization	Custom Focus, External Power, External Trigger
Theft Deterrence	CodeLoc™ Pass-Code Protection

Latrine Site Activity Periods

Table A-3 shows the latrine site activity periods used.

Table A-3. Latrine site activity periods.

Latrine Station Site	Deployment Date	Pull Date	Active Days
LS_1	2/25/2021	3/15/2021	18
LS_2	2/24/2021	3/15/2021	19
LS_3	6/14/2021	7/15/2021	31
LS_4	6/7/2021	7/6/2021	29
LS_5	8/25/2021	9/8/2021	14
LS_6	8/25/2021	9/8/2021	14
LS_7	12/4/2021	12/31/2021	27
LS_8	12/4/2021	12/31/2021	27

Appendix B—Maps

Supplemental maps for the nilgai antelope effort are provided in Figures B-1 to B-9 below.

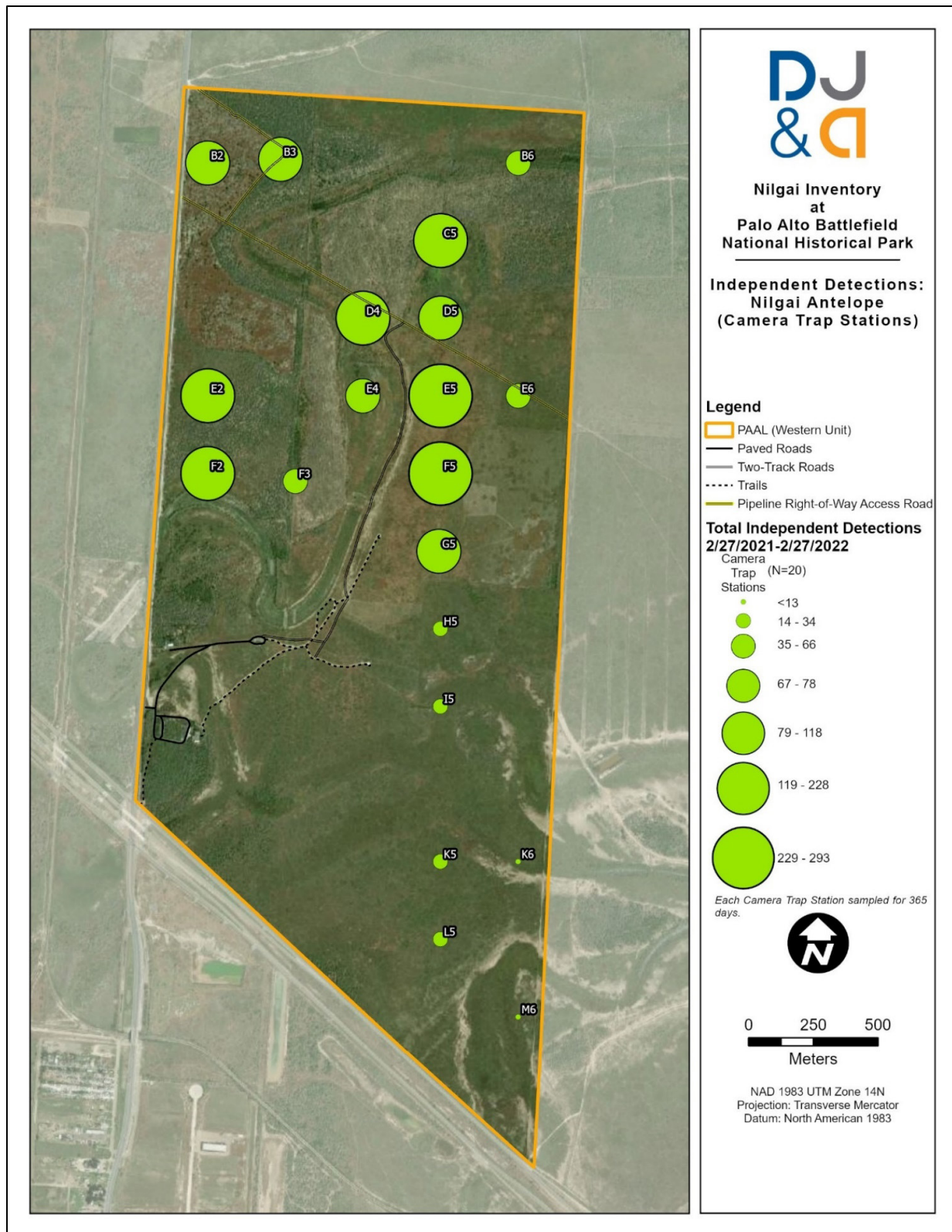


Figure B-1. Independent detections: Nilgai antelope (camera trap stations)-total independent detections.

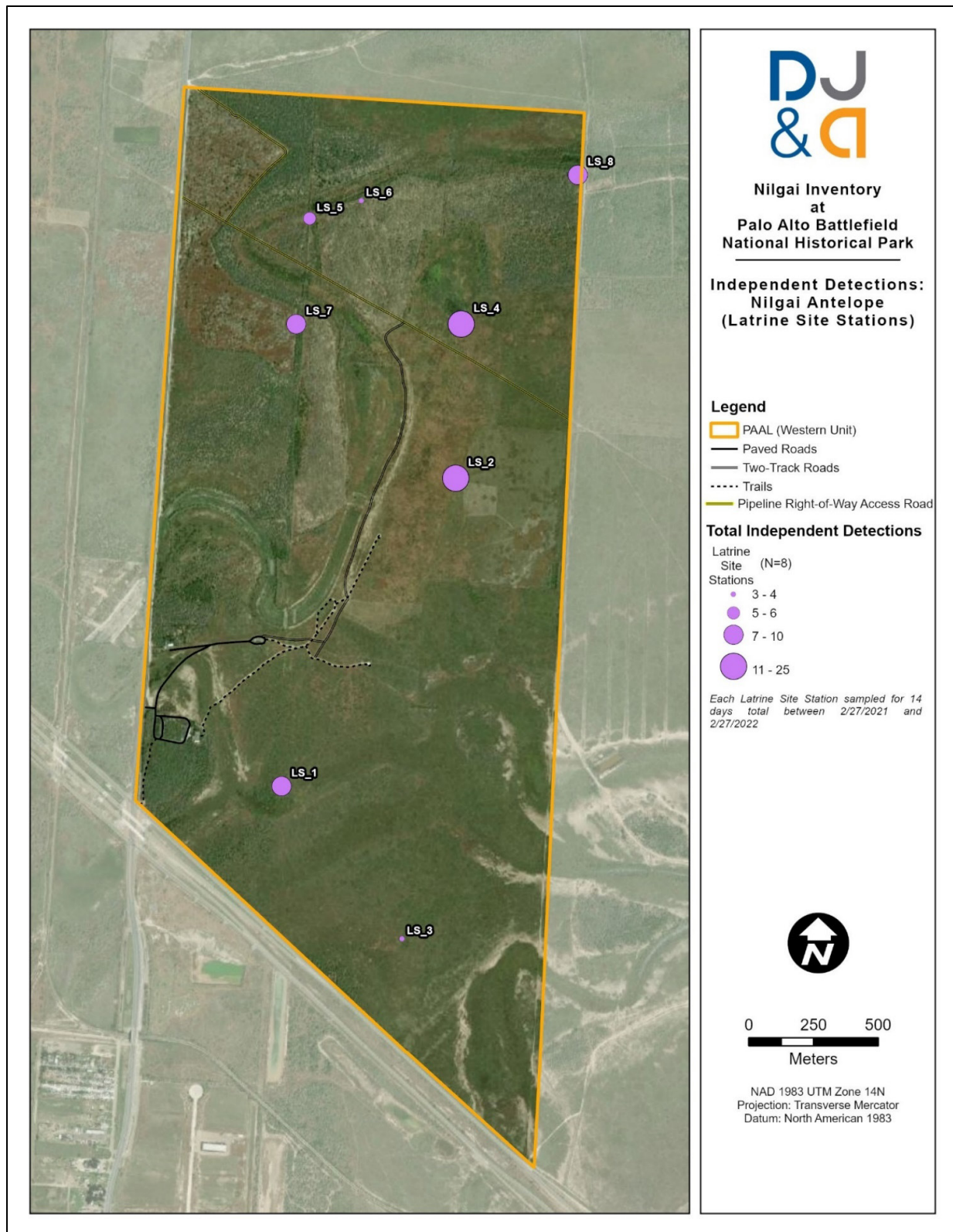


Figure B-2. Independent detections: Nilgai antelope (latrine site stations)-total independent detections.

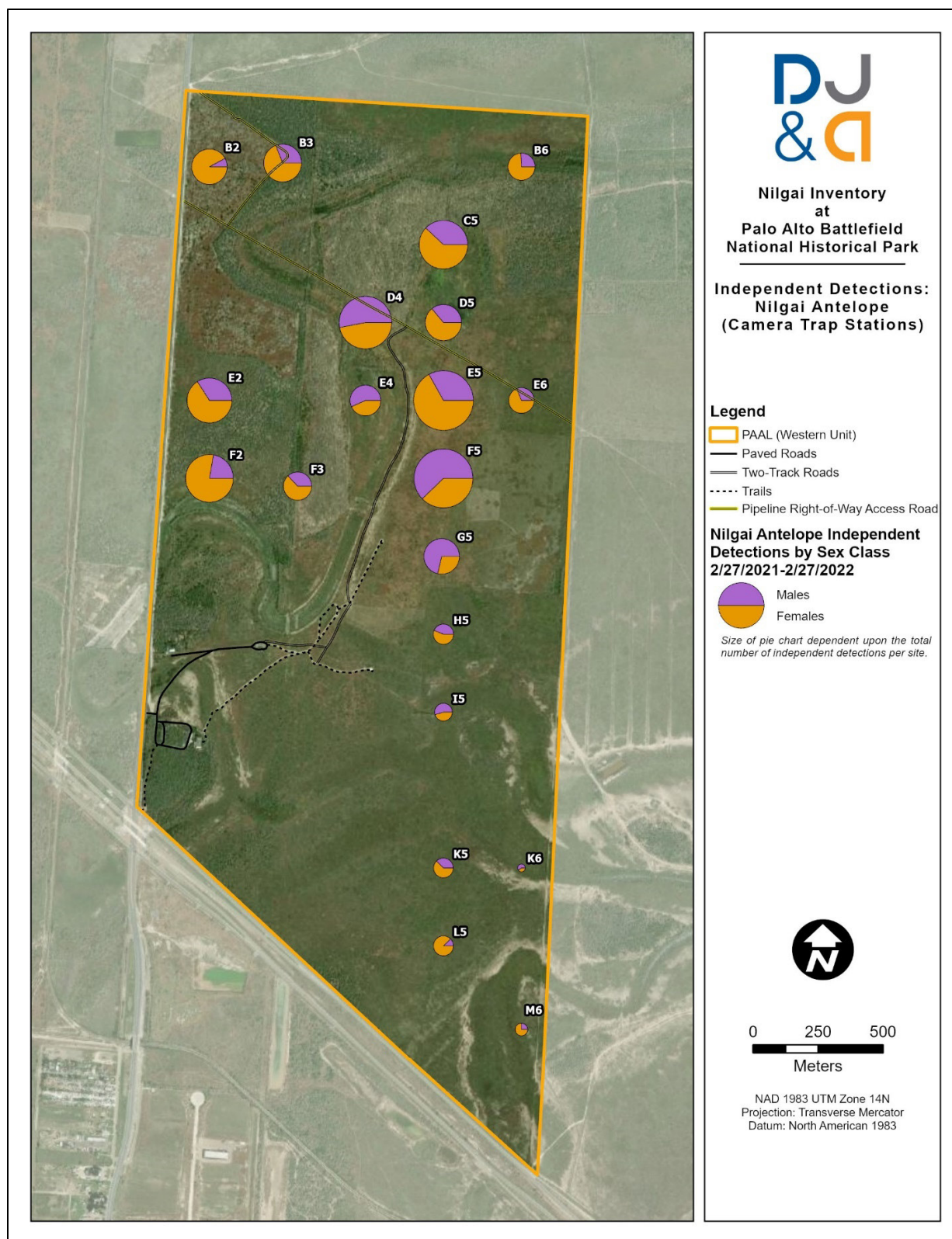


Figure B-3. Independent detections: Nilgai antelope (camera trap stations)-nilgai antelope independent detections by sex class.

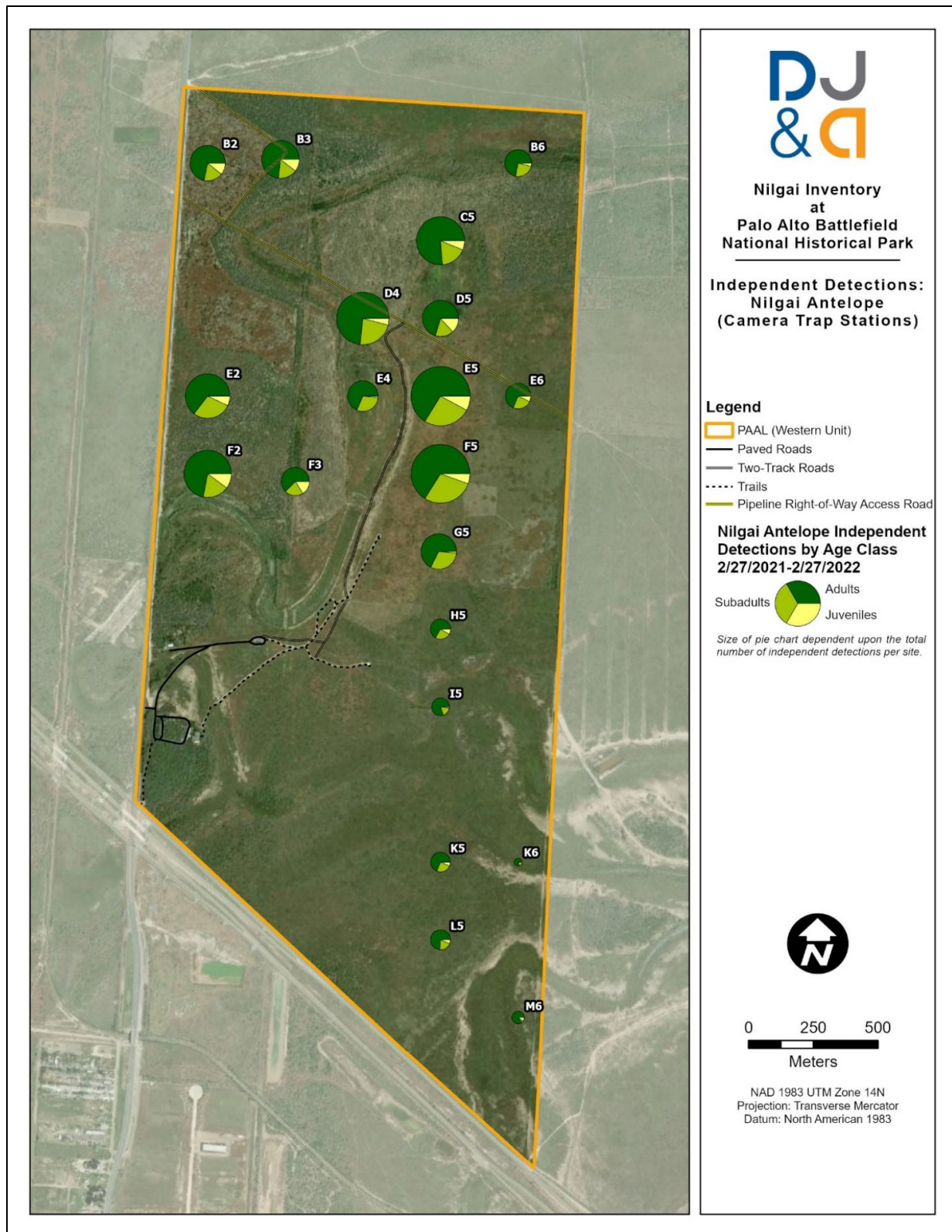


Figure B-4. independent detections: Nilgai antelope (camera trap stations)-nilgai independent detections by age class.

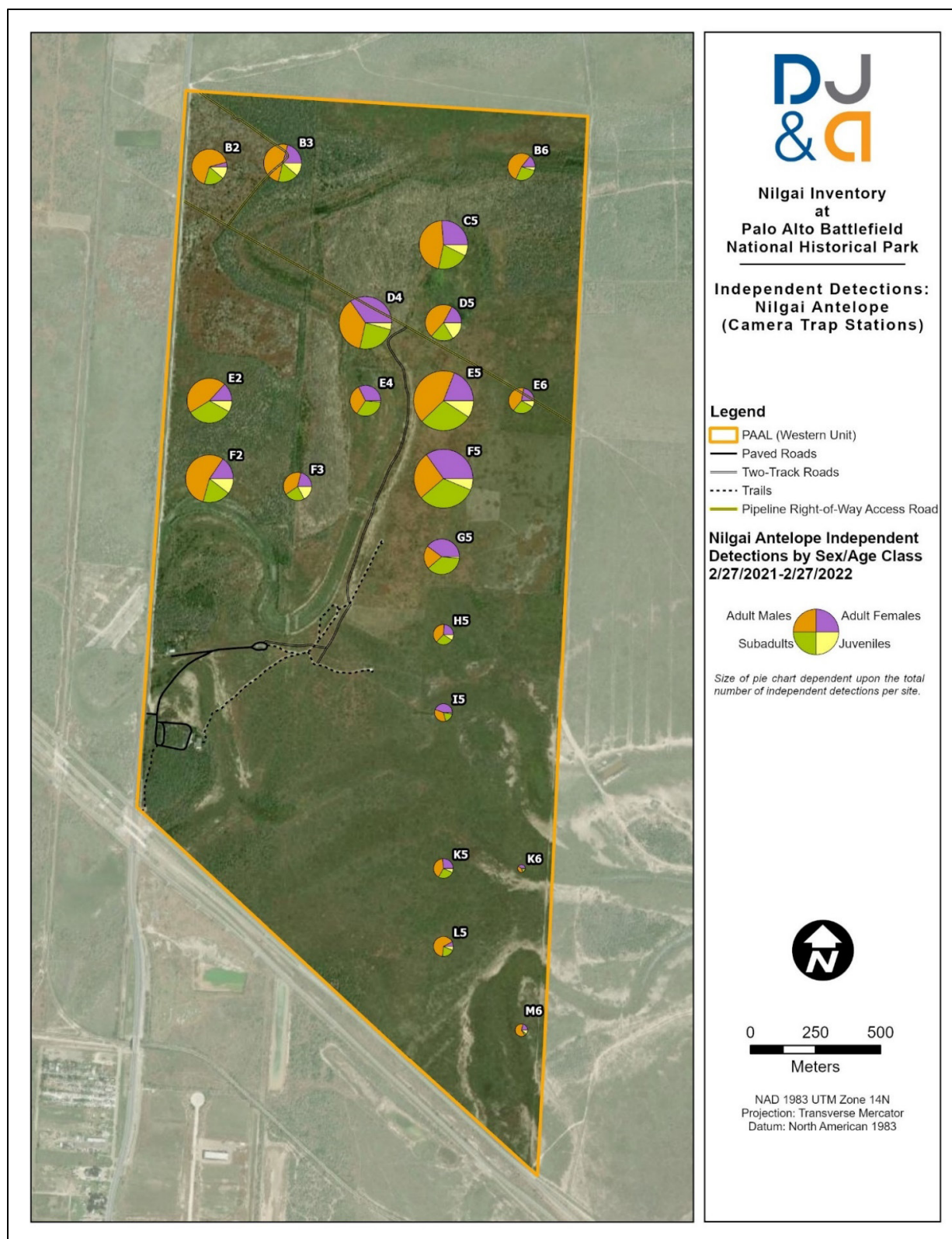


Figure B-5. Independent detections: Nilgai antelope (camera trap stations)-nilgai antelope independent detections by sex/age class.

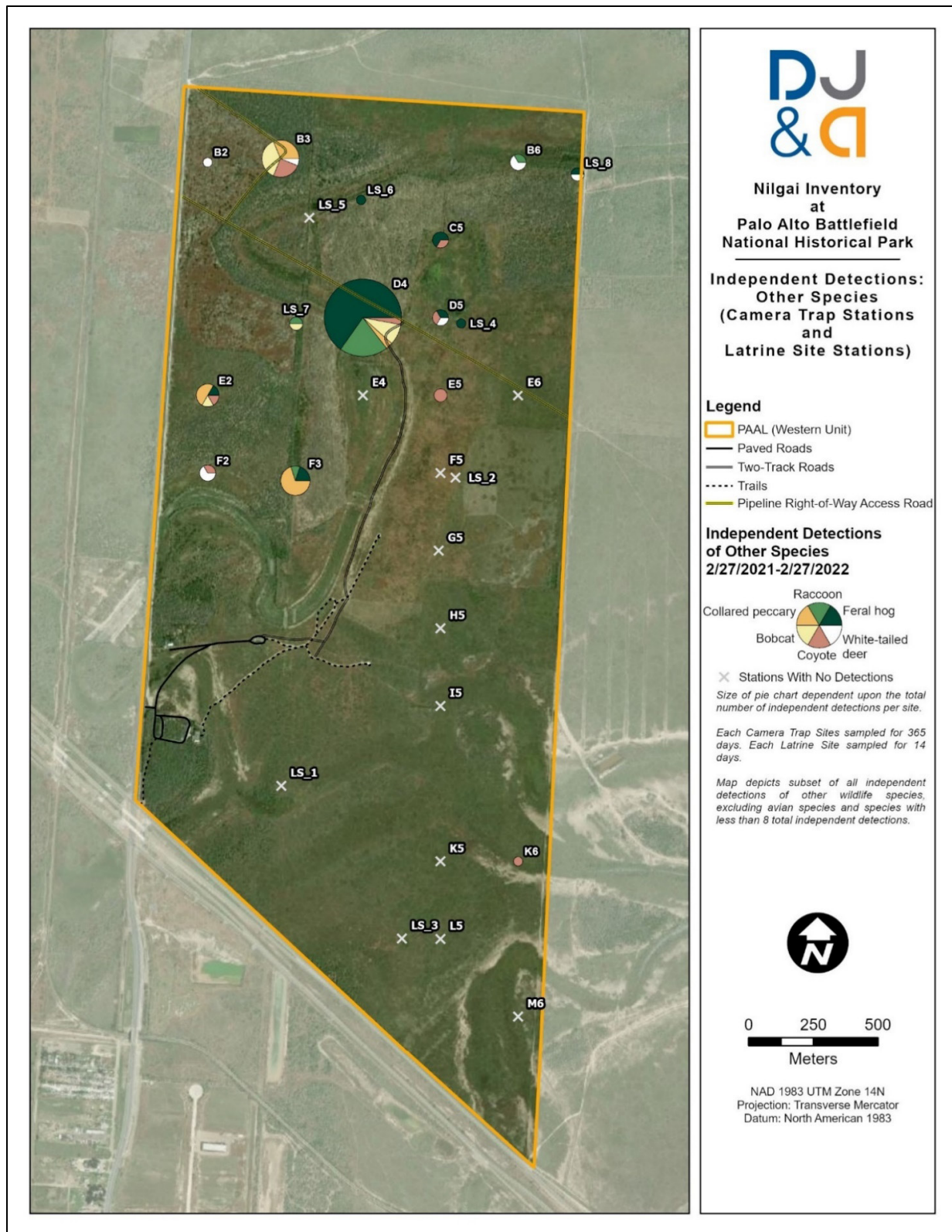
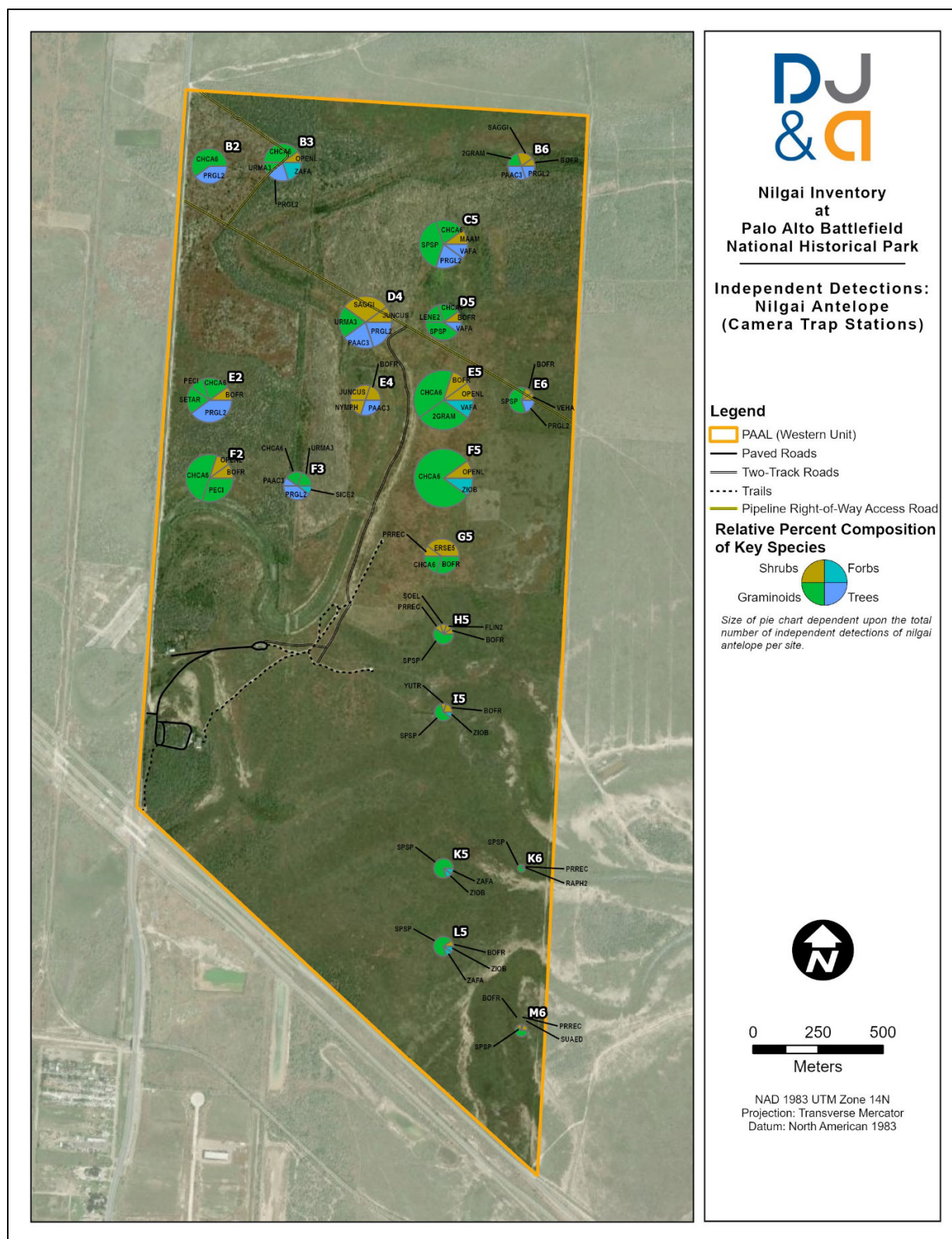


Figure B-6. Independent detections: Other species (camera trap stations and latrine site stations) independent detections of other species.



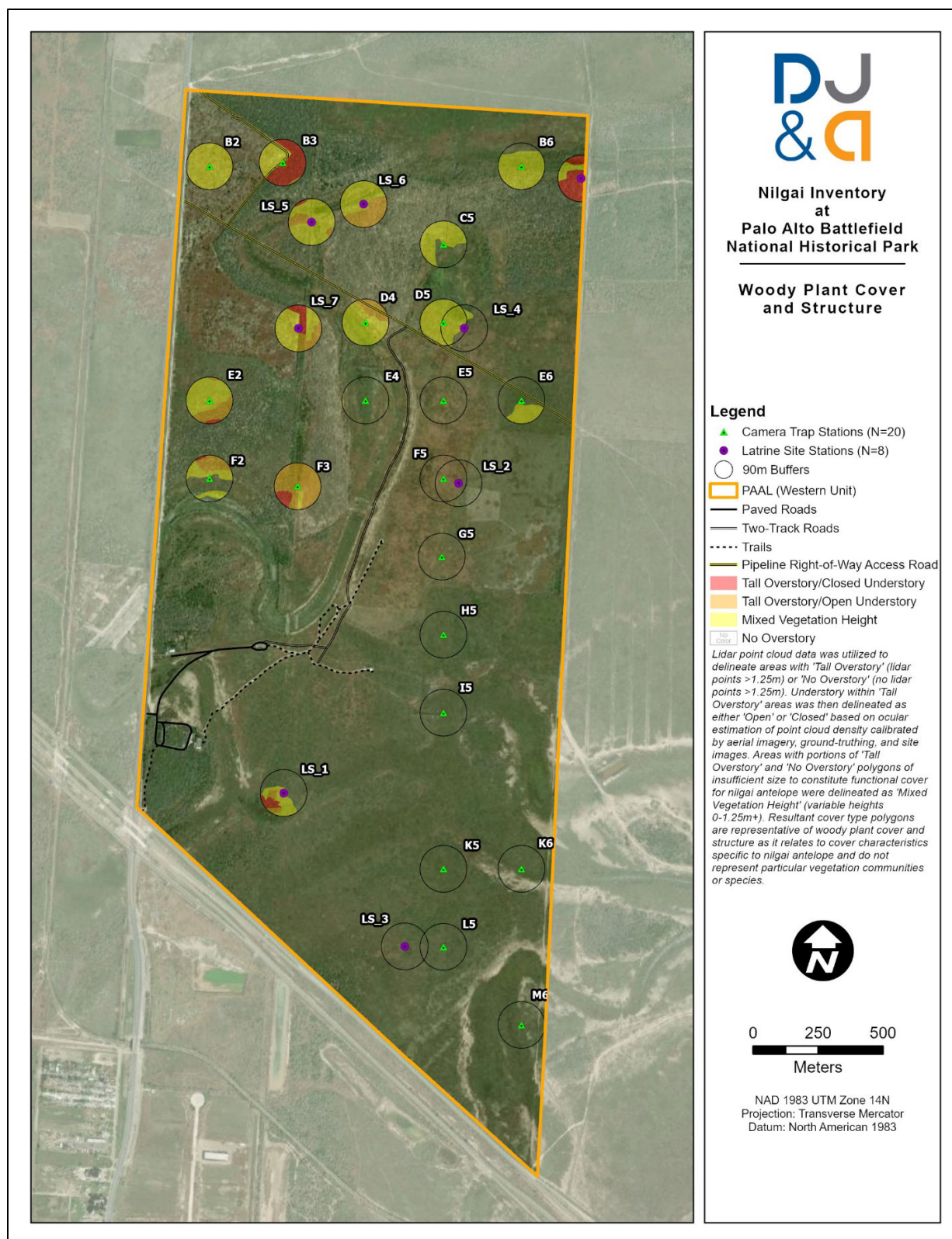


Figure B-8. Woody plant cover and structure.

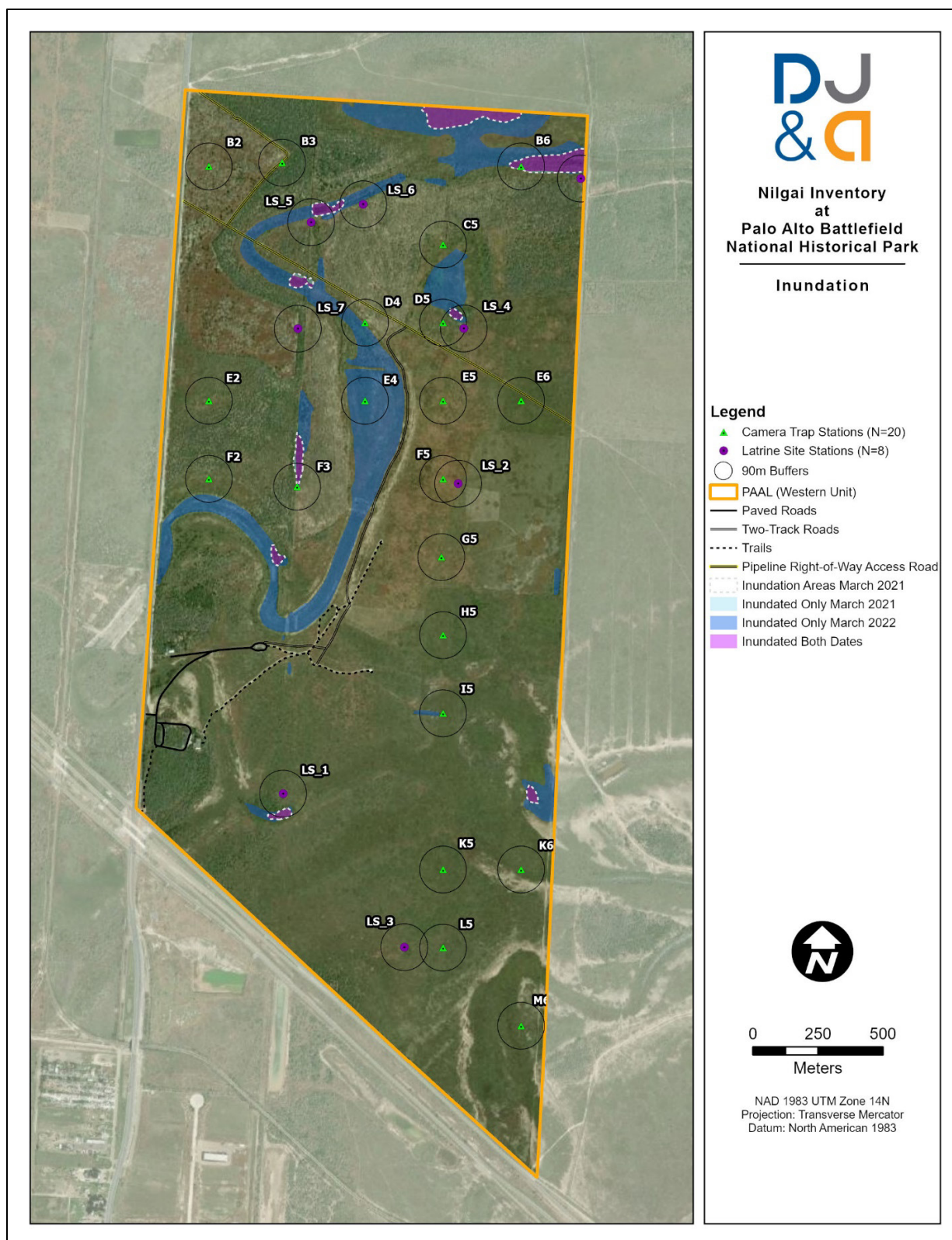


Figure B-9. Inundation.

Appendix C—Independent Detection Event Analysis Results

Comprehensive results from analysis conducted on independent detection events for nilgai antelope and other wildlife species detected at data collection sites (Table C-1 and Table C-2). Nilgai antelope were analyzed according to summaries of each given variable by camera trap station as well as time series analyses derived from daily summaries of each variable throughout the duration of the study period. Other wildlife species were analyzed by total number of detections for a given location due to limiting sample sizes.

Table C-1. Summary of independent detection events per species and camera trap station location.

Taxonomic Group	Common Name	B2	B3	B6	C5	D4	D5	E2	E4	E5	E6	F2	F3	F5	G5	H5	I5	K5	K6	L5	M6	Total
Avian	American Coot	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
	Black-bellied Whistling Duck	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
	Blue-winged Teal	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
	Common Gallinule	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
	Eastern Meadowlark	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
	Golden-fronted Woodpecker	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Groove-billed Ani	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Mottled Duck	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Red-tailed Hawk	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Total Avian	0	0	0	0	4	0	0	7	0	0	0	0	1	0	0	0	0	0	0	0	12
Mammalian	black-tailed jackrabbit	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	bobcat	0	6	0	0	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	13
	collared peccary	0	5	0	0	2	0	3	0	0	0	0	7	0	0	0	0	0	0	0	0	17
	coyote	0	4	0	1	2	1	1	0	2	0	1	0	0	0	0	0	0	1	0	0	13
	Domestic cow	0	0	1	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	4
	feral hog	0	0	0	2	45	1	1	0	0	0	0	2	0	0	0	0	0	0	0	0	51
	nilgai antelope	104	118	60	194	228	108	165	78	294	54	188	66	286	104	34	26	32	5	33	13	2190
	nine-banded armadillo	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
	raccoon	0	0	1	0	14	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	16
	southern plains woodrat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
	Virginia opossum	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	white-tailed deer	1	1	2	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	7
	Total Mammalian	105	137	64	197	303	111	171	79	298	54	191	76	286	104	34	26	32	6	34	13	2321
All Groups	Total (all)	105	137	64	197	307	111	171	86	298	54	191	76	287	104	34	26	32	6	34	13	2333

Table C-2. Summary of independent detection events per species and latrine site station location.

Taxonomic Group	Common Name	LS_1	LS_2	LS_3	LS_4	LS_5	LS_6	LS_7	LS_8	Total
Avian	Black-bellied Whistling Duck	0	0	0	2	0	0	0	0	2
	Common Ground Dove	0	0	0	4	0	0	0	0	4
	Curve-billed Thrasher	0	0	0	15	0	0	0	0	15
	Great-tailed Grackle	0	0	0	1	0	0	0	0	1
	Mourning Dove	0	0	0	14	0	0	0	0	14
	Turkey Vulture	0	0	0	1	0	0	0	0	1
	White-tailed Hawk	0	0	0	1	0	0	0	0	1
	Total Avian	0	0	0	38	0	0	0	0	38
Mammalian	bobcat	0	0	0	0	0	0	1	0	1
	feral hog	0	0	0	1	0	1	0	1	3
	nilgai antelope	8	25	4	23	6	3	10	8	87
	raccoon	0	0	0	0	0	0	1	0	1
	Virginia opossum	0	0	0	0	0	0	1	0	1
	white-tailed deer	0	0	0	0	0	0	0	1	1
	Total Mammalian	8	25	4	24	6	4	13	10	94
All Groups	Total (all)	8	25	4	62	6	4	13	10	132

All Variables Summarized by Location (CTS Sites and LS Stations)

Number of independent detection events per site and total number of individuals per a given sex and age class category for nilgai antelope including individuals, adults, females, adult females, males, adult males, subadults, and juveniles. Per each variable, a summary of all collected data was compiled per each Camera Trap Station (Figures C-1 to C-9) and Latrine Site Station (Figures C-10 to C-18).

Camera Trap Stations

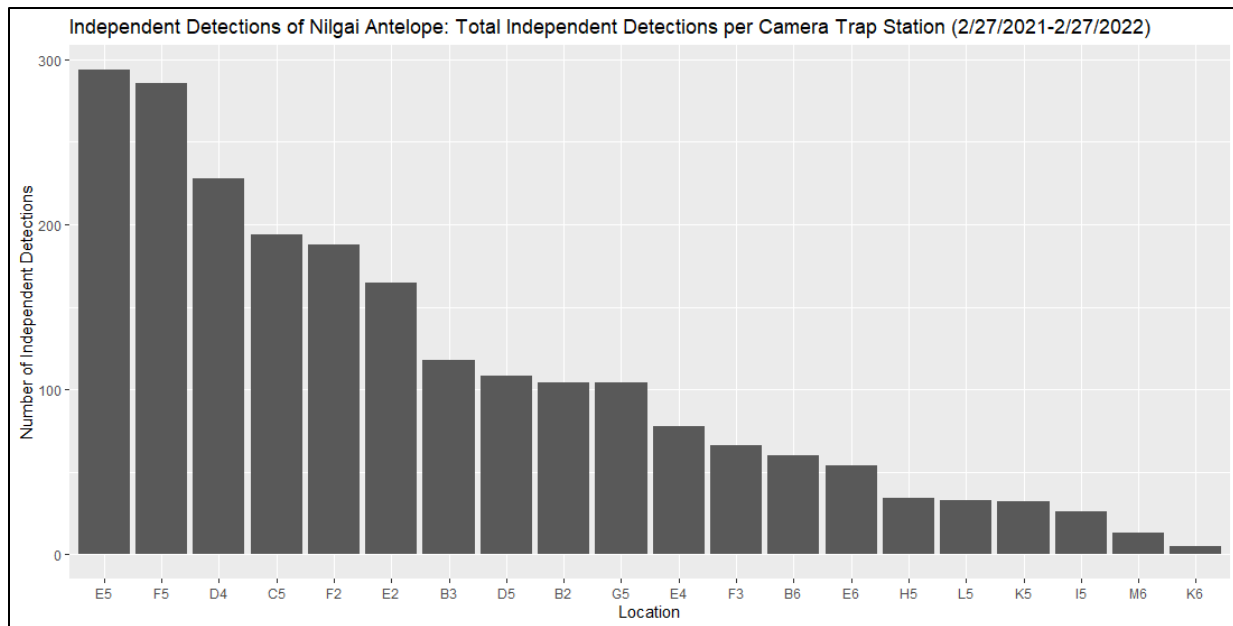


Figure C-1. Independent detections of nilgai antelope: Total independent detections per camera trap station (2/27/2021–2/27/2022).

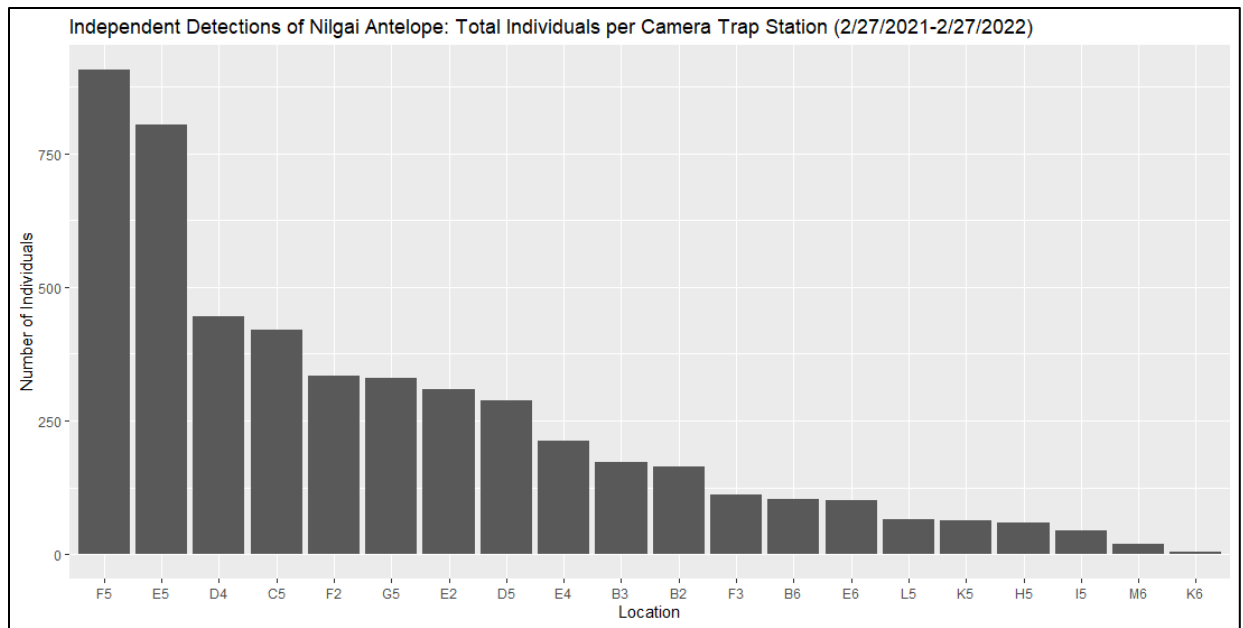


Figure C-2. Independent detections of nilgai antelope: Total individuals per camera trap station (2/27/2021–2/27/2022).

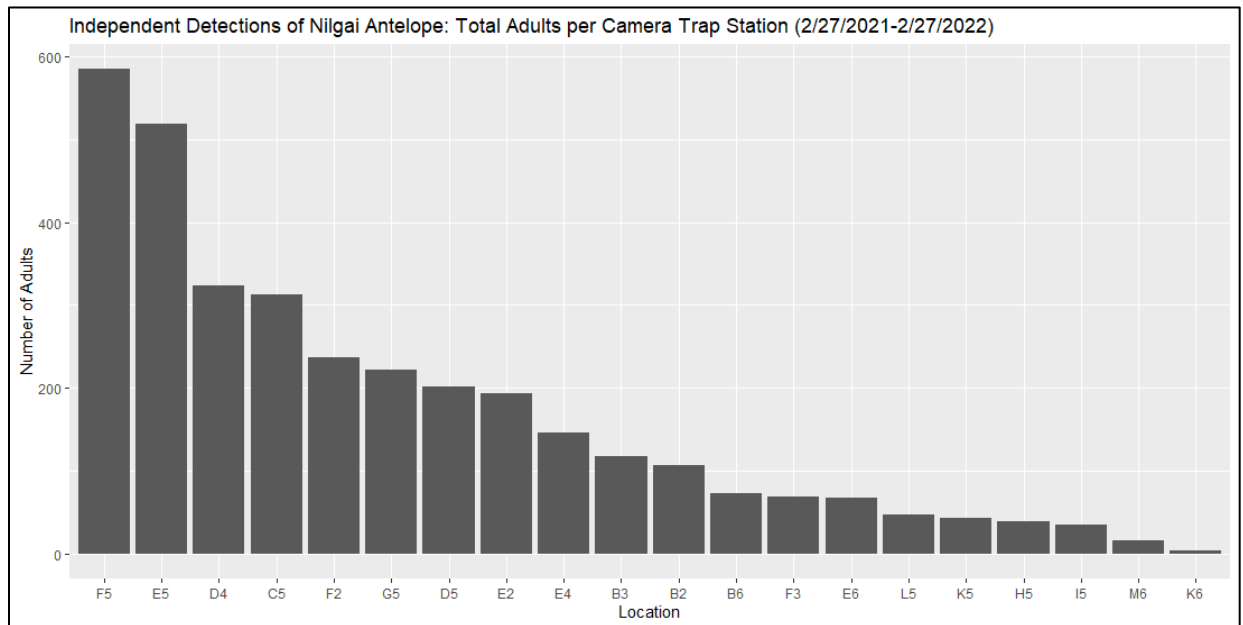


Figure C-3. Independent detections of nilgai antelope: Total adults per camera trap station (2/27/2021–2/27/2022).

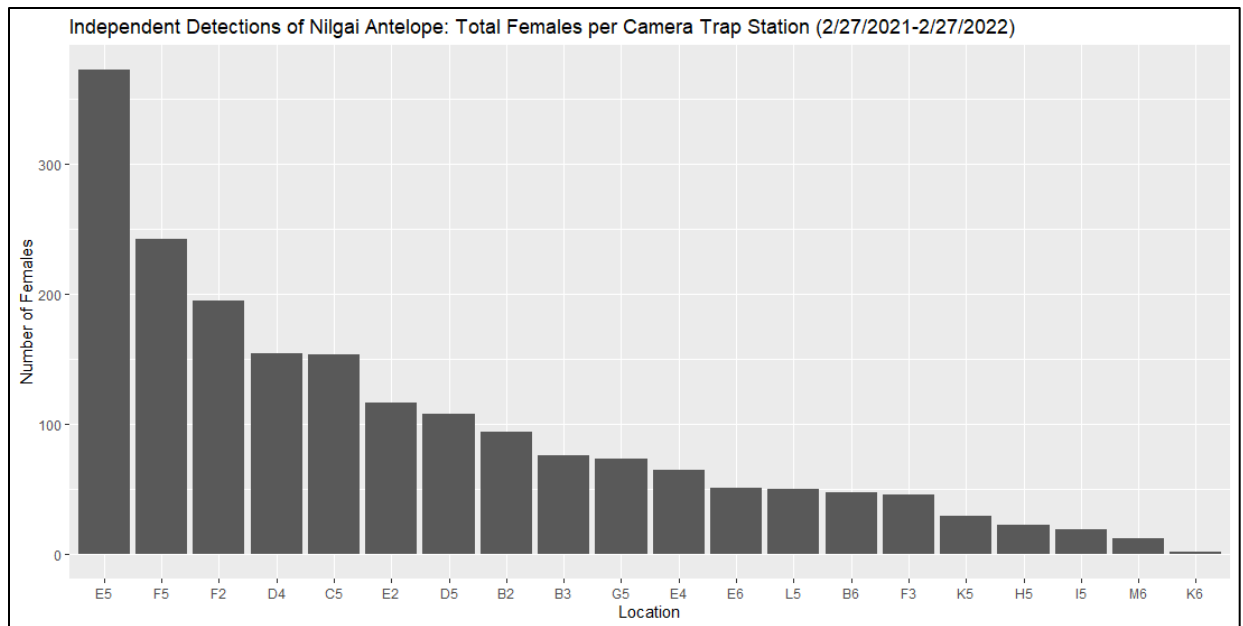


Figure C-4. Independent detections of nilgai antelope: Total females per camera trap station (2/27/2021–2/27/2022).

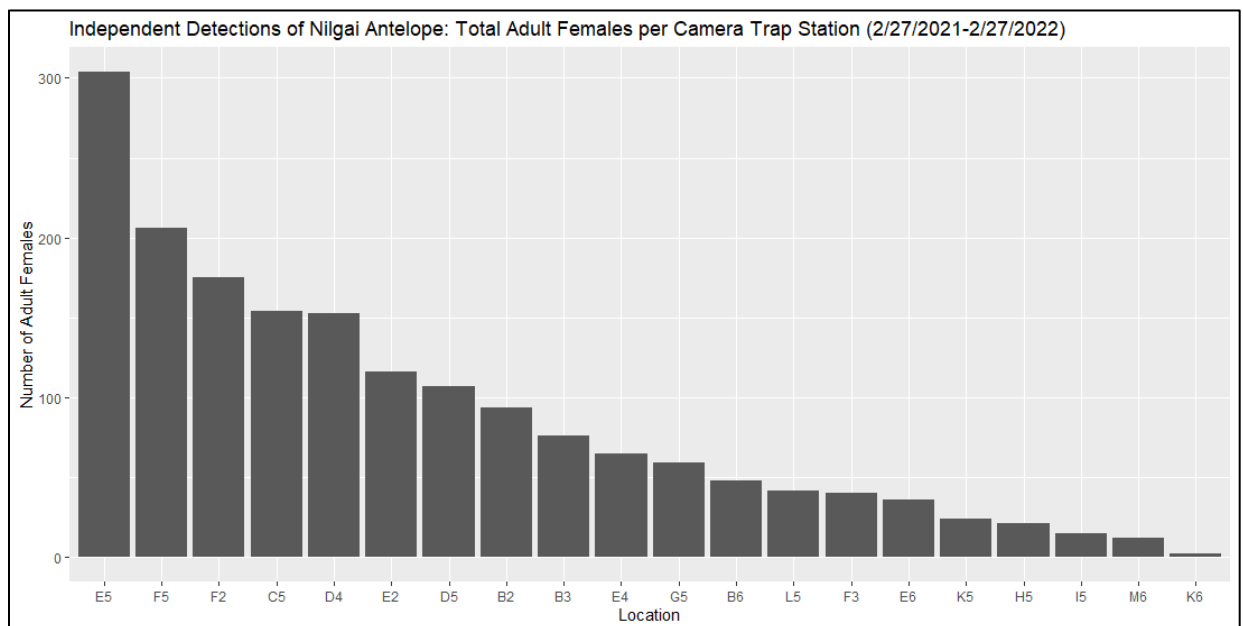


Figure C-5. Independent detections of nilgai antelope: Total adult females per camera trap station (2/27/2021–2/27/2022).

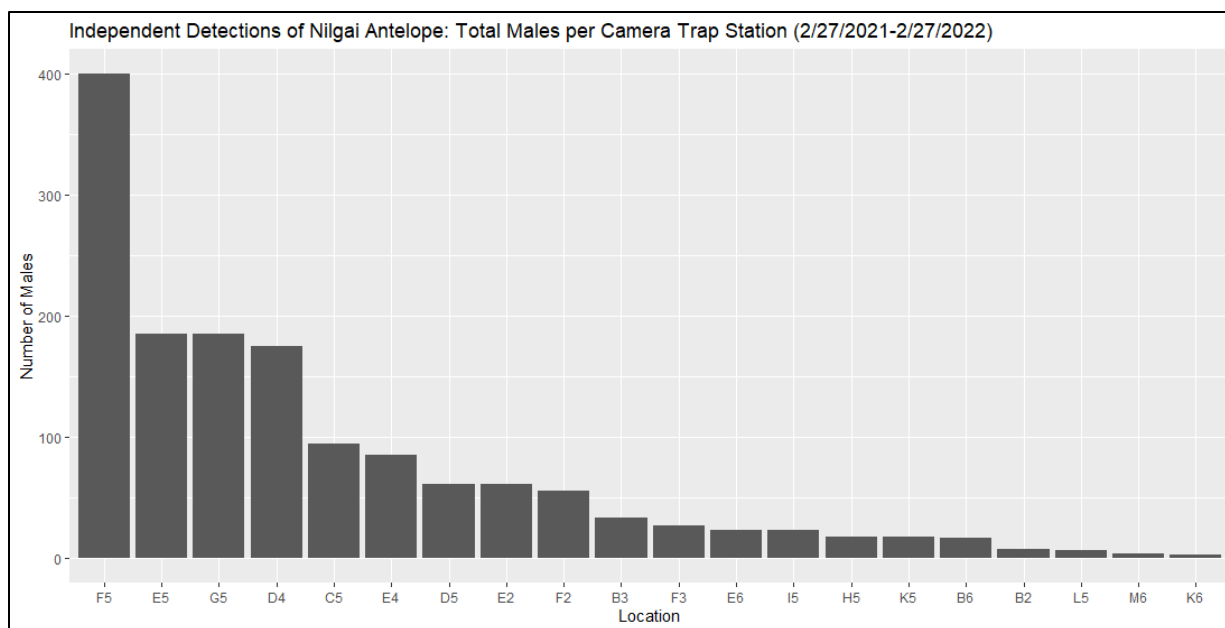


Figure C-6. Independent detections of nilgai antelope: Total males per camera trap station (2/27/2021–2/27/2022).

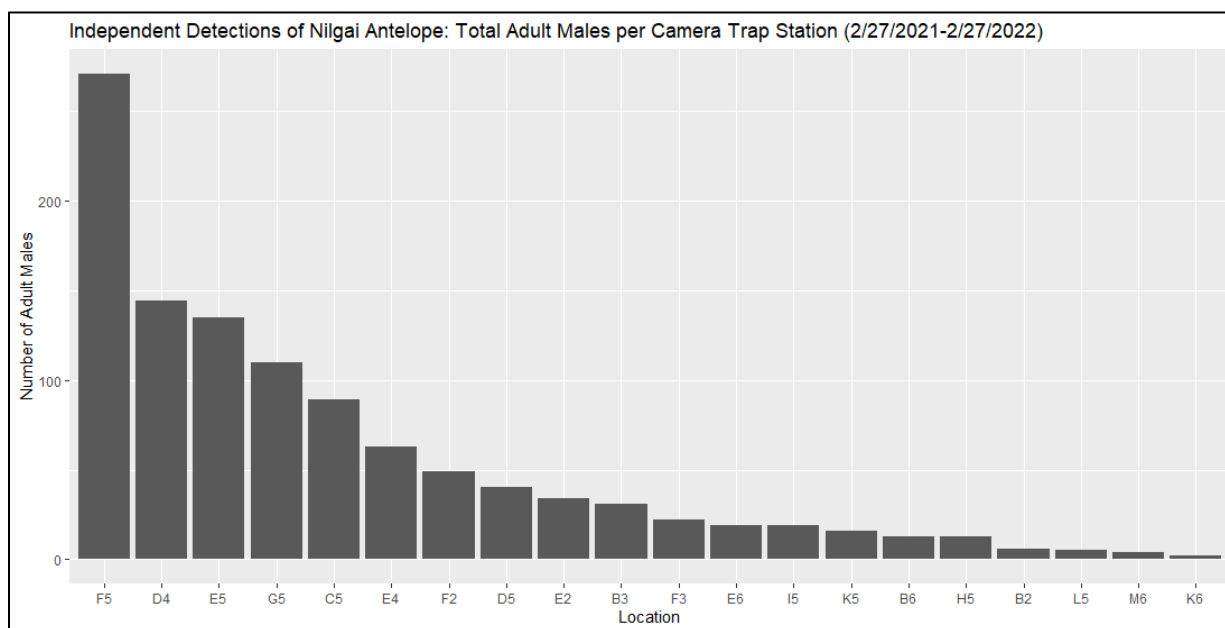


Figure C-7. independent detections of nilgai antelope: Total adult males per camera trap station (2/27/2021–2/27/2022).

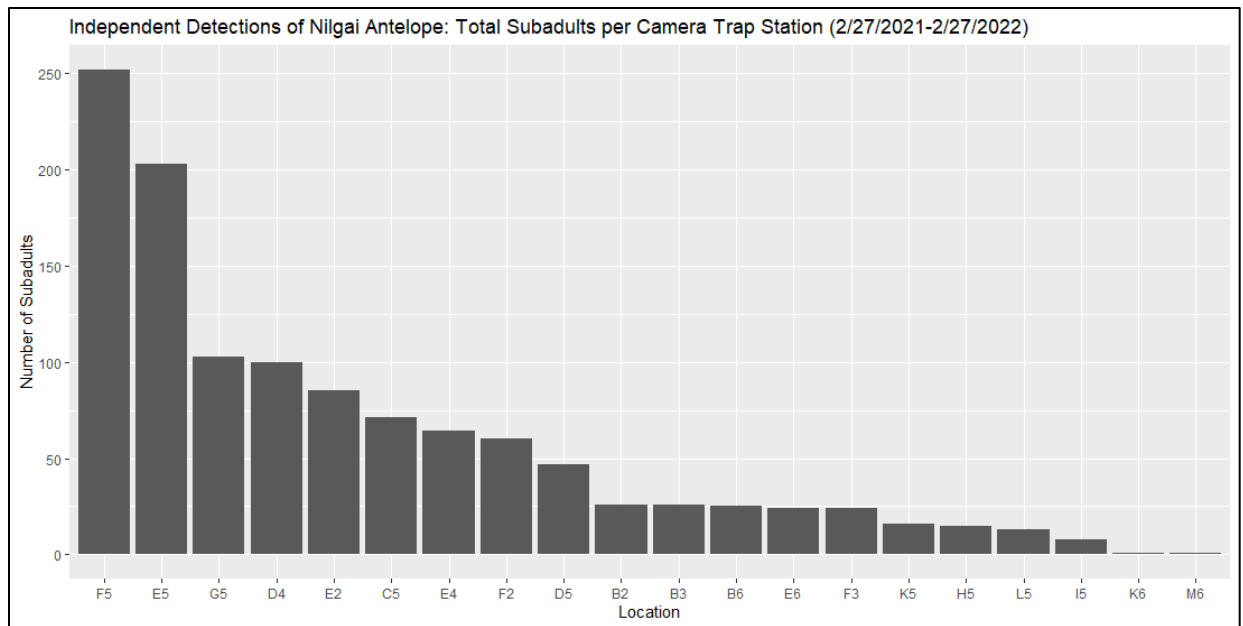


Figure C-8. Independent detections of nilgai antelope: Total subadults per camera trap station (2/27/2021–2/27/2022).

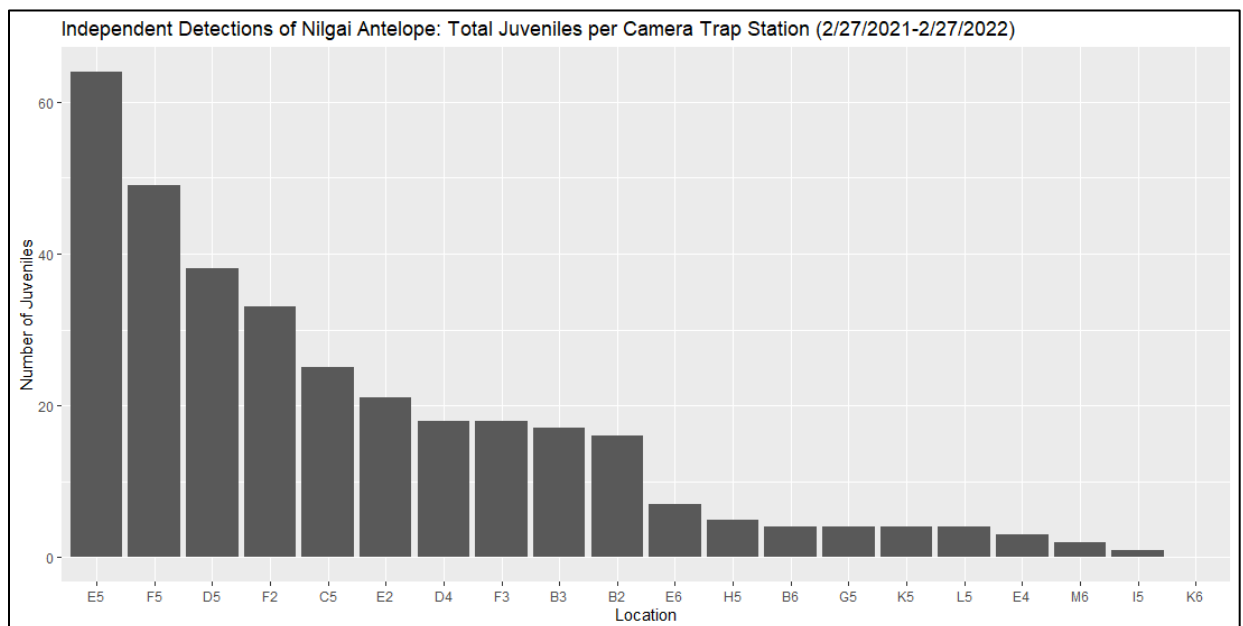


Figure C-9. Independent detections of nilgai antelope: Total juveniles per camera trap station (2/27/2021–2/27/2022).

Latrine Site Stations

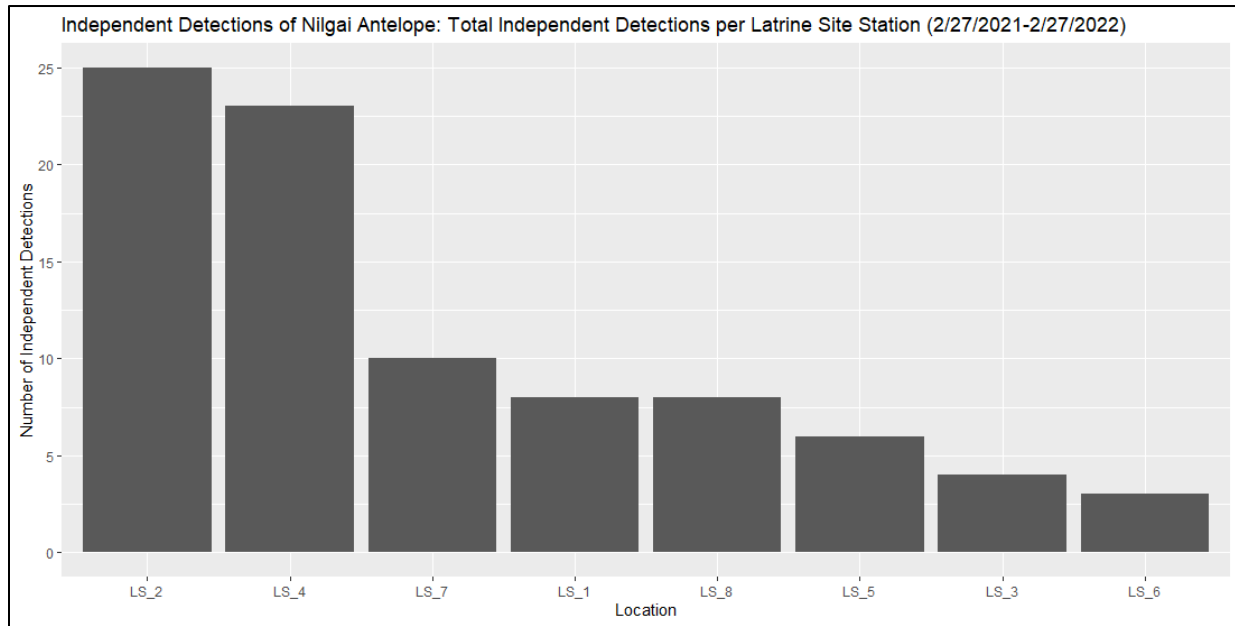


Figure C-10. Independent detections of nilgai antelope: Total independent detections per latrine site station (2/27/2021–2/27/2022).

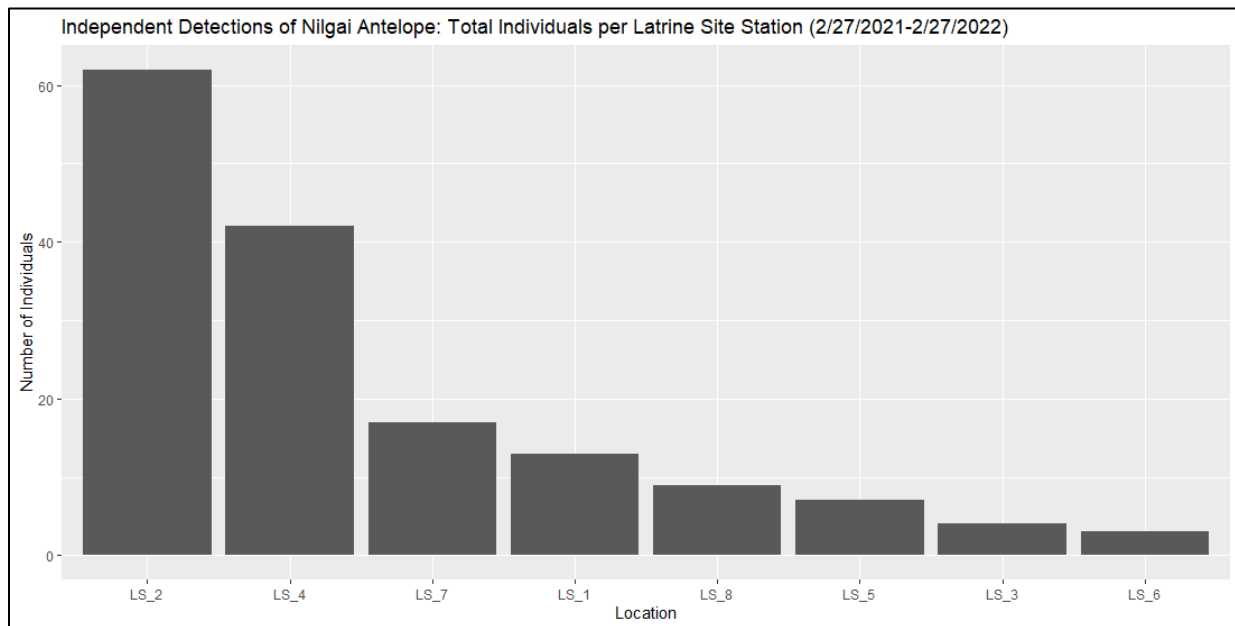


Figure C-11. Independent detections of nilgai antelope: Total individuals per latrine site station (2/27/2021–2/27/2022).

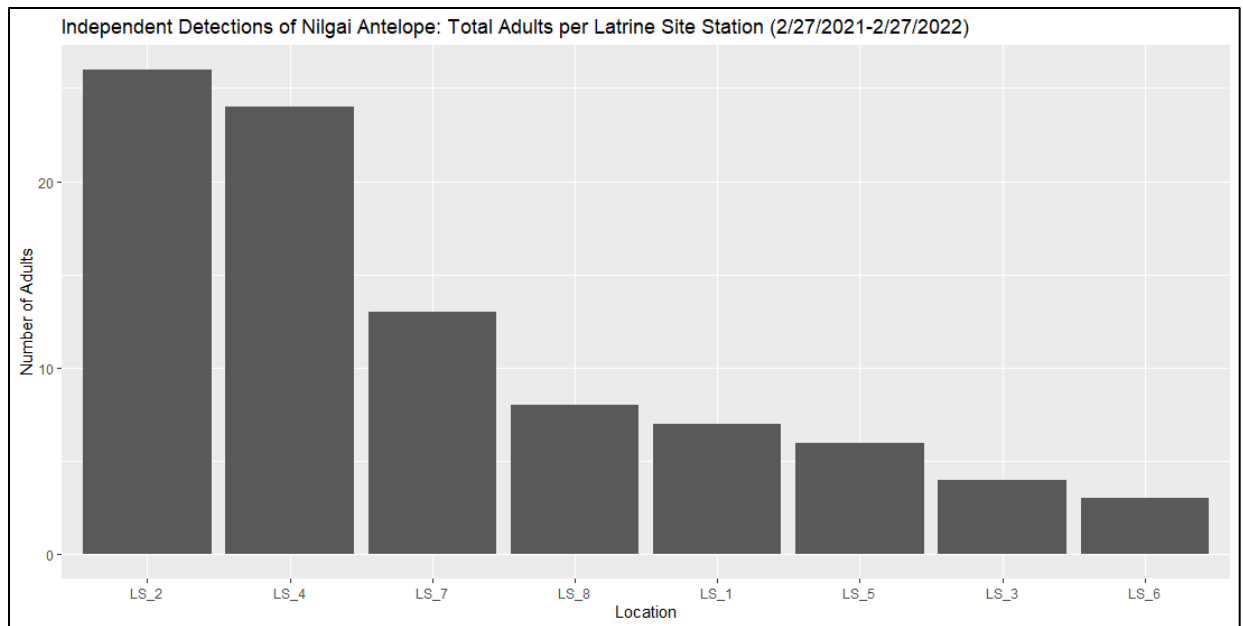


Figure C-12. Independent detections of nilgai antelope: Total adults per latrine site station (2/27/2021–2/27/2022).

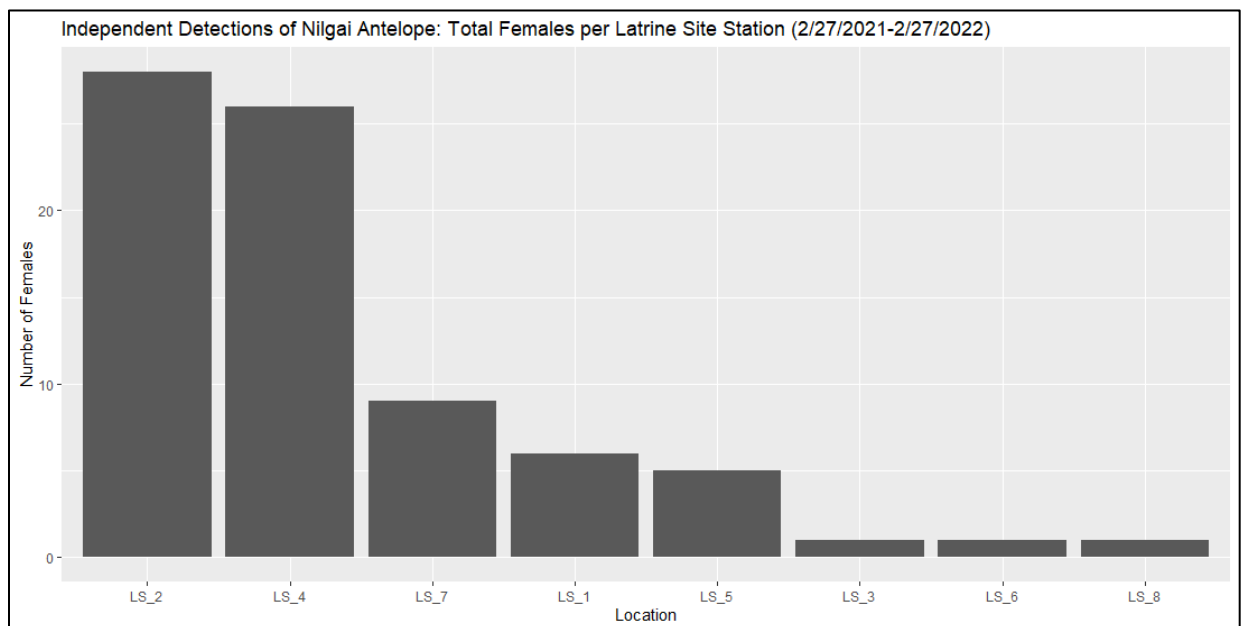


Figure C-13. Independent detections of nilgai antelope: Total females per latrine site station (2/27/2021–2/27/2022).

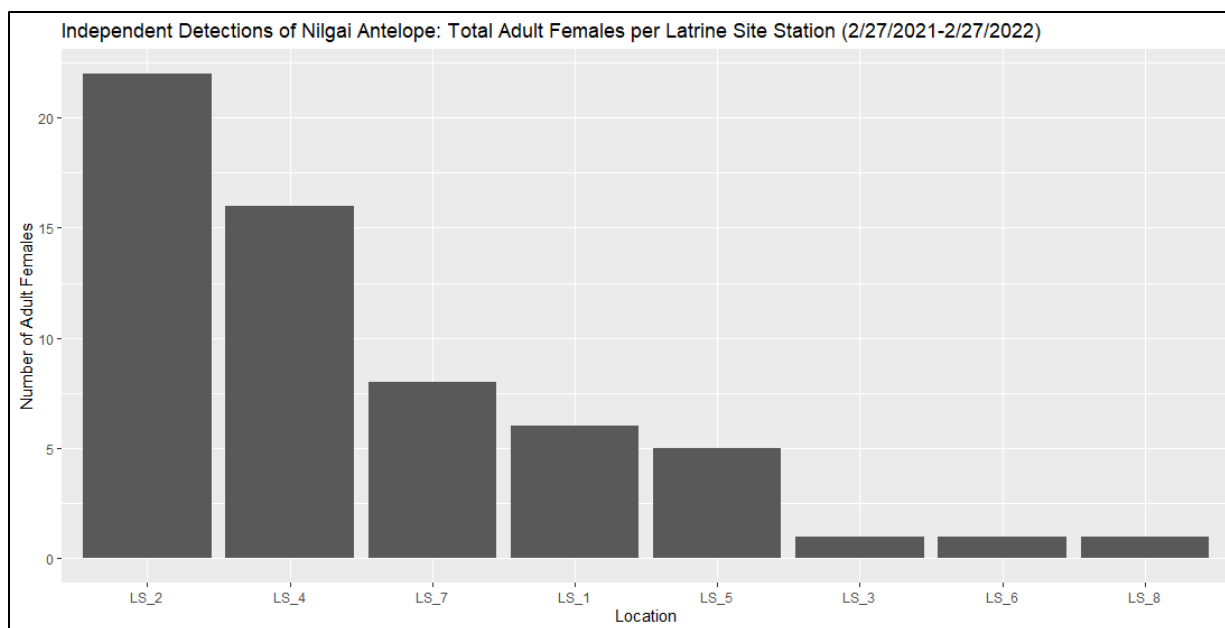


Figure C-14. Independent detections of nilgai antelope: Total adult females per latrine site station (2/27/2021–2/27/2022).

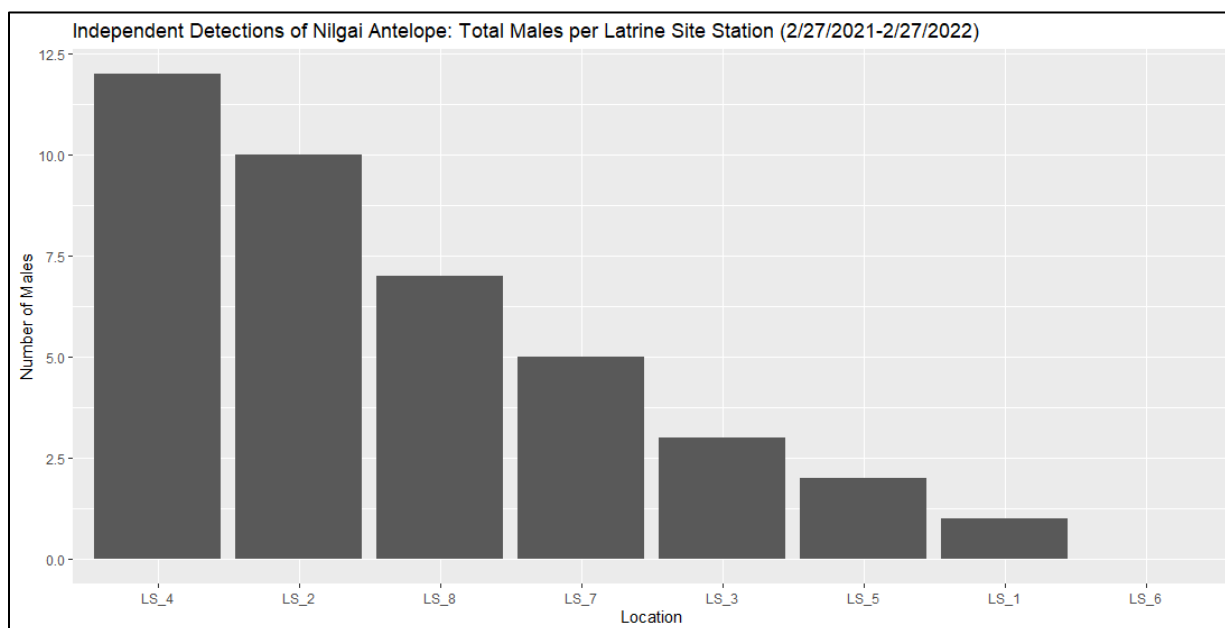


Figure C-15. Independent detections of nilgai antelope: Total males per latrine site station (2/27/2021–2/27/2022).

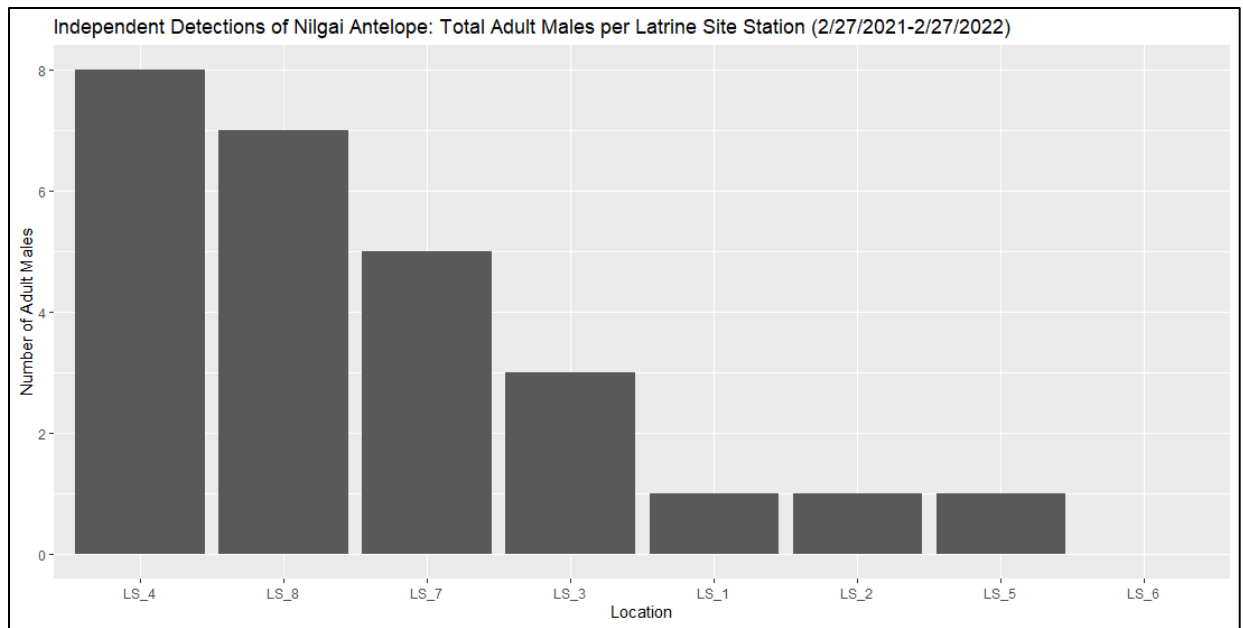


Figure C-16. Independent detections of nilgai antelope: Total adult males per latrine site station (2/27/2021–2/27/2022).

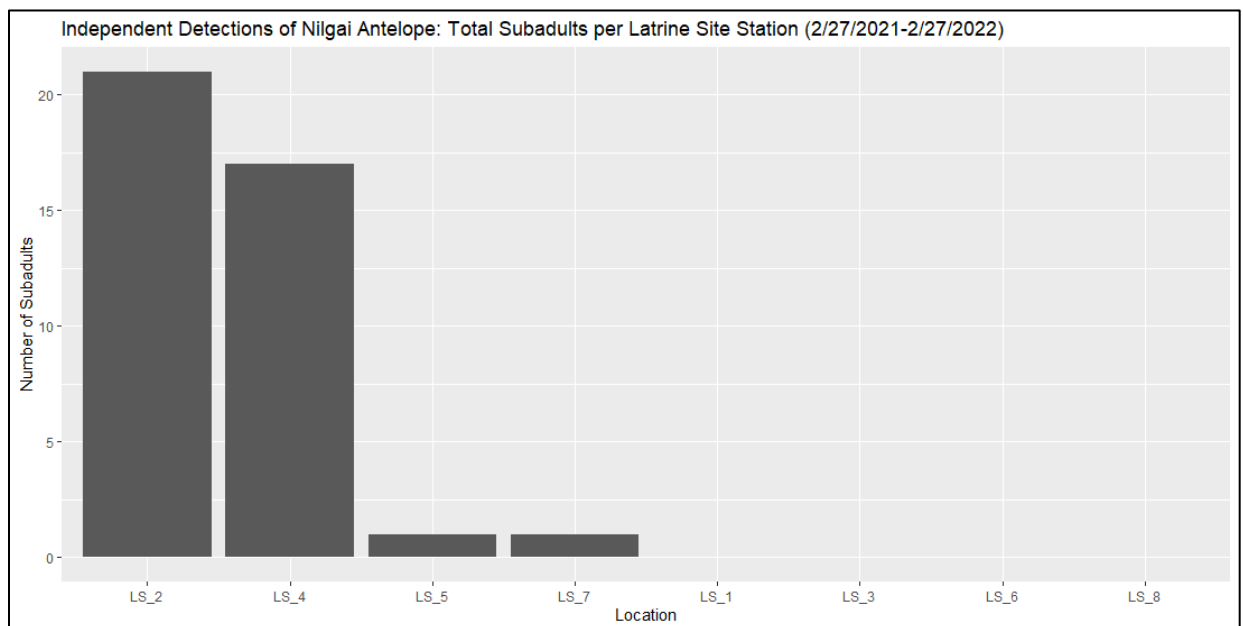


Figure C-17. Independent detections of nilgai antelope: Total subadults per latrine site station (2/27/2021–2/27/2022).

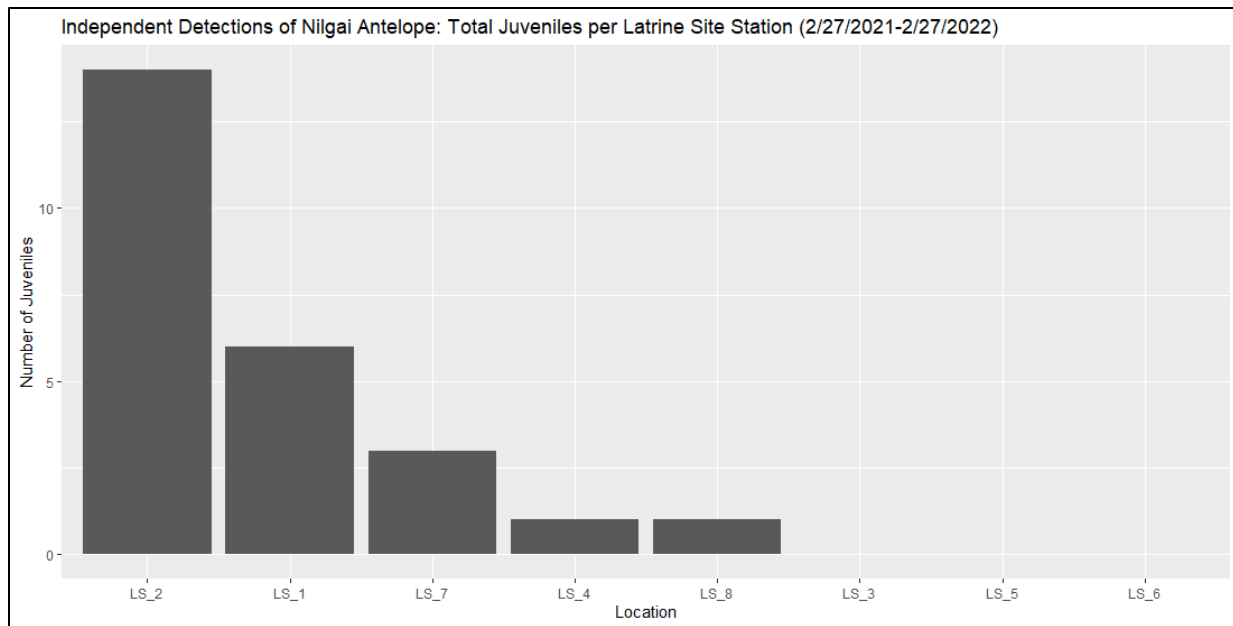


Figure C-18. Independent detections of nilgai antelope: Total juveniles per latrine site station (2/27/2021–2/27/2022).

All Variables Summarized by Location – Stacked Comparison (CTS Sites and LS Stations)

Stacked comparison of all analyzed sex and age class categories (adults, adult females, adult males, males, females, subadults, and juveniles) per Camera Trap Station (Figures C-19 to C-21) and Latrine Site Station (Figures C-22 to C-24).

Camera Trap Stations

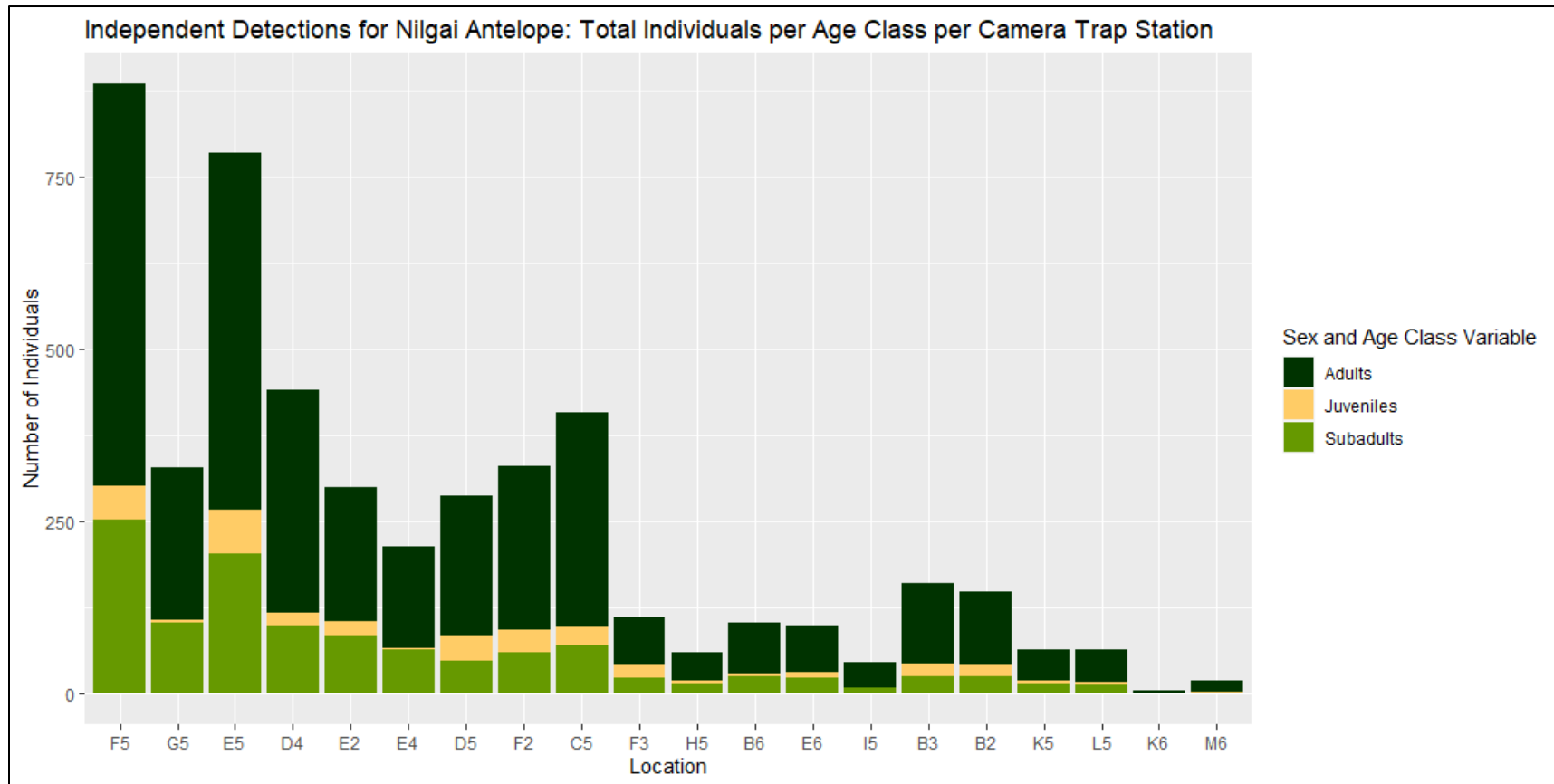


Figure C-19. Independent Detections of Nilgai Antelope: Total Individuals per Age Class per Camera Trap Station.

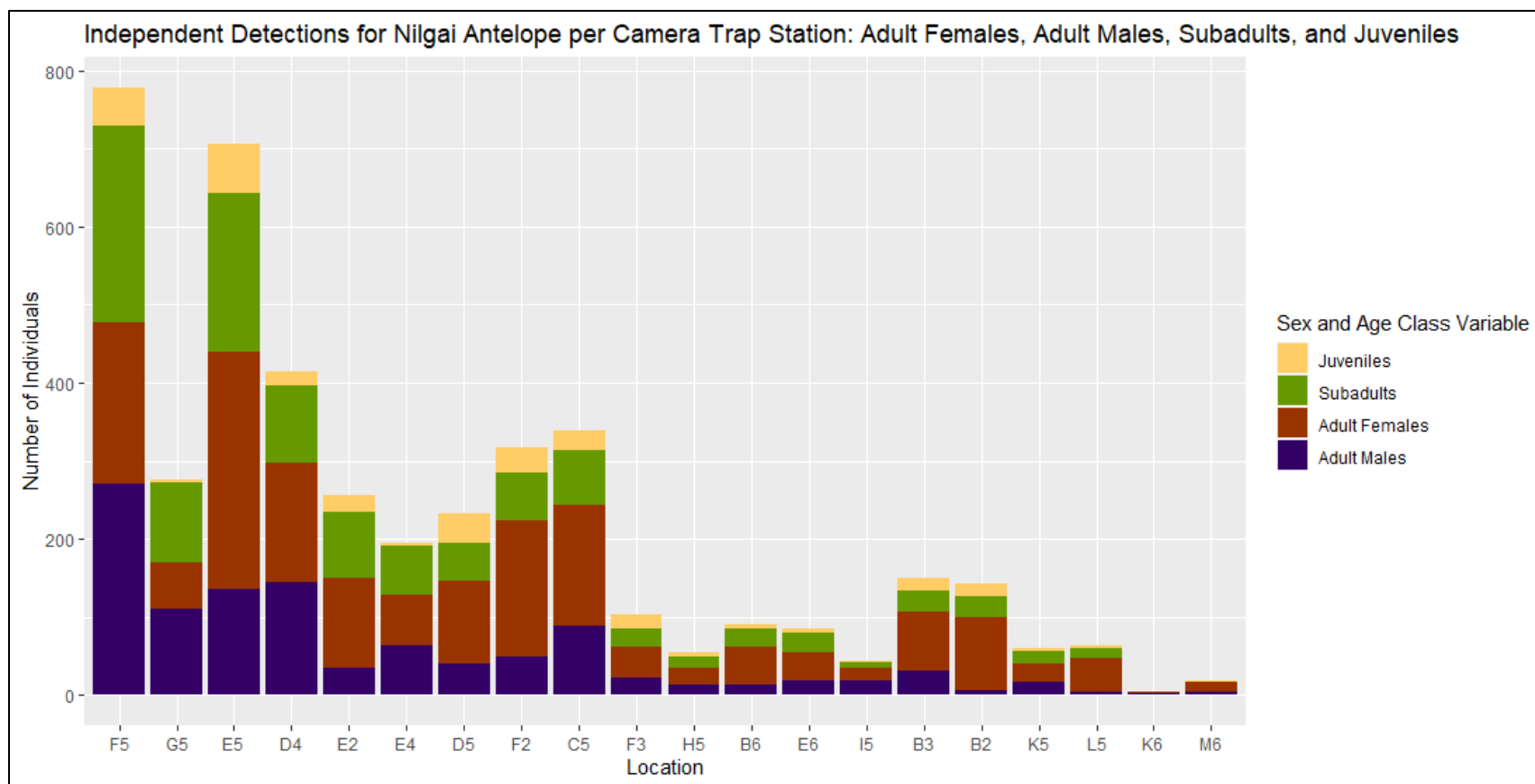


Figure C-20. Independent detections for nilgai antelope per camera trap station: Adult females, adult males, subadults, and juveniles.

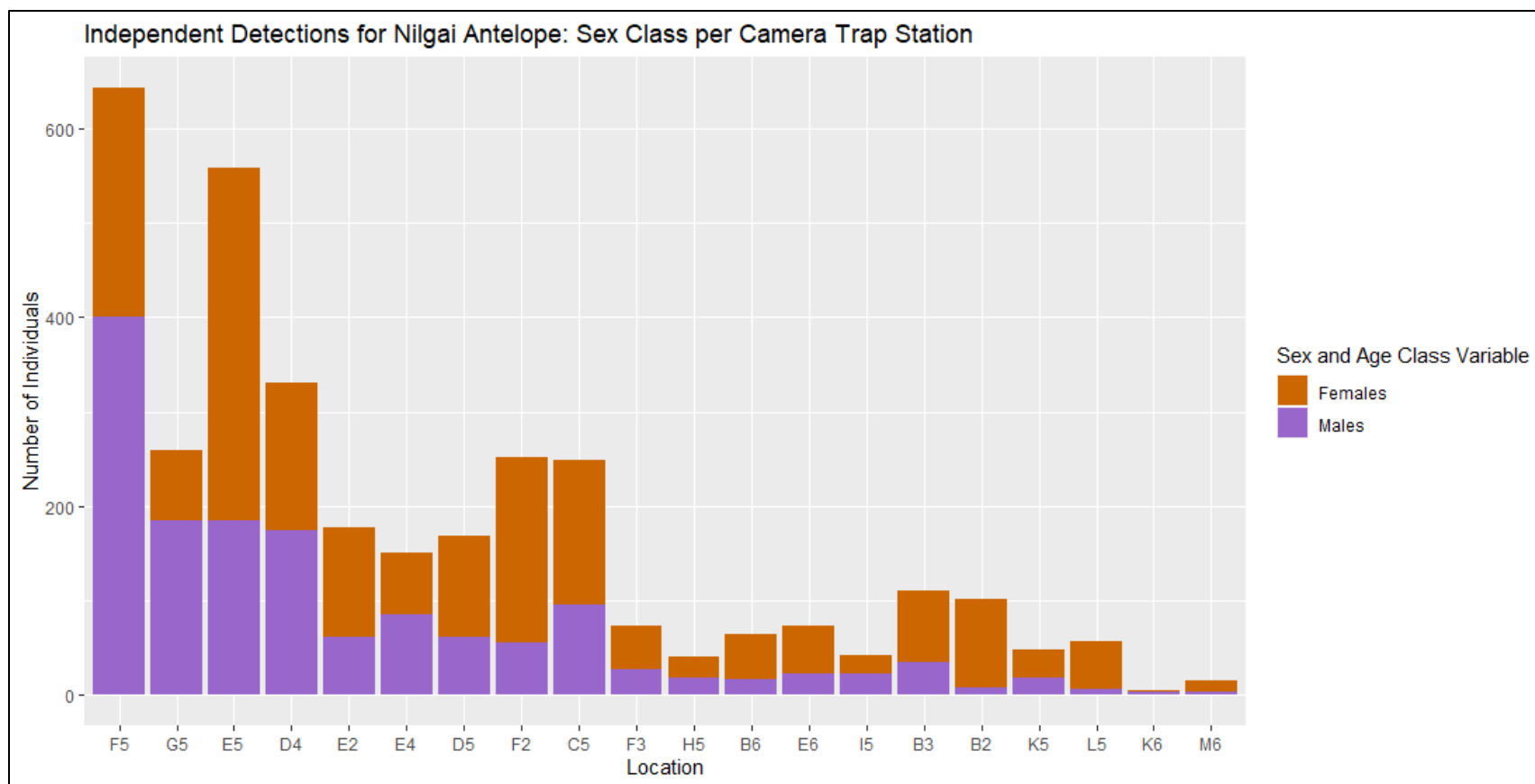


Figure C-21. Independent detections for nilgai antelope: Sex class per camera trap station.

Latrine Site Stations

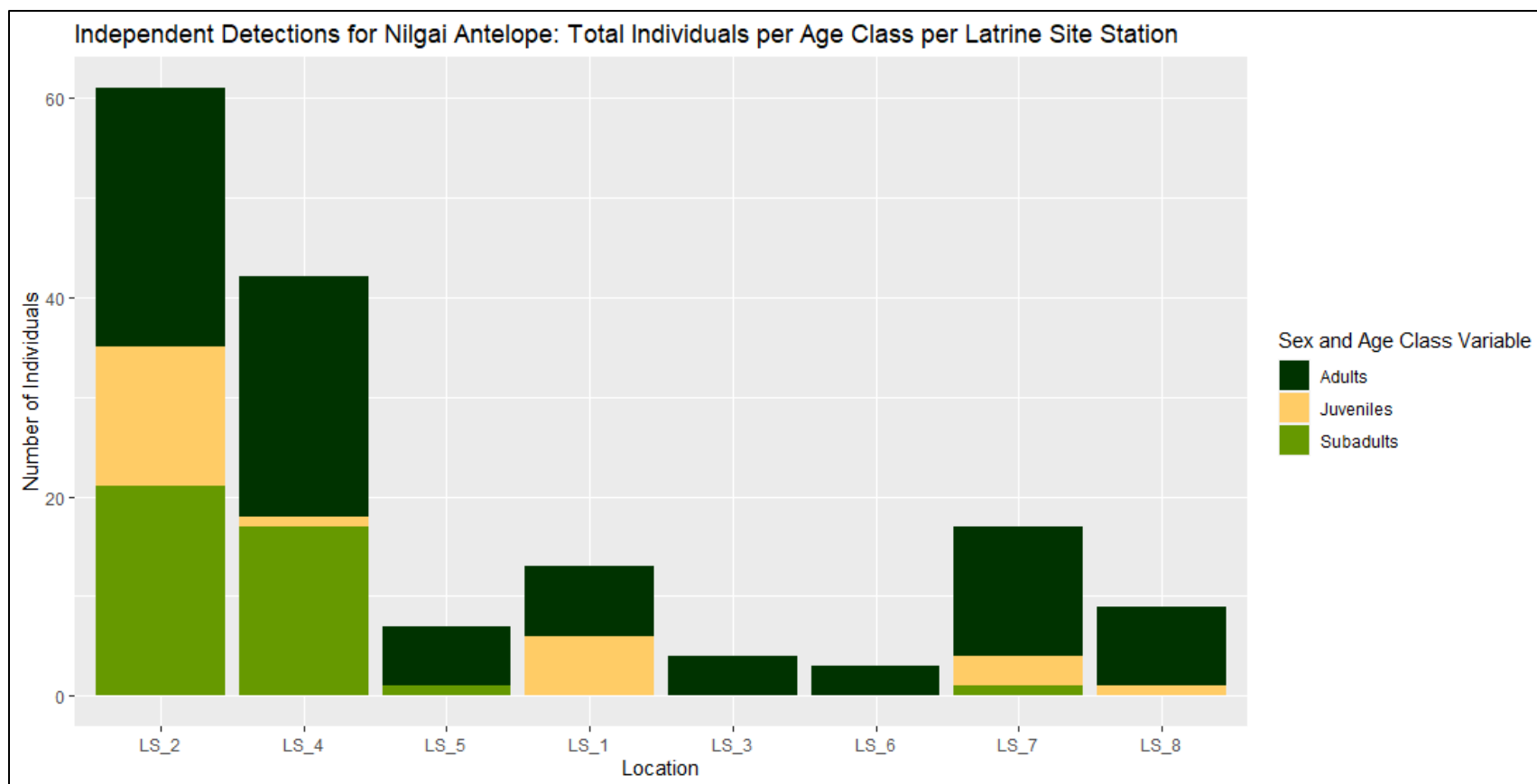


Figure C-22. Independent detections for nilgai antelope: Total individuals per age class per latrine site station.

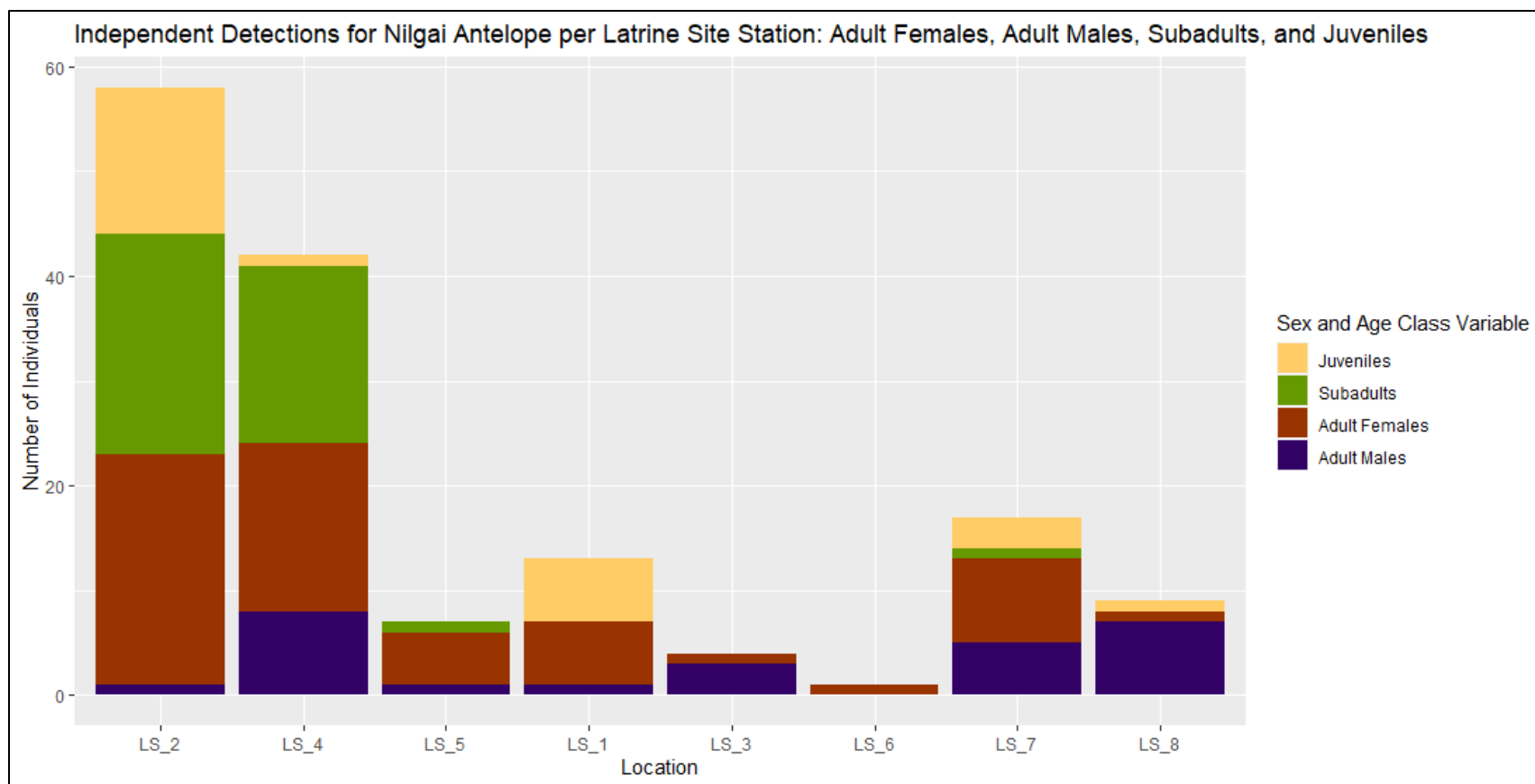


Figure C-23. Independent detections for nilgai antelope per latrine site station: Adults females, adult males, subadults, and juveniles.

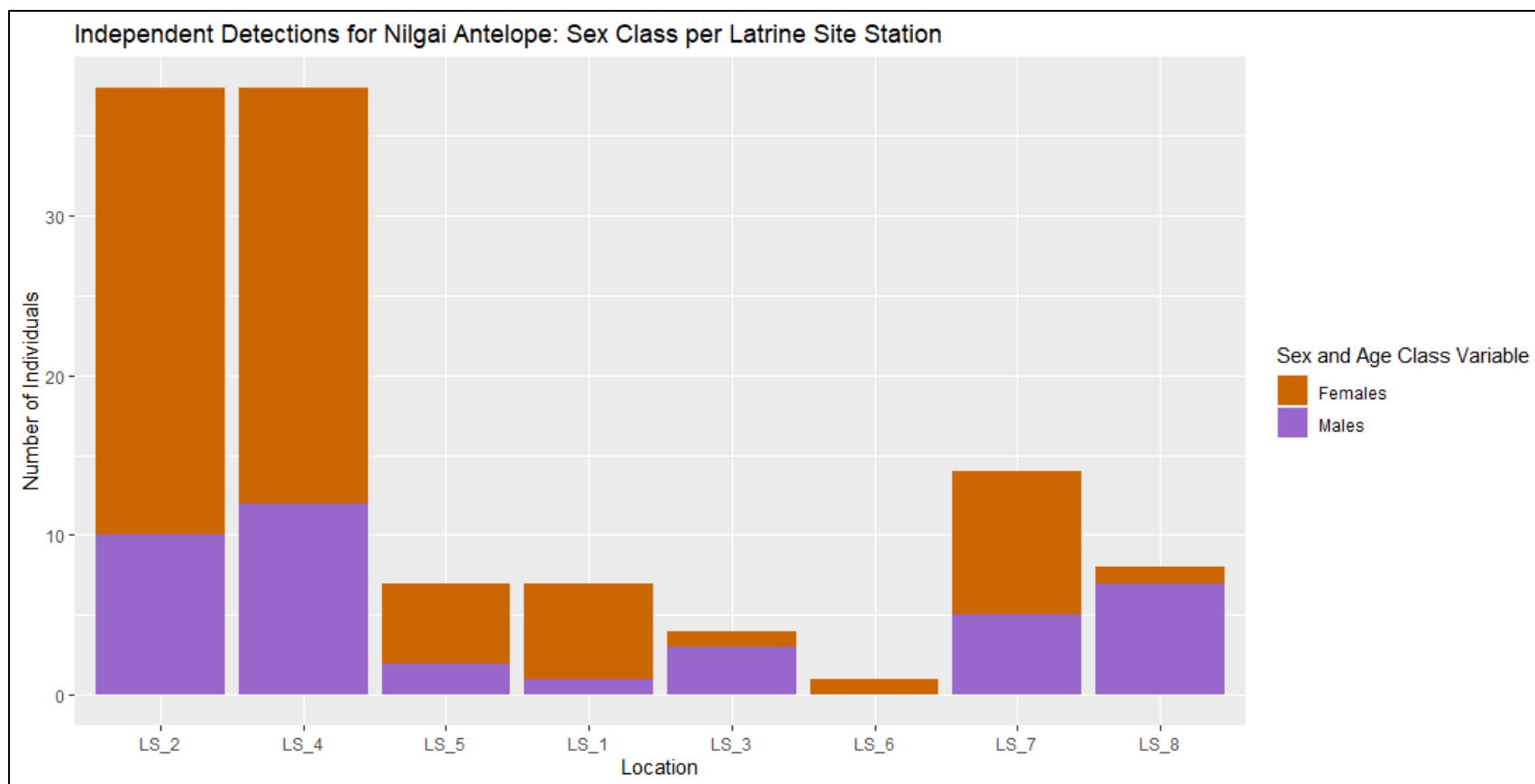


Figure C-24. Independent detections for nilgai antelope: sex class per latrine site station.

Time Series: All Variables Summarized per CTS Site

Per each Camera Trap Station, a daily summary of each analyzed variable (adults, adult females, adult males, males, females, subadults, and juveniles) was calculated to illustrate how a given variable fluctuated throughout the duration of the study (Figures C-25 to C-44). Time series analysis allows for interpretation of trends over time and patterns of use across data collection sites within the study area.

Camera Trap Stations

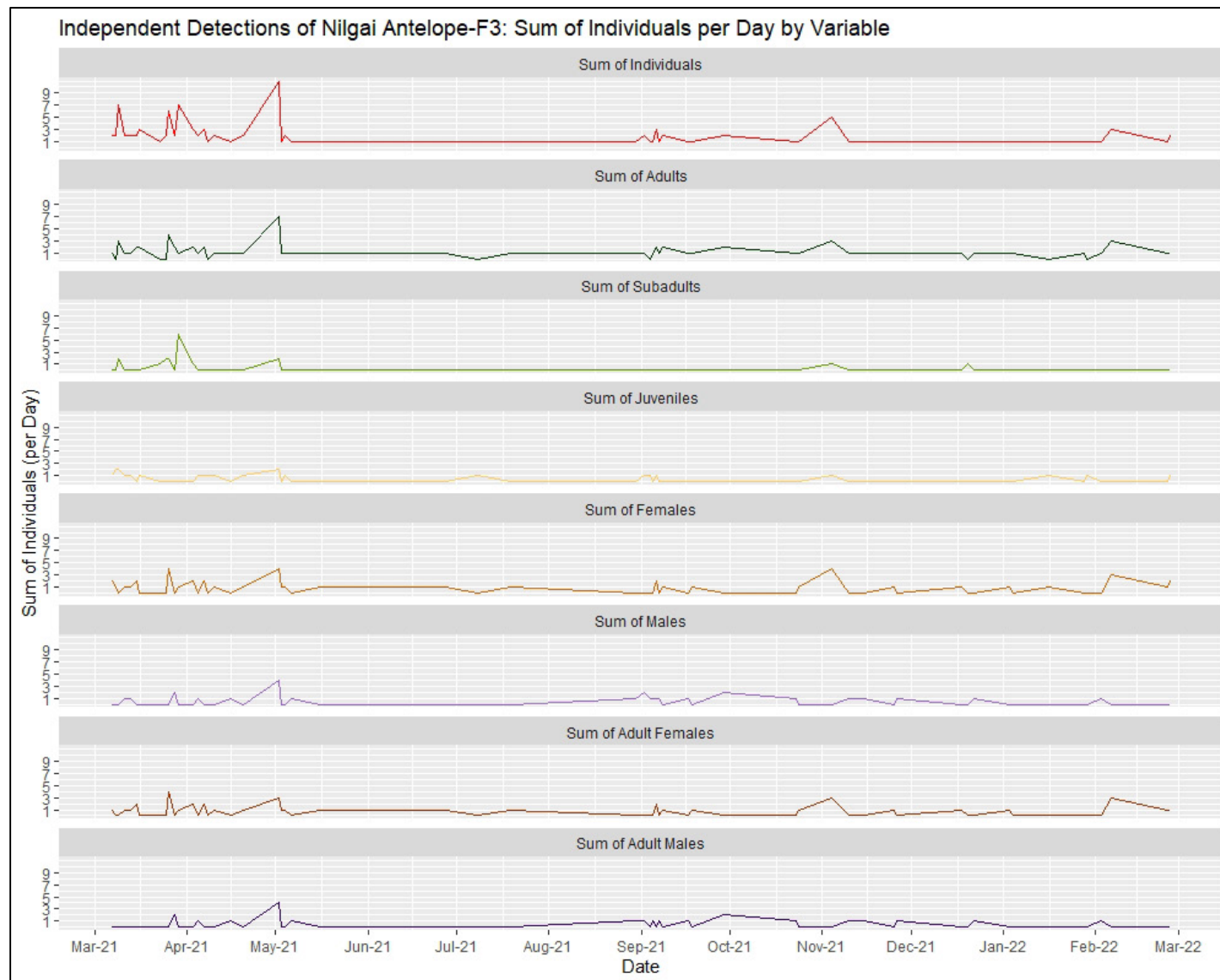


Figure C-25. Independent detections of nilgai antelope-F3: Sum of individuals per day by variable.

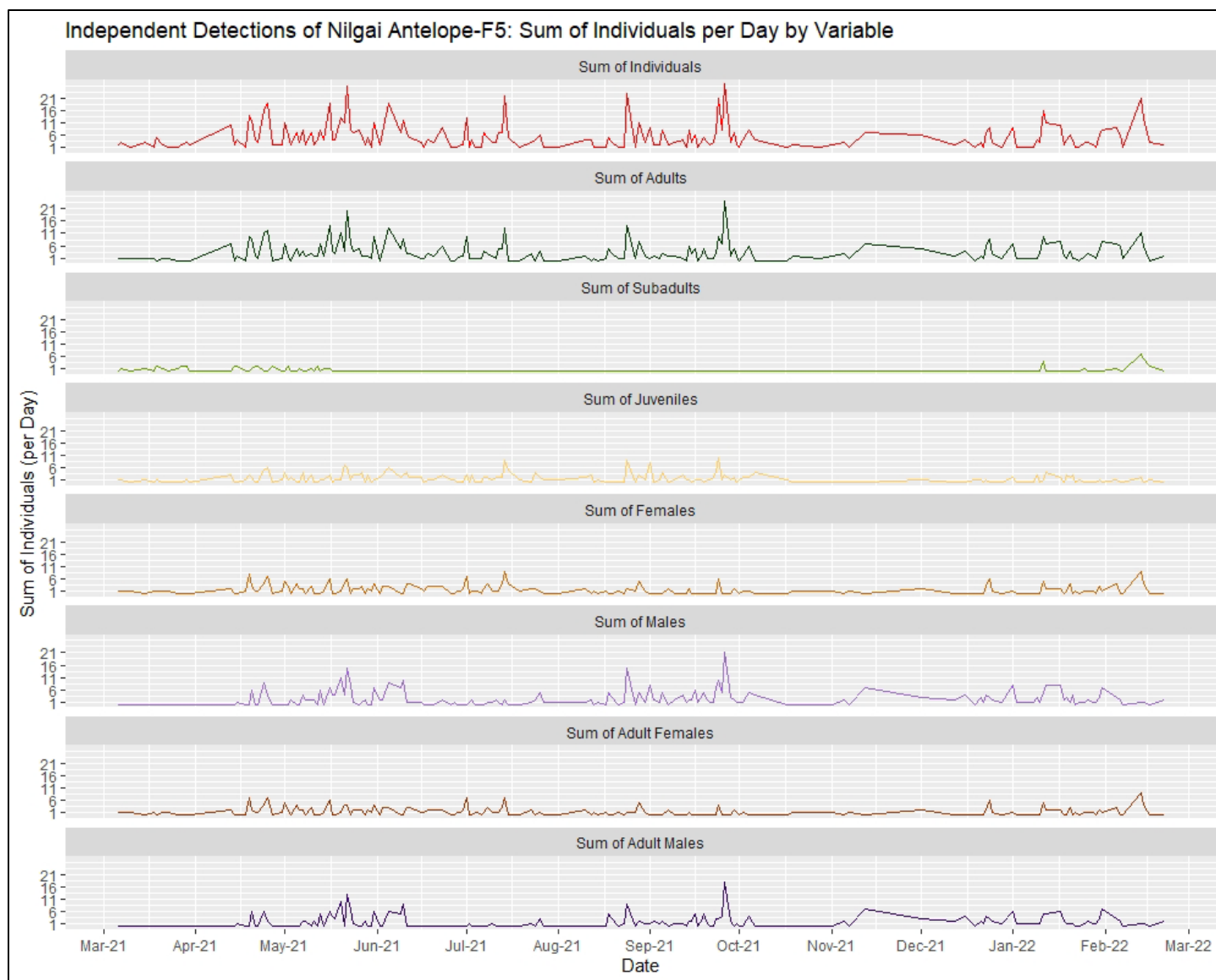


Figure C-26. Independent detections of nilgai antelope-F5: Sum of individuals per day by variable.

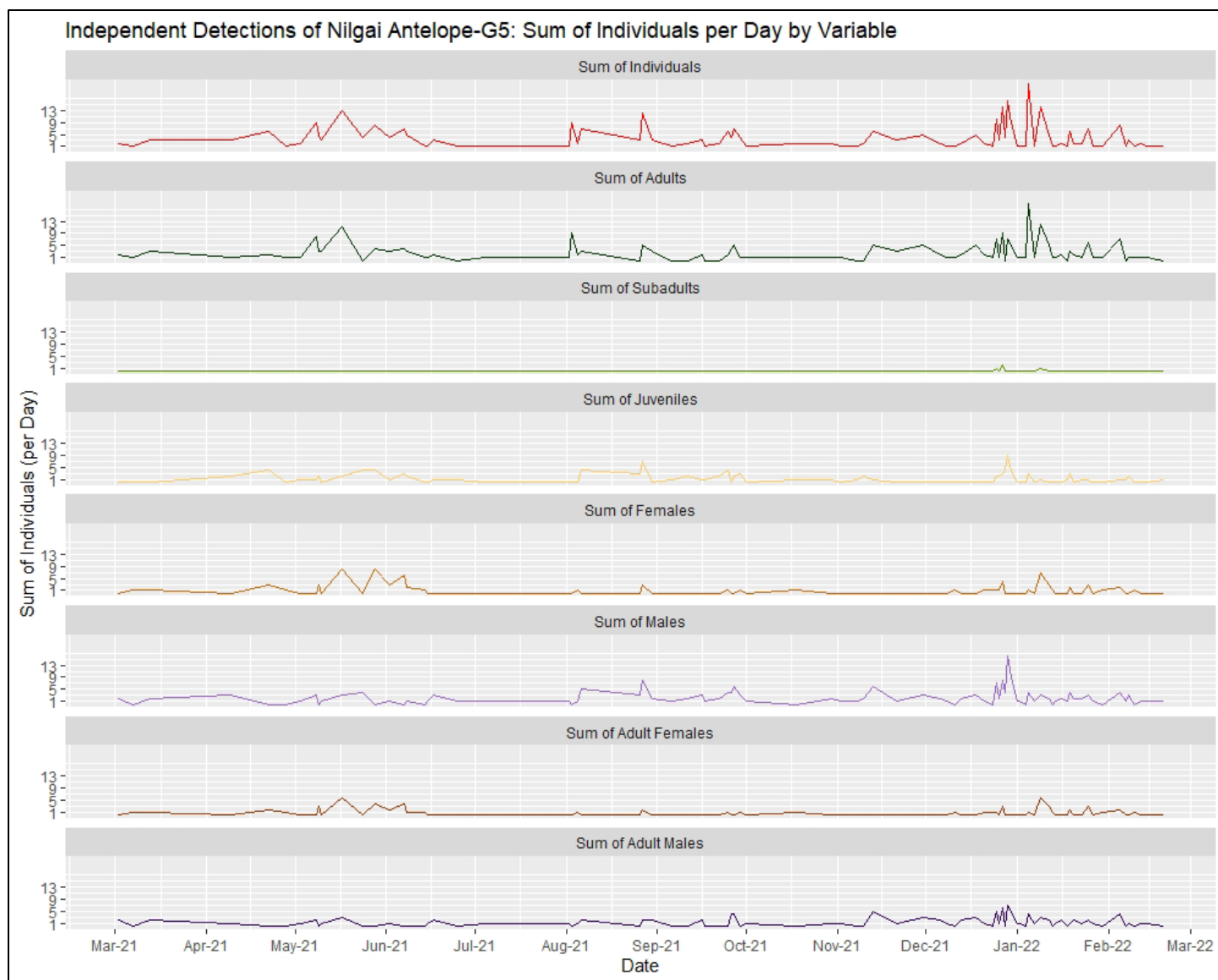


Figure C-27. Independent detections of nilgai antelope-G5: Sum of individuals per day by variable.

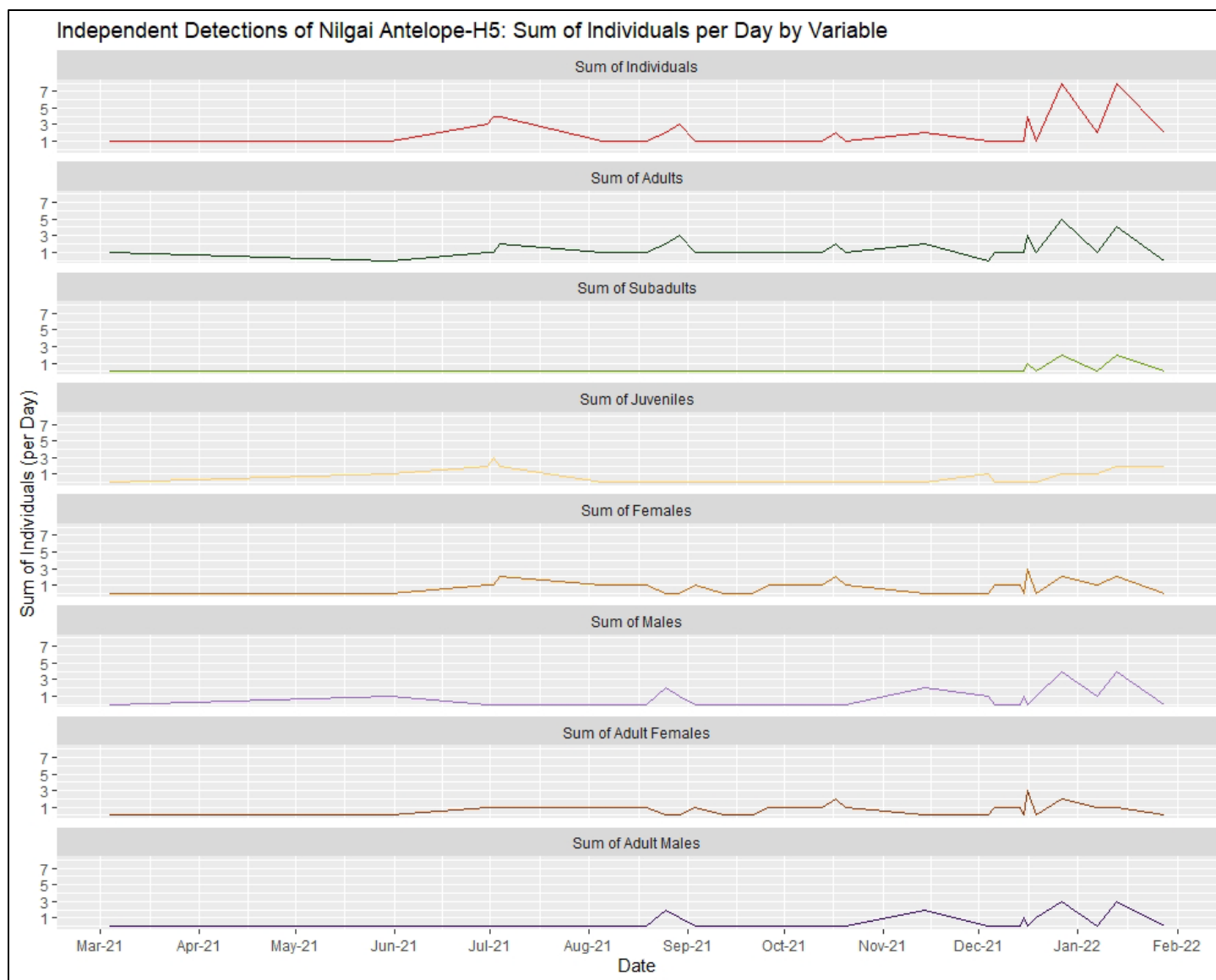


Figure C-28. Independent detections of nilgai antelope-H5: Sum of individuals per day by variable.

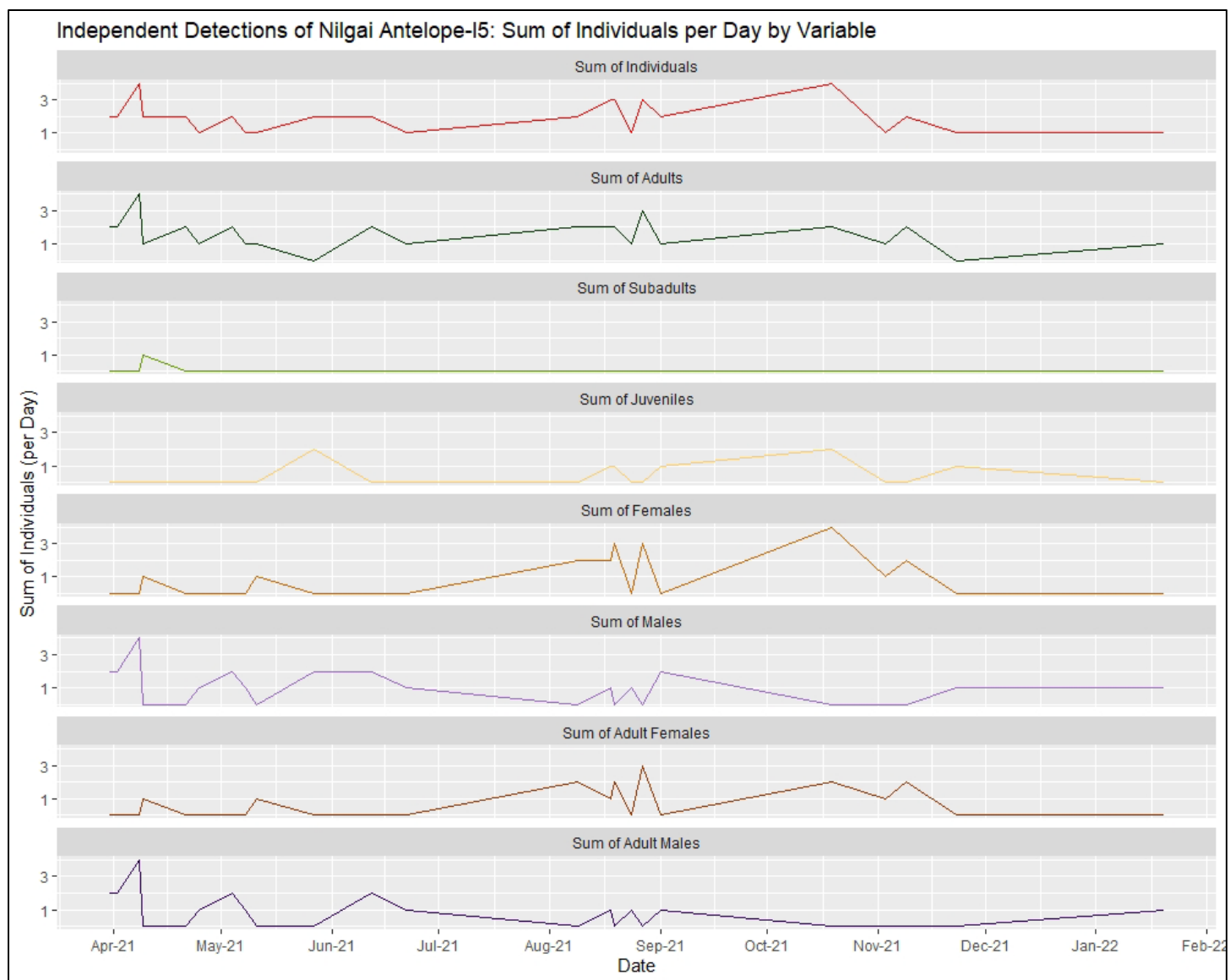


Figure C-29. Independent detections of nilgai antelope-I5: Sum of individuals per day by variable.

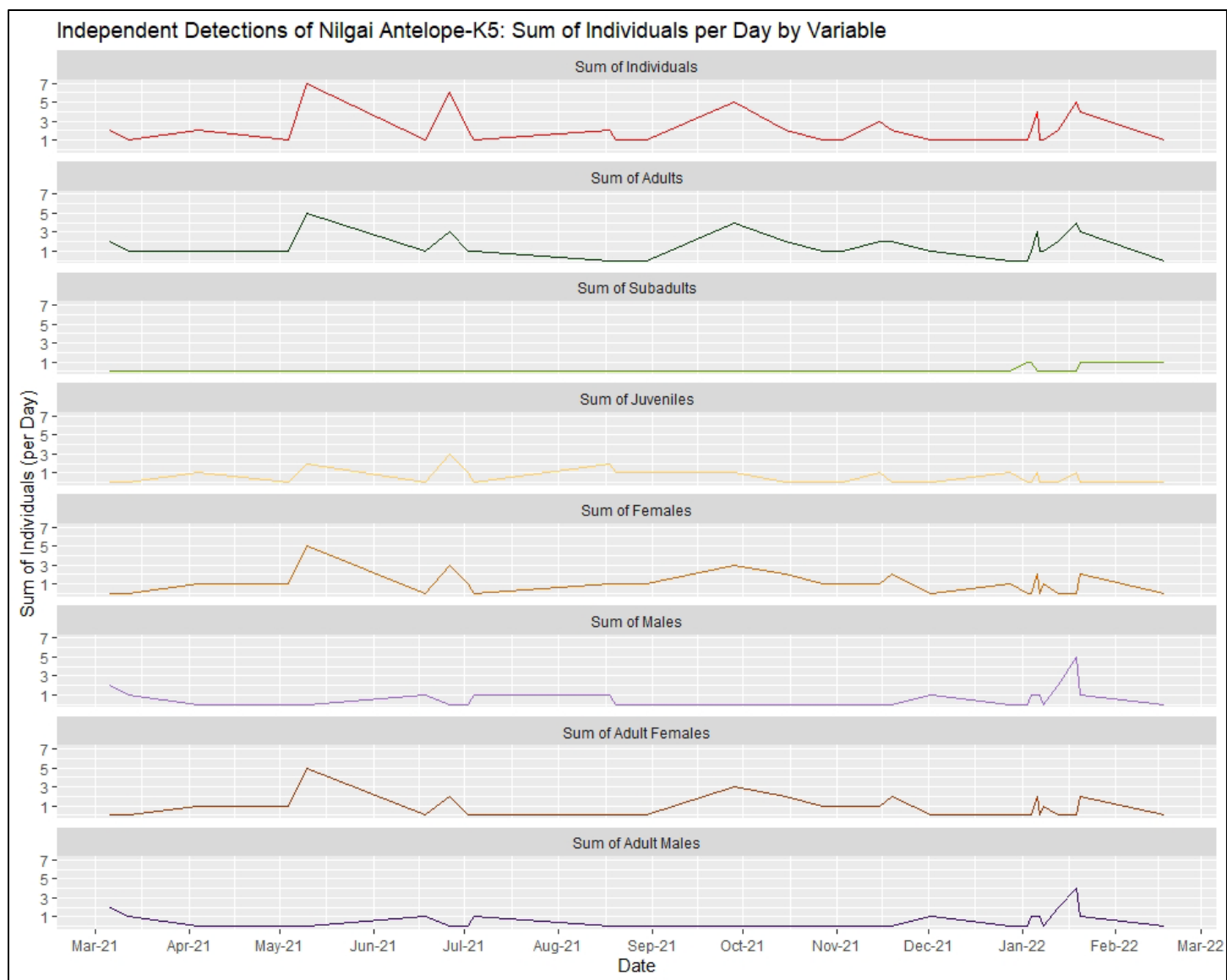


Figure C-30. Independent detections of nilgai antelope-K5: Sum of individuals per day by variable.

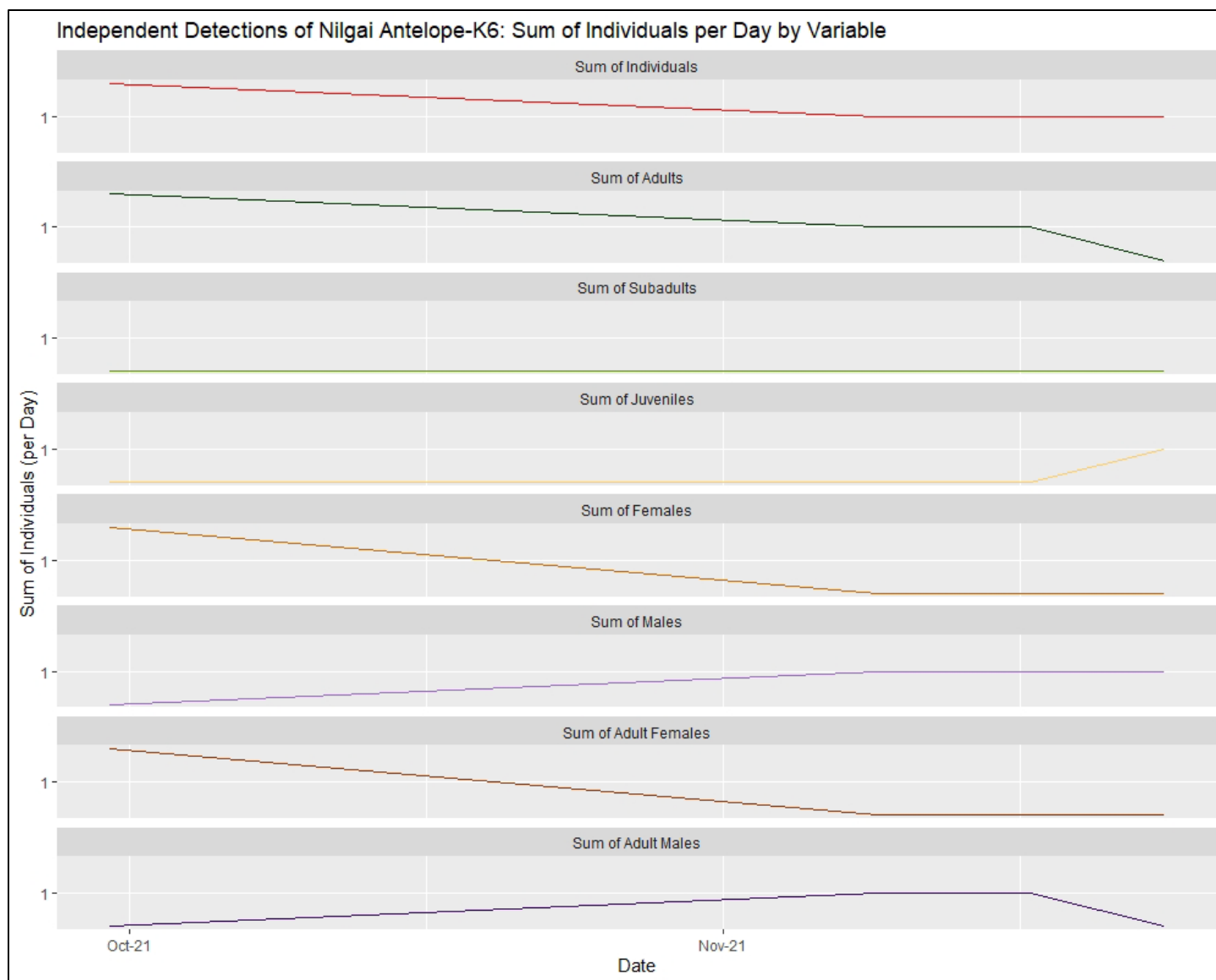


Figure C-31. Independent detections of nilgai antelope-K6: Sum of individuals per day by variable.

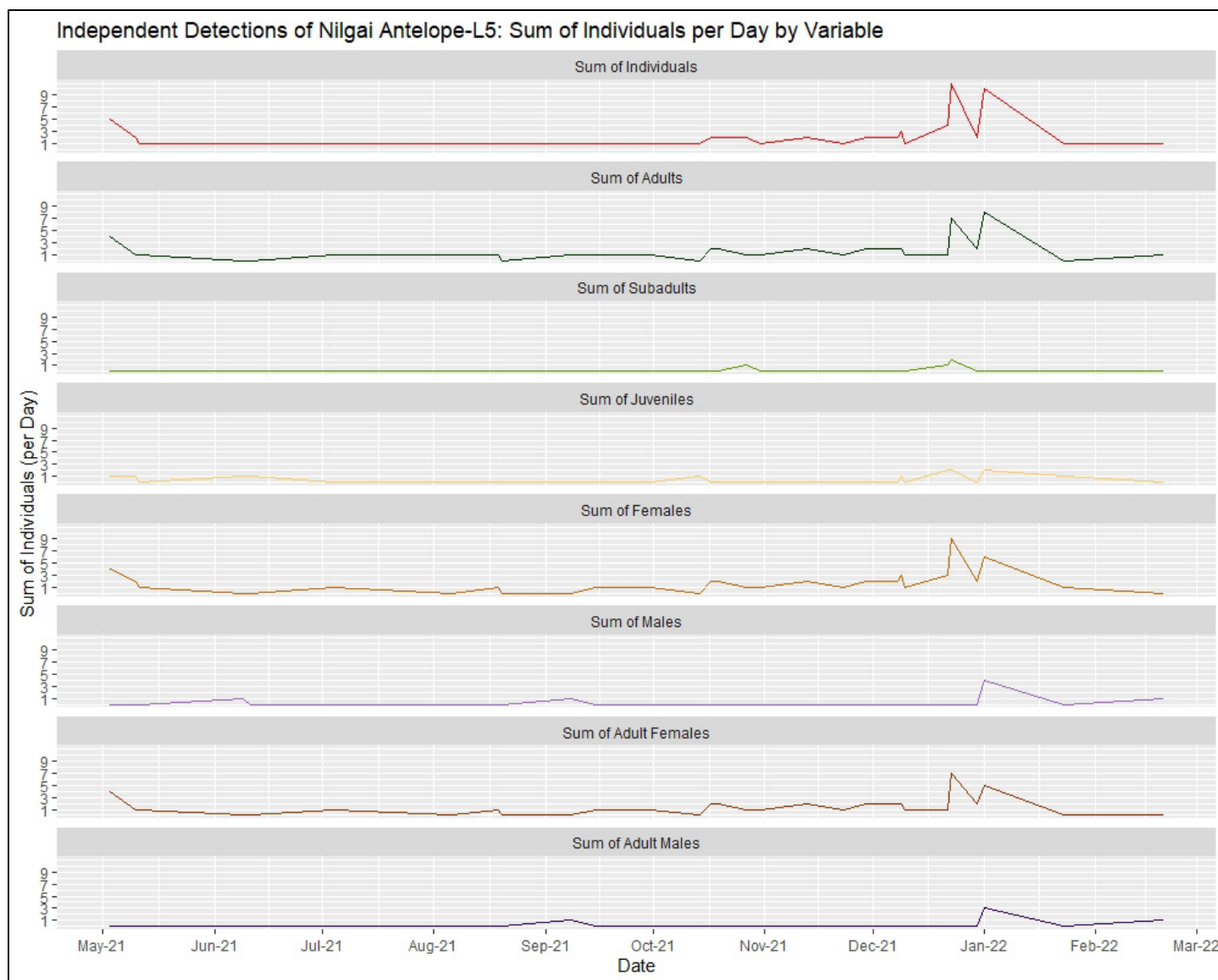


Figure C-32. Independent detections of nilgai antelope-L5: Sum of individuals per day by variable.

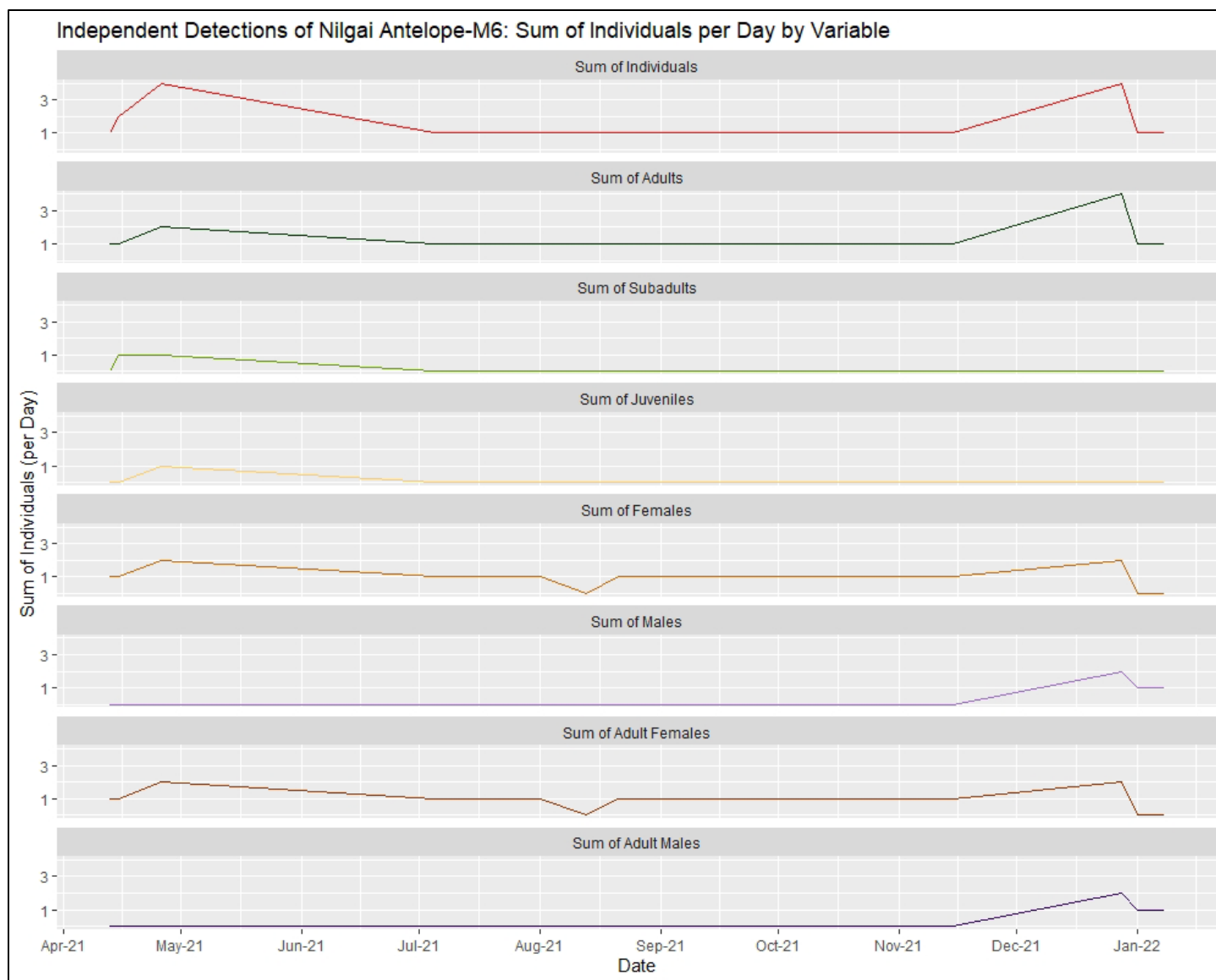


Figure C-33. Independent detections of nilgai antelope-M6: Sum of individuals per day by variable.

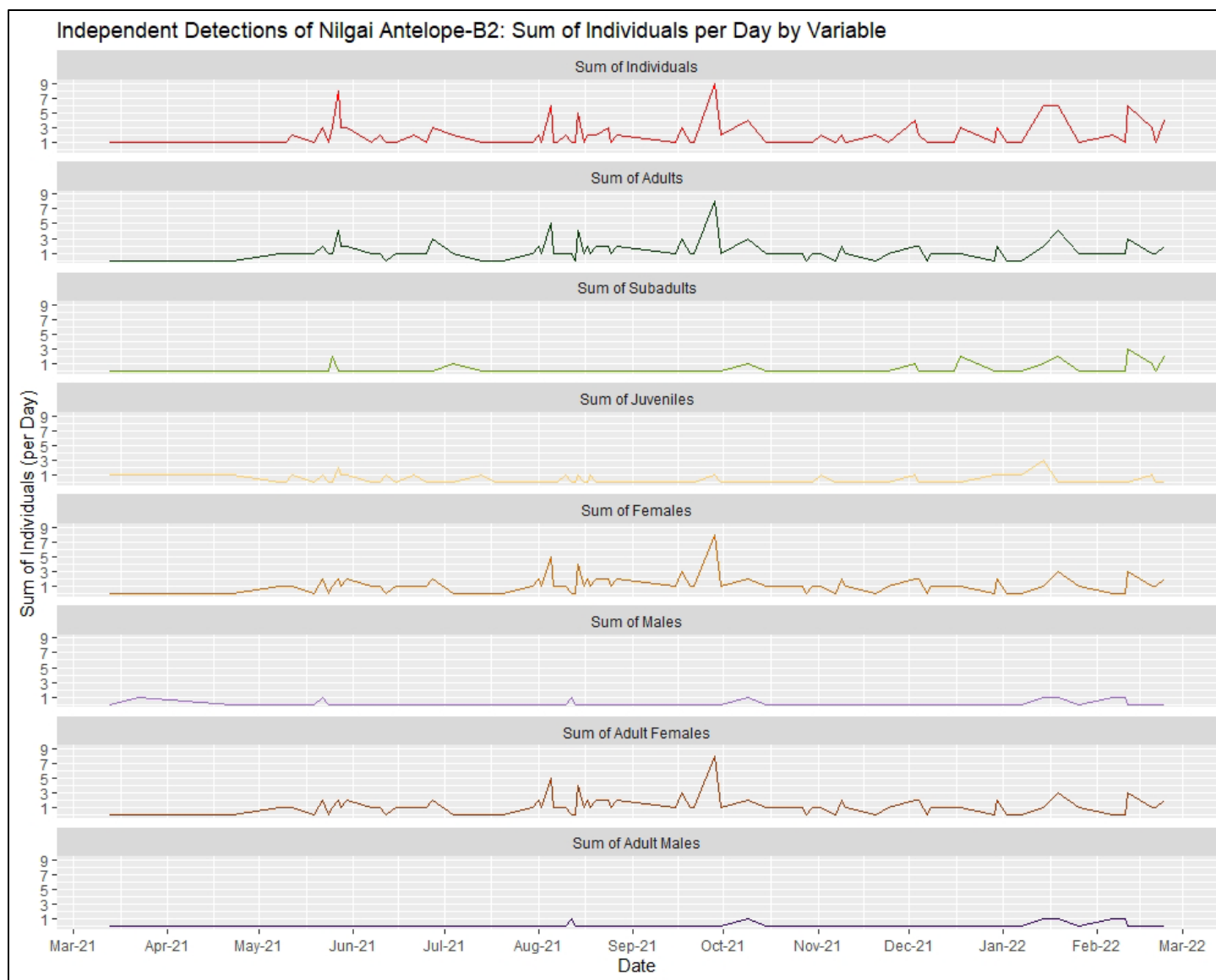


Figure C-34. Independent detections of nilgai antelope-B2: Sum of individuals per day by variable.

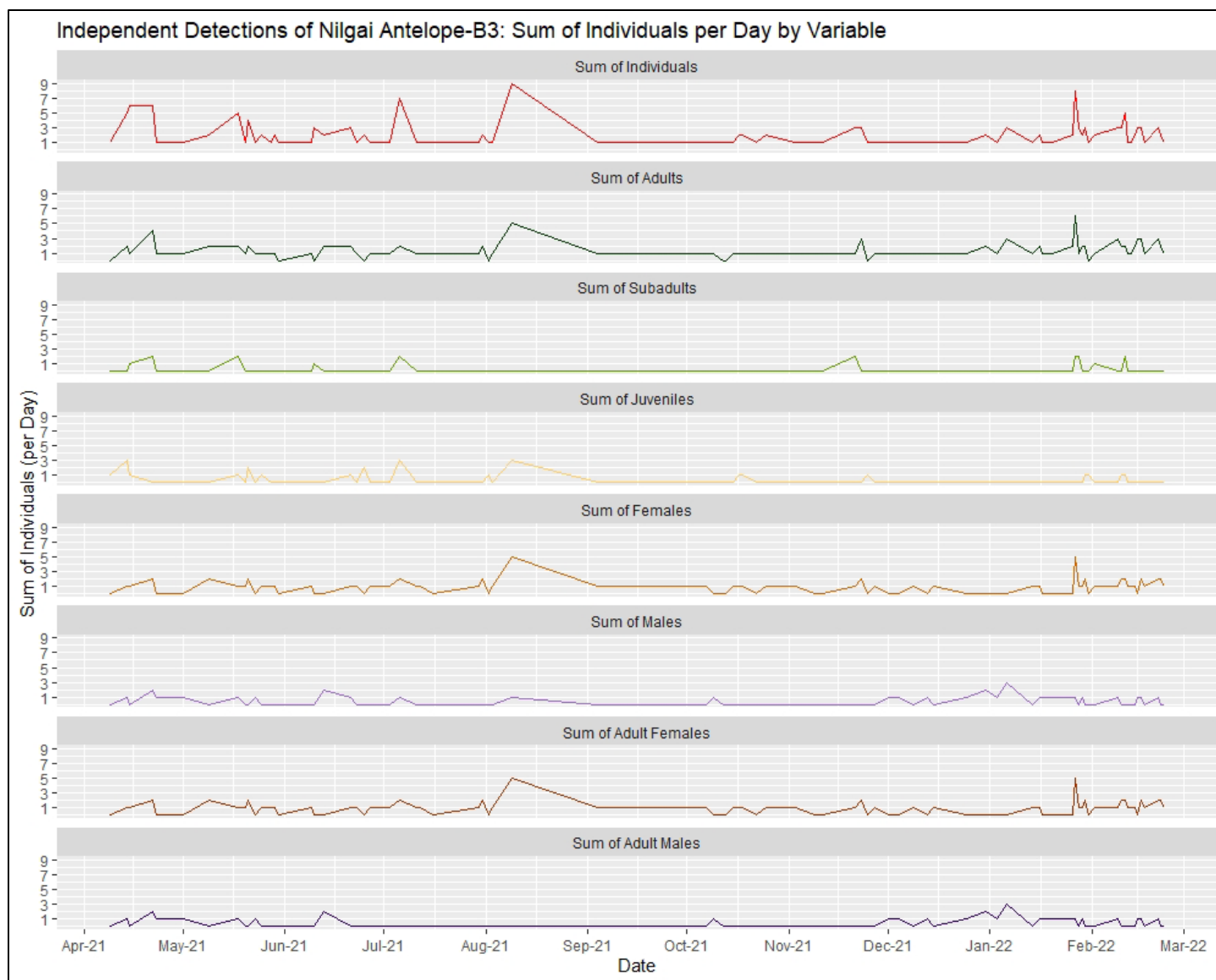


Figure C-35. Independent detections of nilgai antelope-B3: Sum of individuals per day by variable.

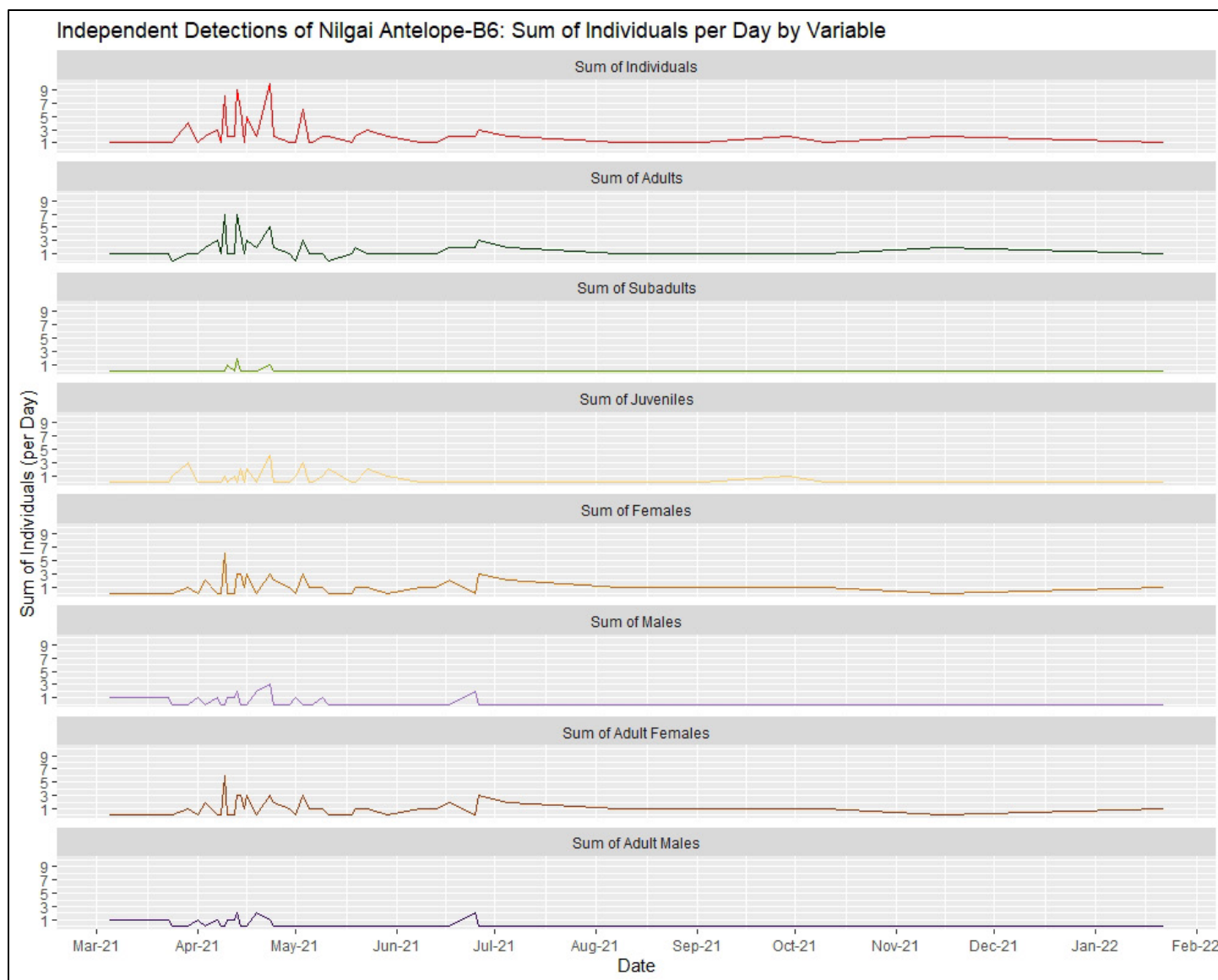


Figure C-36. Independent detections of nilgai antelope-B6: Sum of individuals per day by variable.

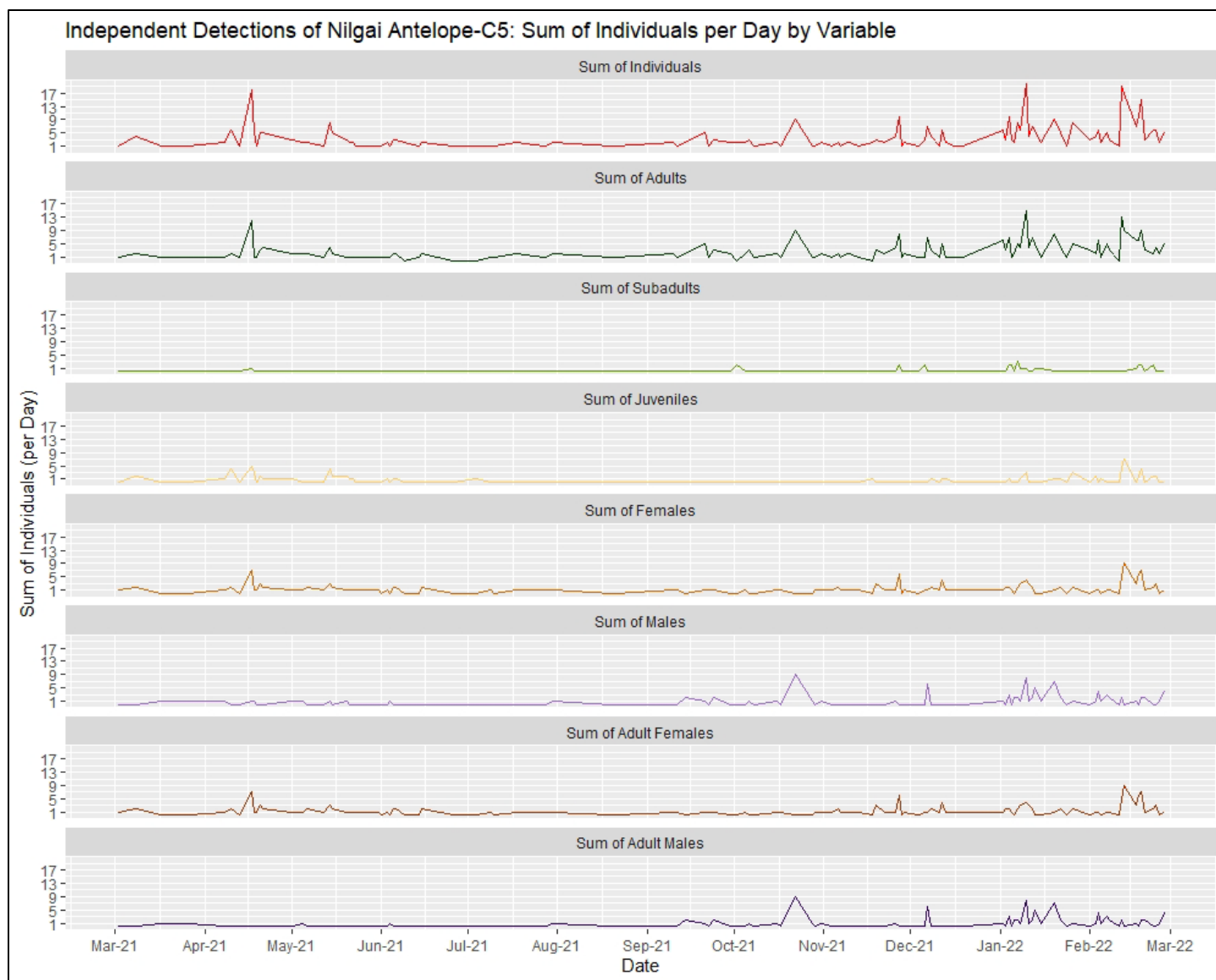


Figure C-37. Independent detections of nilgai antelope-C5: Sum of individuals per day by variable.

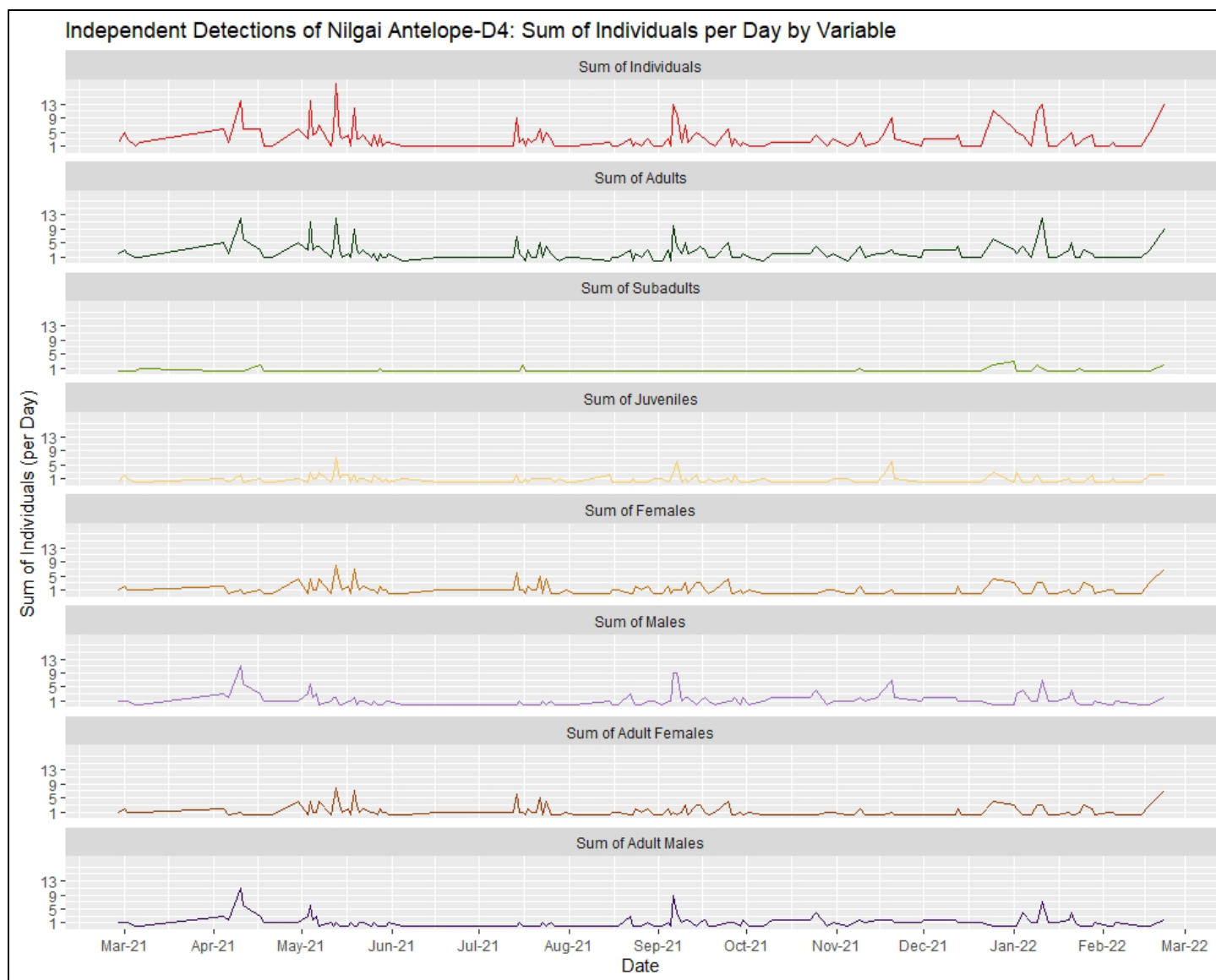


Figure C-38. Independent detections of nilgai antelope-D4: Sum of individuals per day by variable.

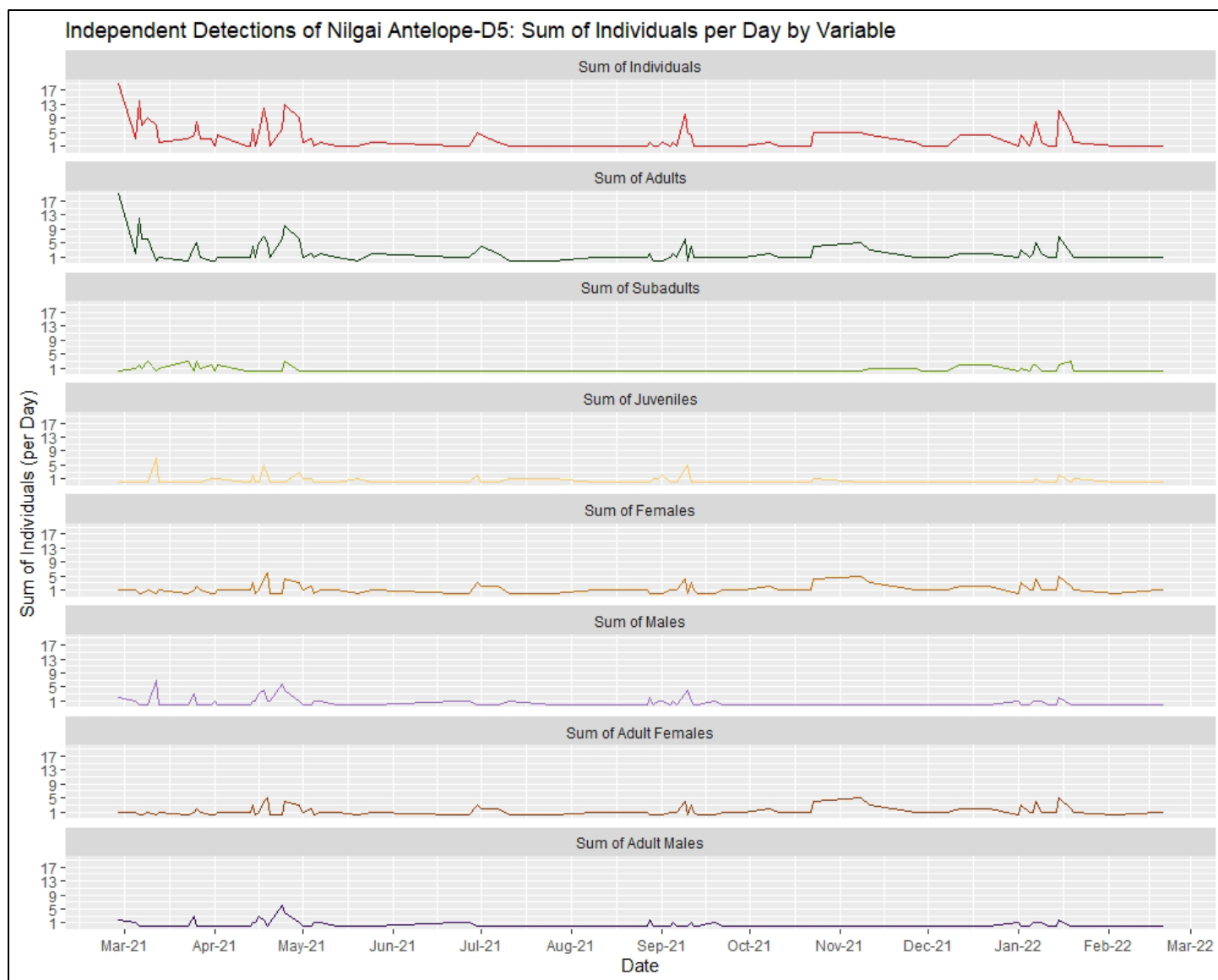


Figure C-39. Independent detections of nilgai antelope-D5: Sum of individuals per day by variable.

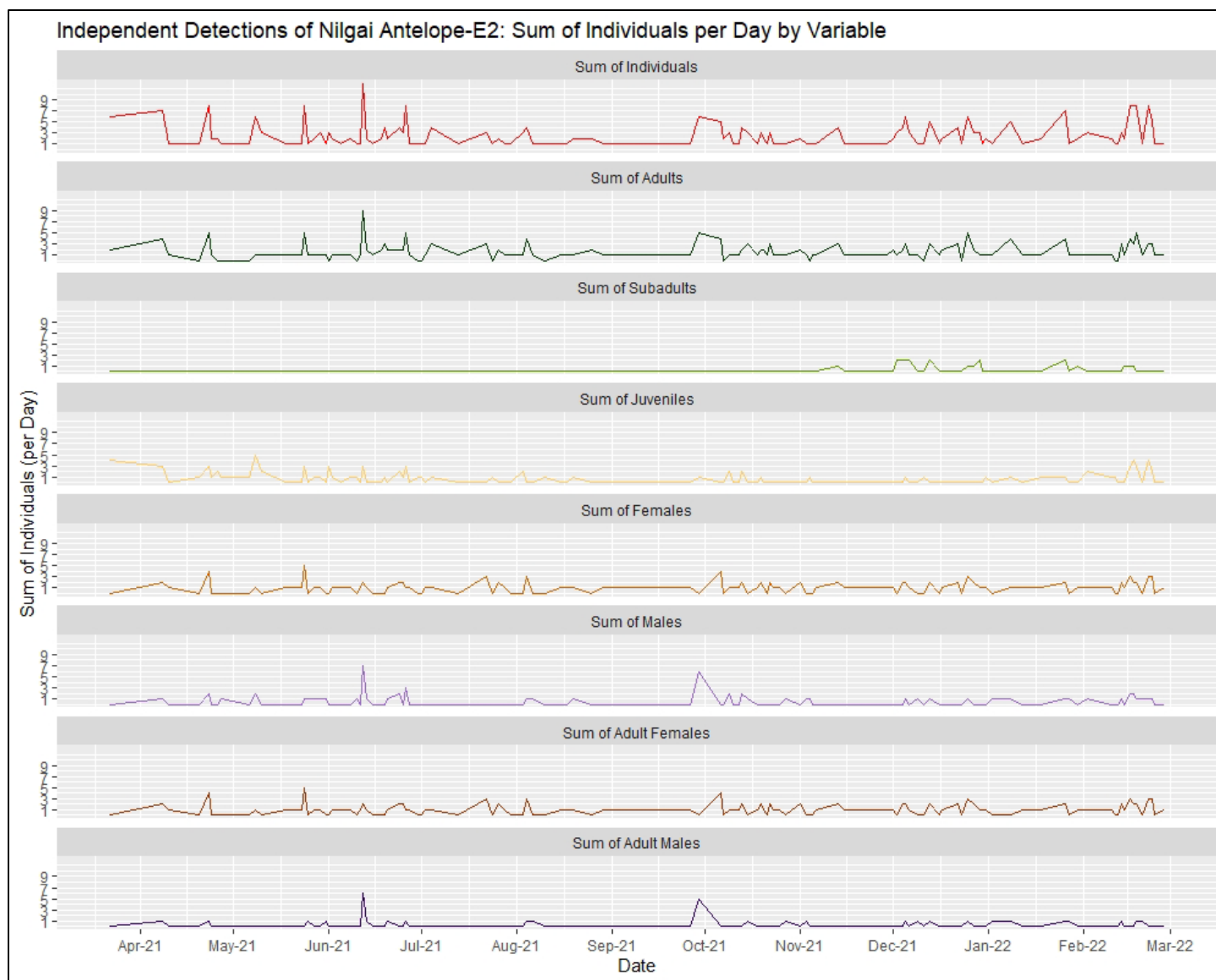


Figure C-40. Independent detections of nilgai antelope-E2: Sum of individuals per day by variable.

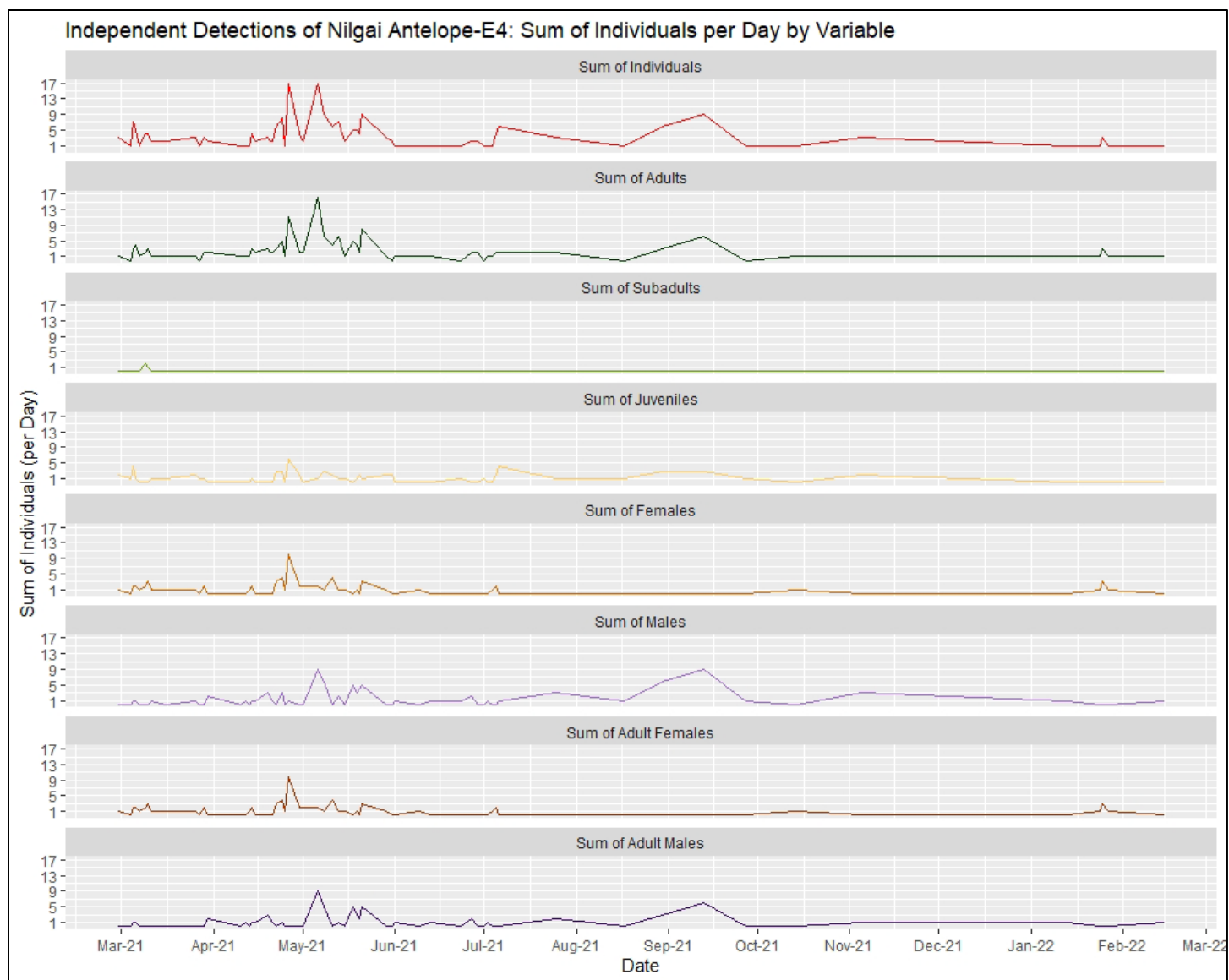


Figure C-41. Independent detections of nilgai antelope-E4: Sum of individuals per day by variable.

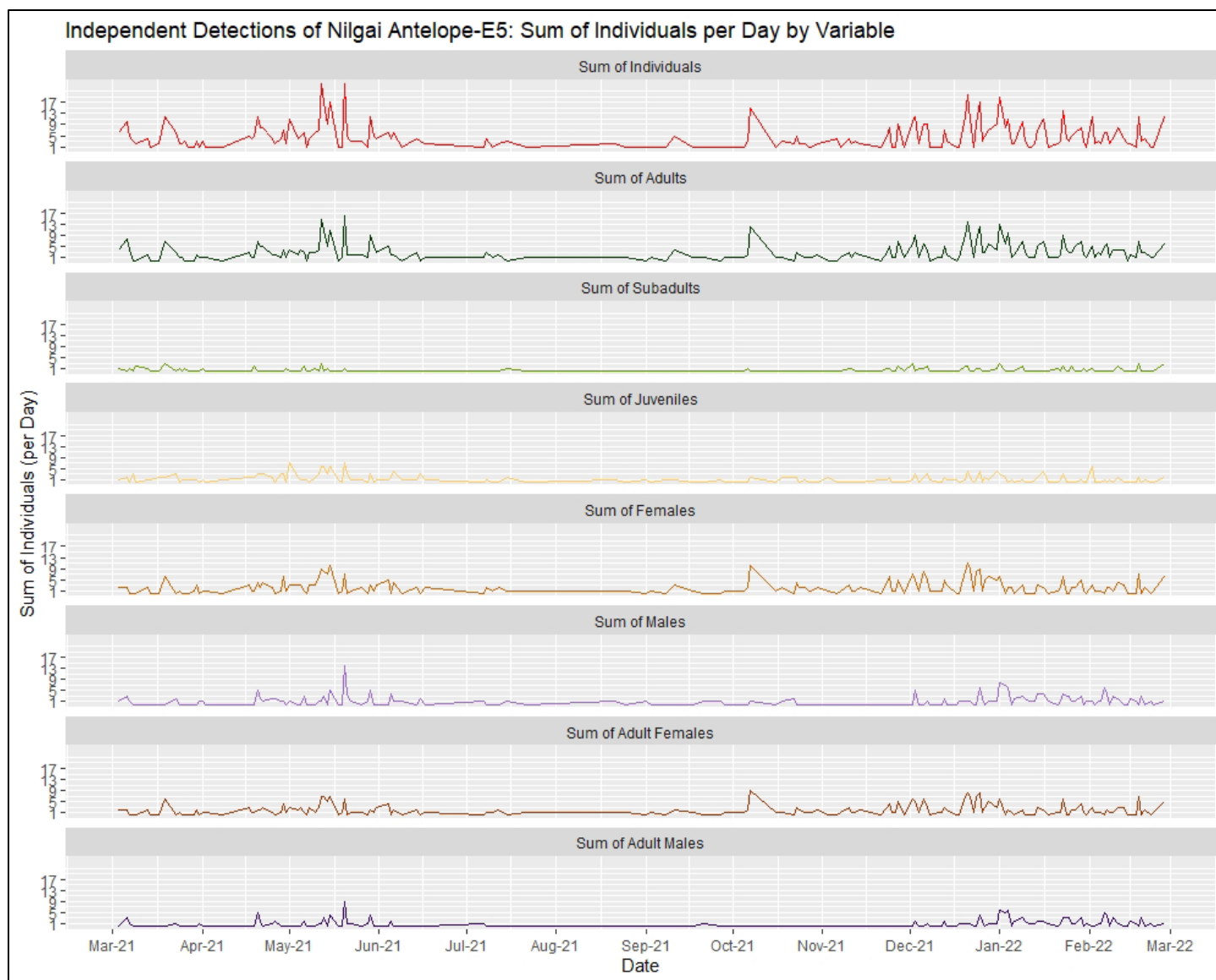


Figure C-42. Independent detections of nilgai antelope-E5: Sum of individuals per day by variable.

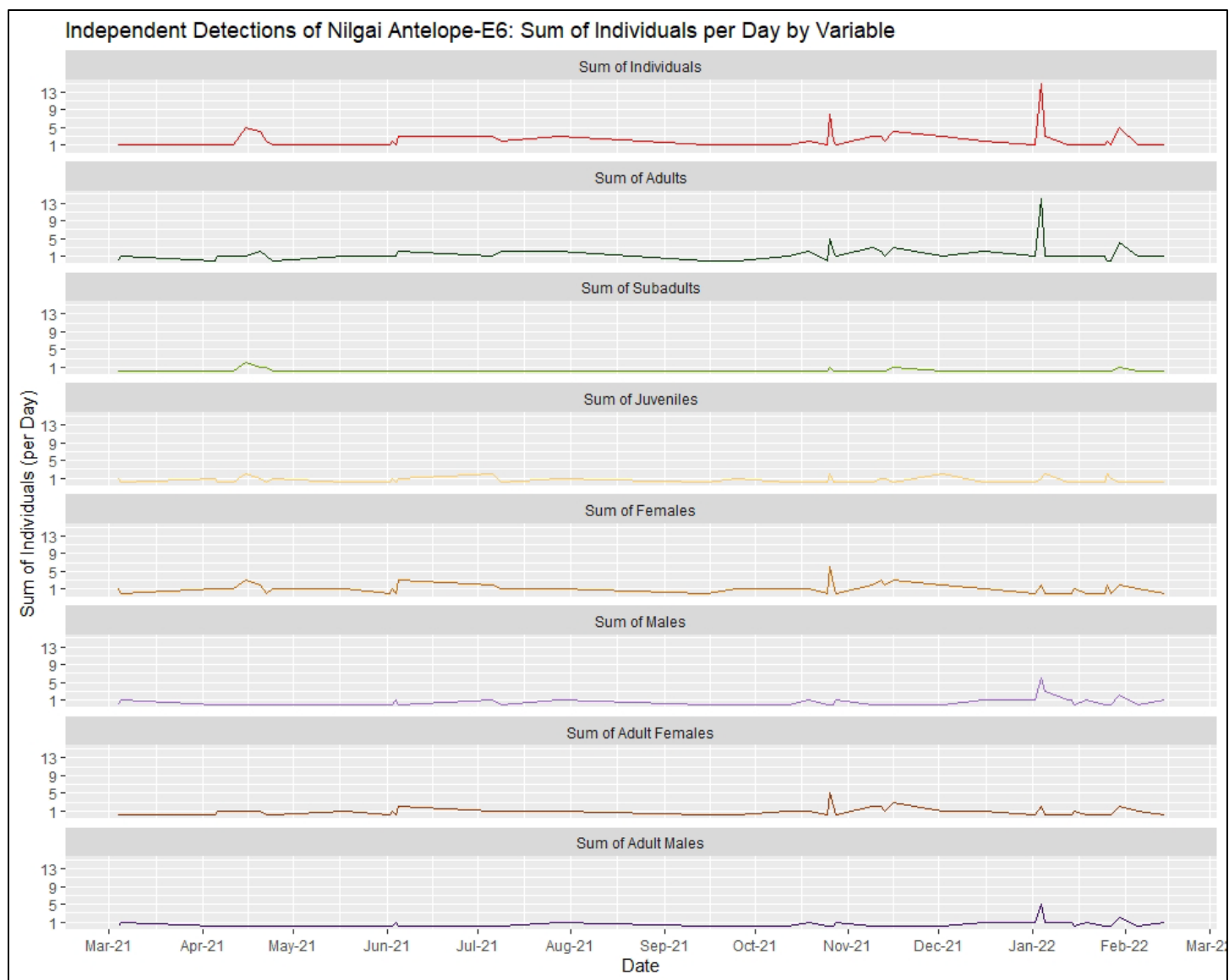


Figure C-43. Independent detections of nilgai antelope-E6: Sum of individuals per day by variable.

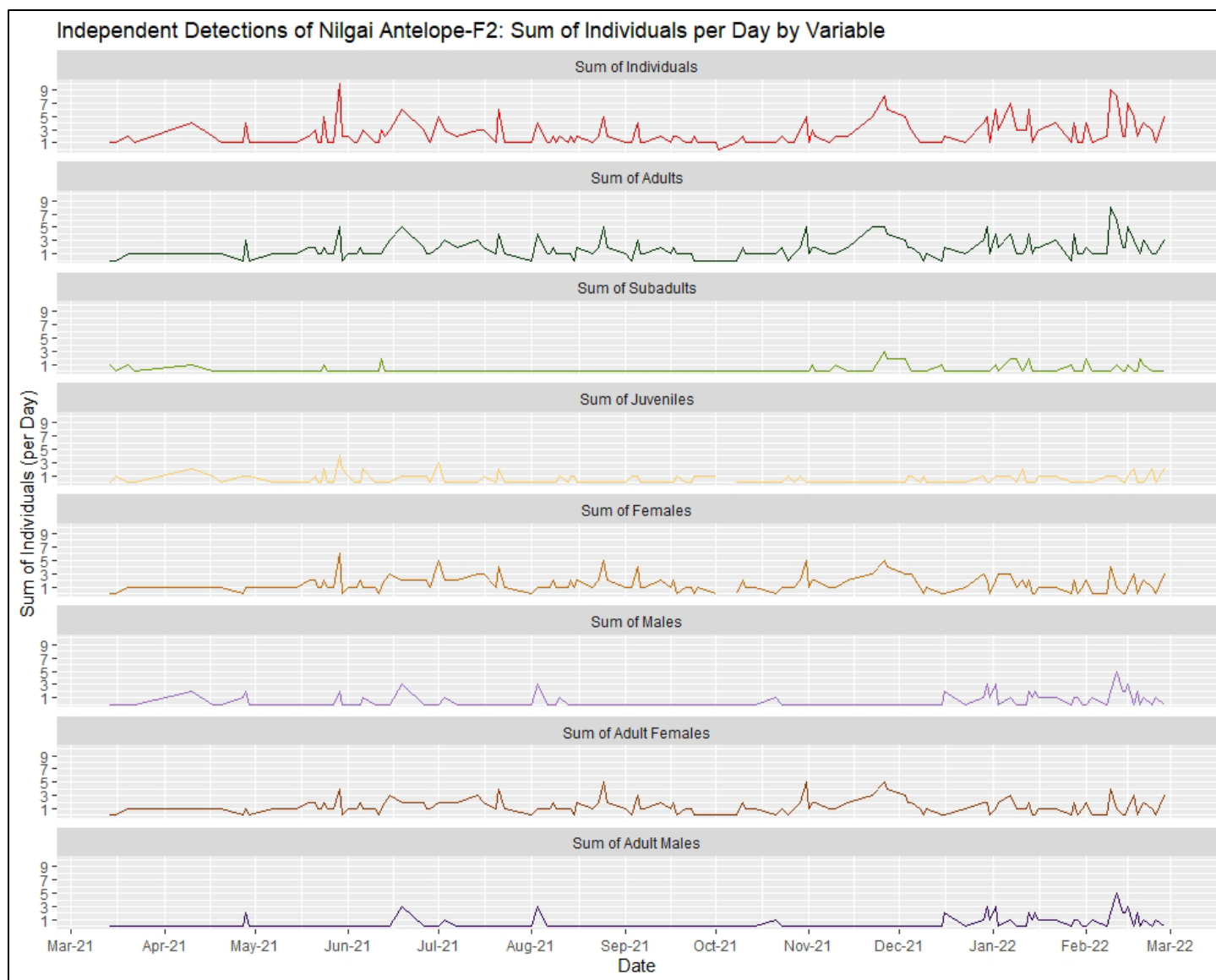


Figure C-44. Independent detections of nilgai antelope-F2: Sum of individuals per day by variable.

Time Series: Daily Summaries per Variable per CTS Sites

Per each variable collected for nilgai antelope (adults, adult females, adult males, subadults, males, females, and juveniles), daily summary data from all Camera Trap Station sites was compiled to reveal patterns throughout the duration of the study at the level of the study area, or the western unit of the Palo Alto Battlefield National Historical Park (Figures C-45 to C-53). This data facilitates visualization of broad trends of movement, activity, and use by nilgai antelope within the study area.

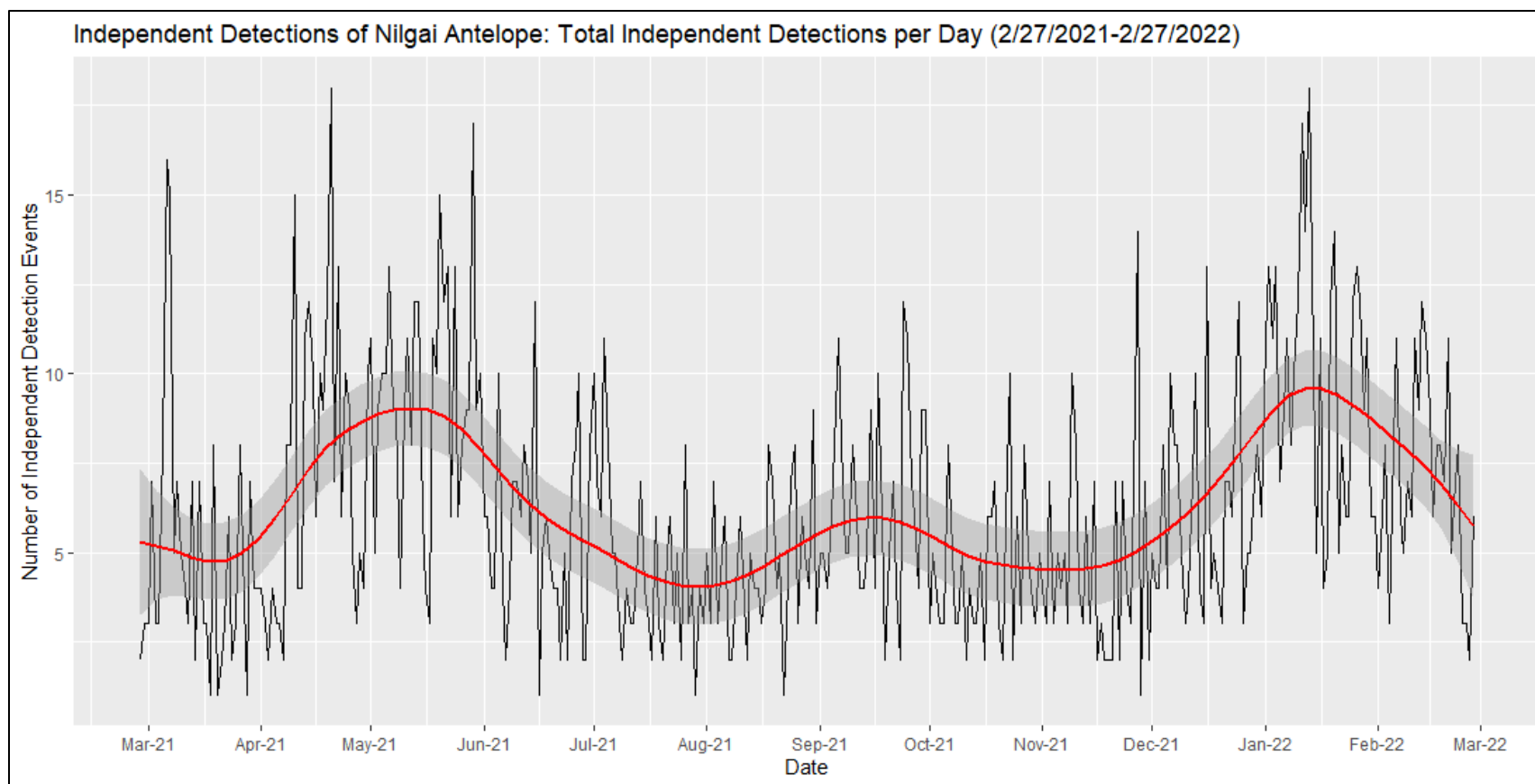


Figure C-45. Independent detections of nilgai antelope: Total independent detections per day (2/27/2021–2/27/2022).

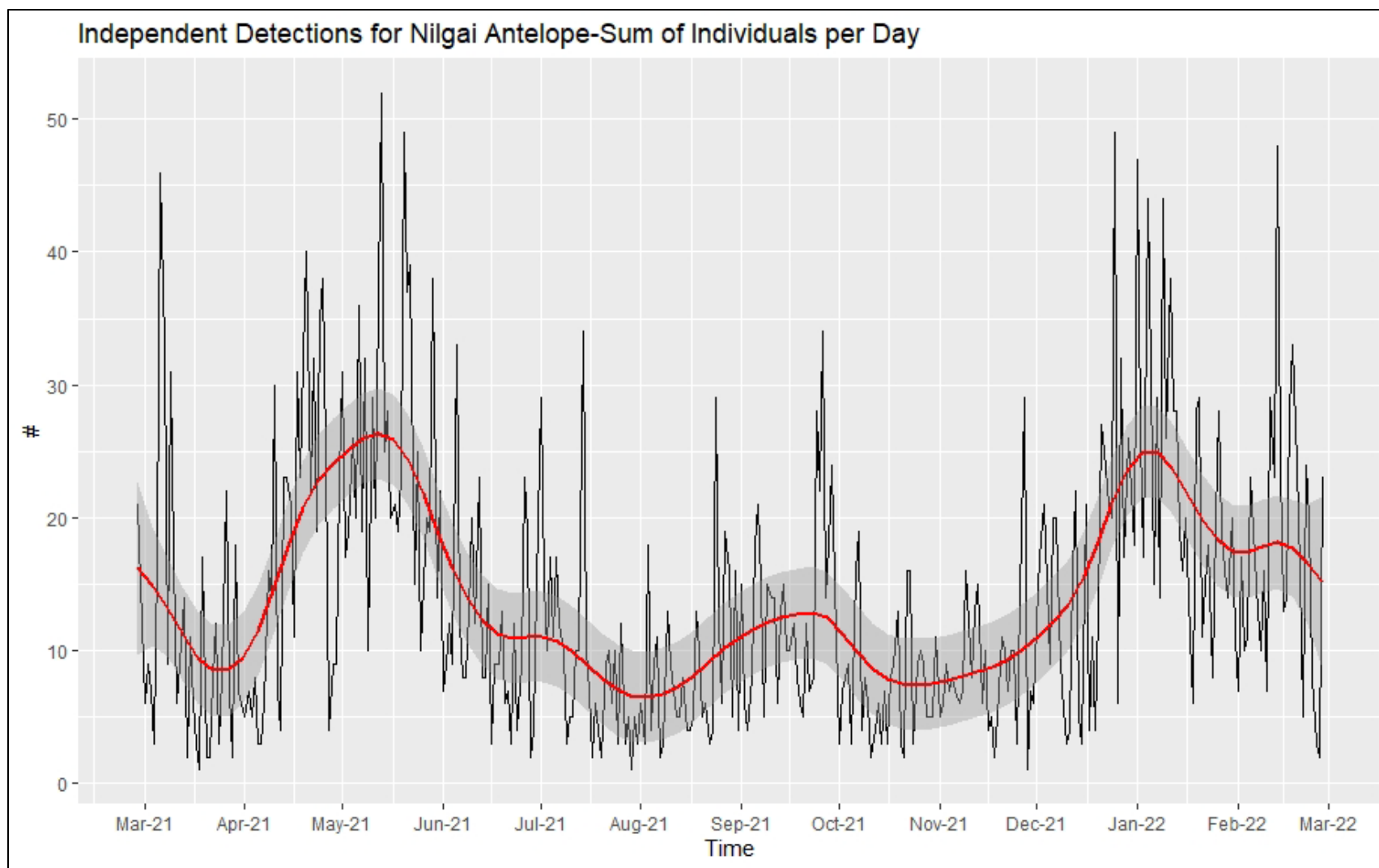


Figure C-46. Independent detections of nilgai antelope: Sum of individuals per day (2/27/2021–2/27/2022).

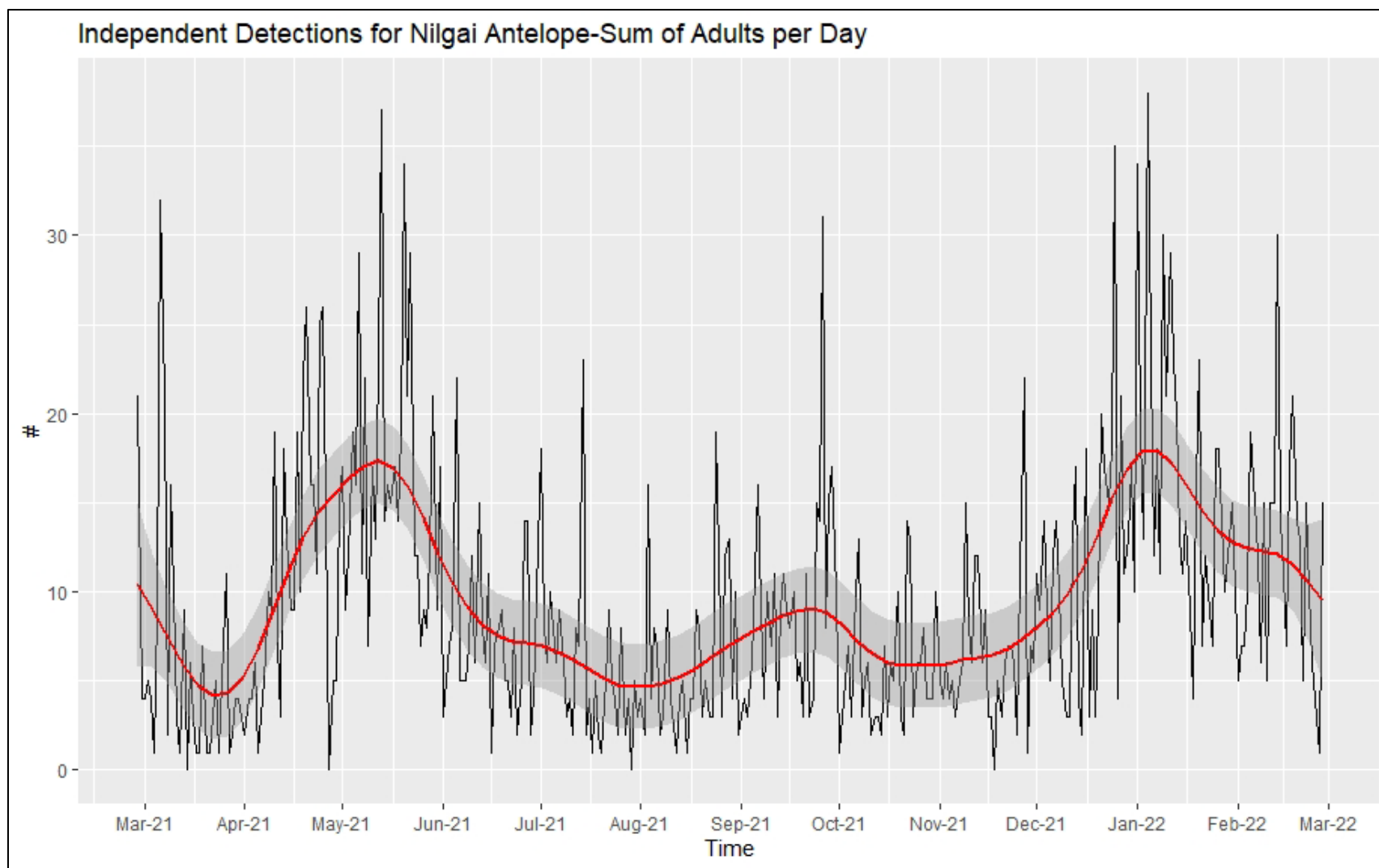


Figure C-47. Independent detections of nilgai antelope: Sum of adults per day (2/27/2021–2/27/2022).

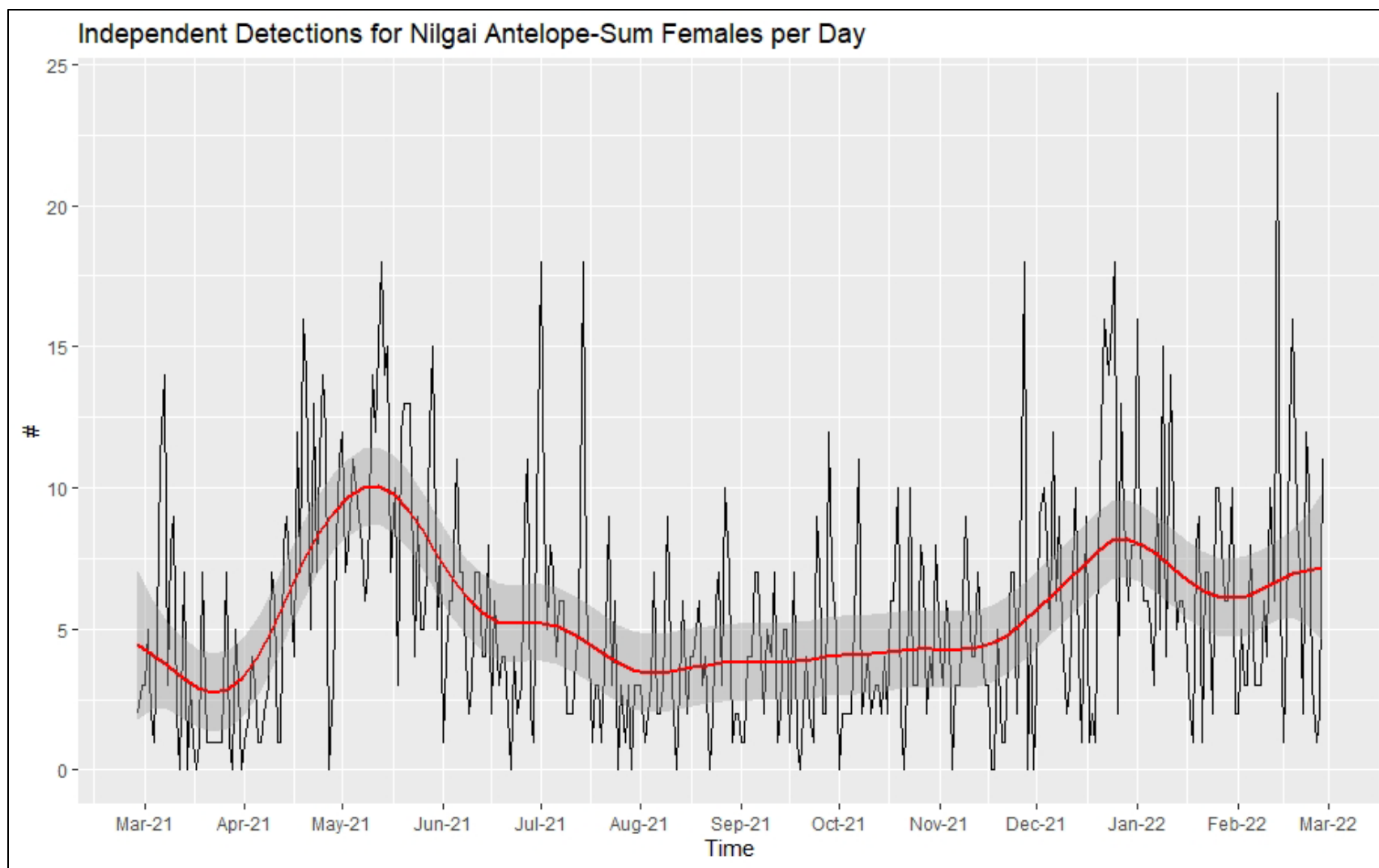


Figure C-48. Independent detections of nilgai antelope: Sum females per day (2/27/2021–2/27/2022).

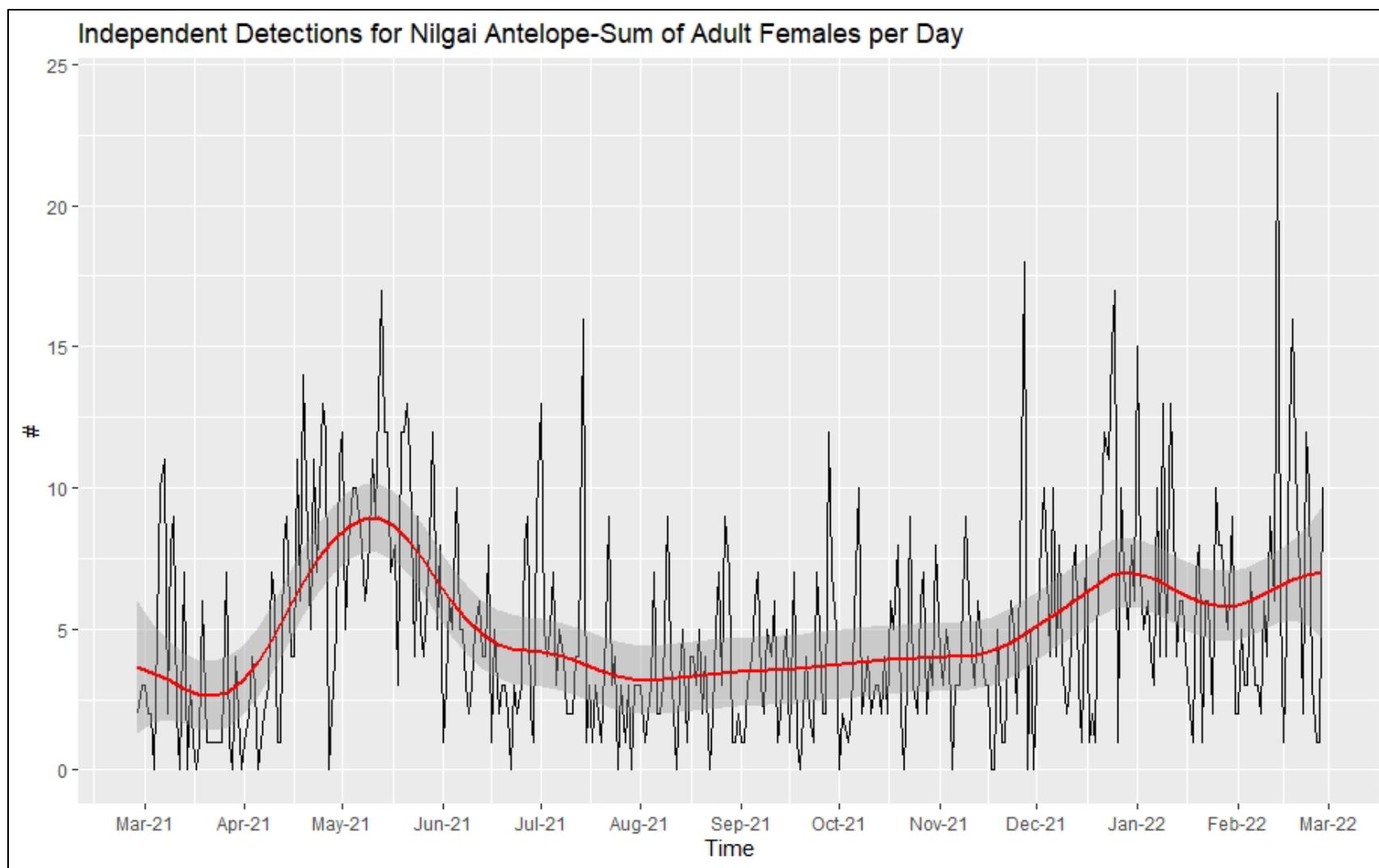


Figure C-49. Independent detections of nilgai antelope: Sum of adult females per day (2/27/2021–2/27/2022).

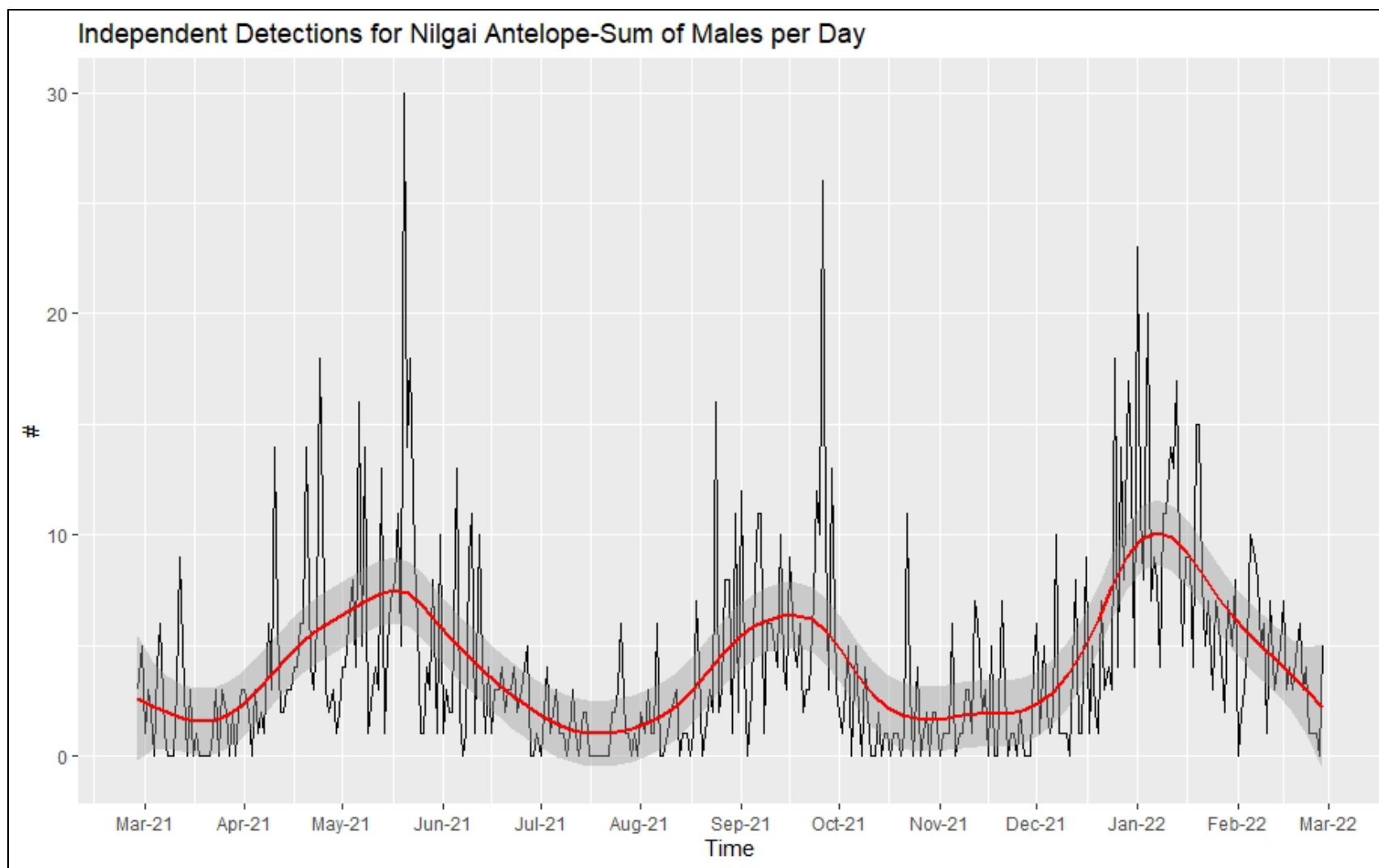


Figure C-50. Independent detections of nilgai antelope: Sum of males per day (2/27/2021–2/27/2022).

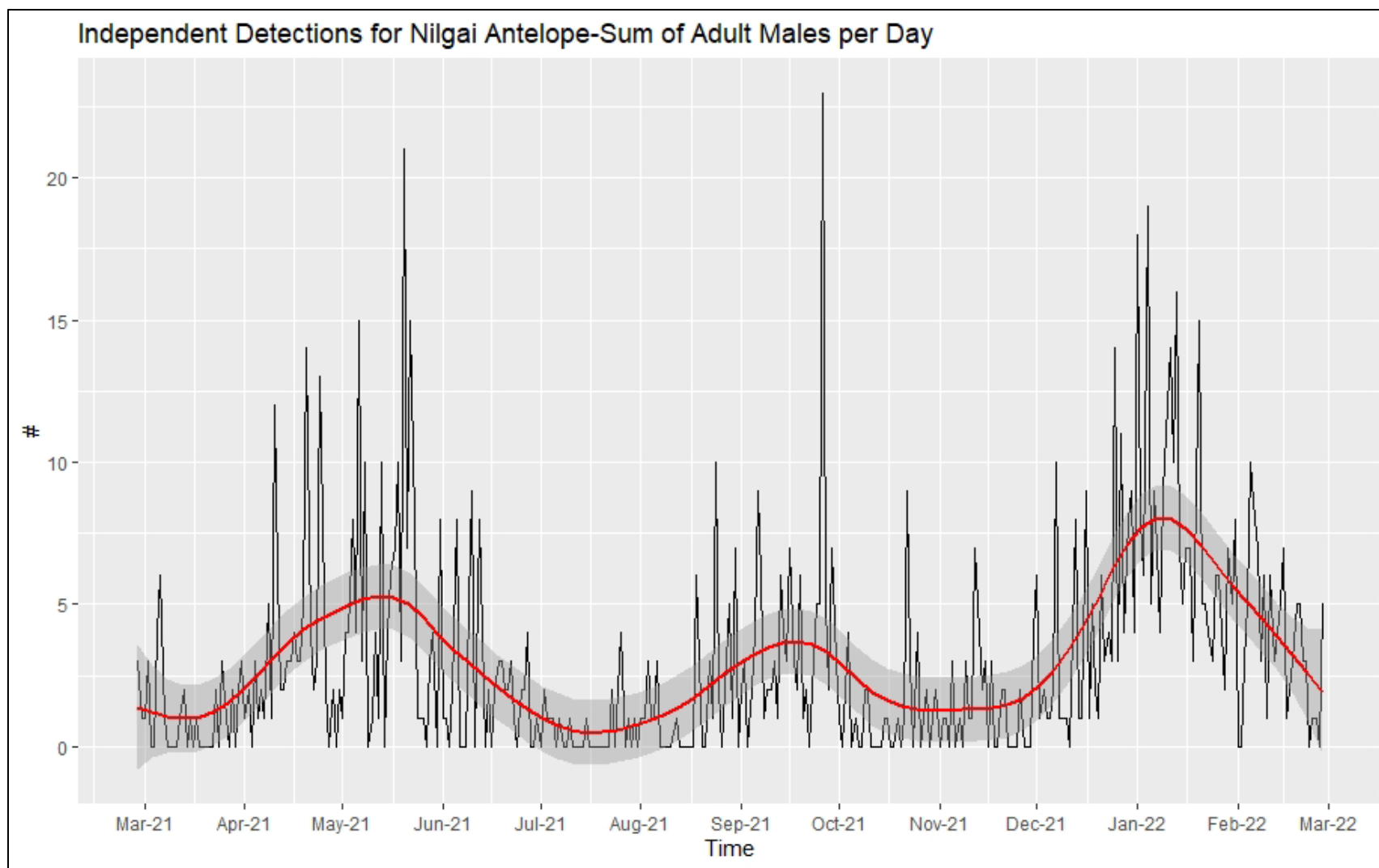


Figure C-51. Independent detections of nilgai antelope: Sum of adult males per day (2/27/2021–2/27/2022).

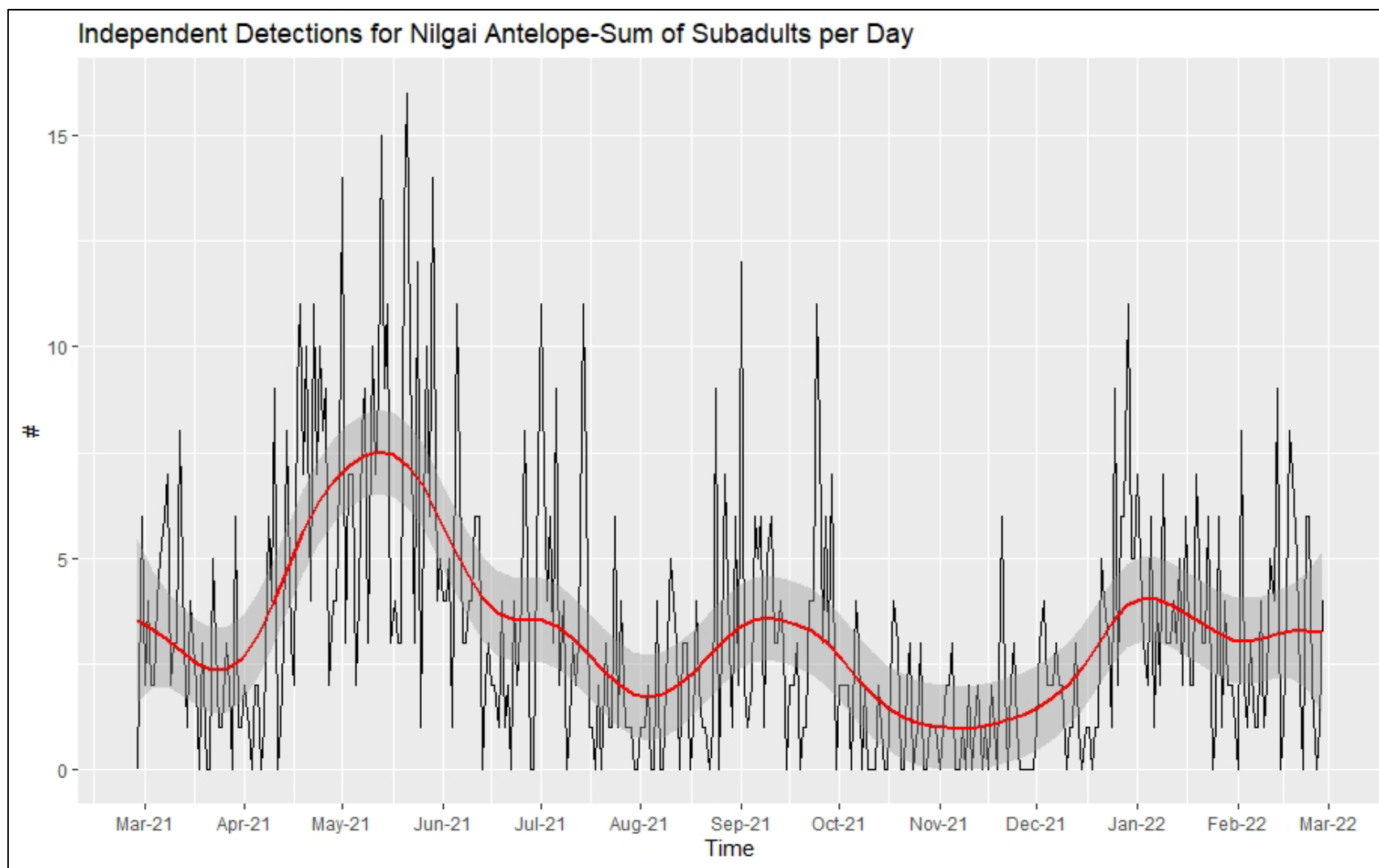


Figure C-52. Independent detections of nilgai antelope: Sum of subadults per day (2/27/2021–2/27/2022).

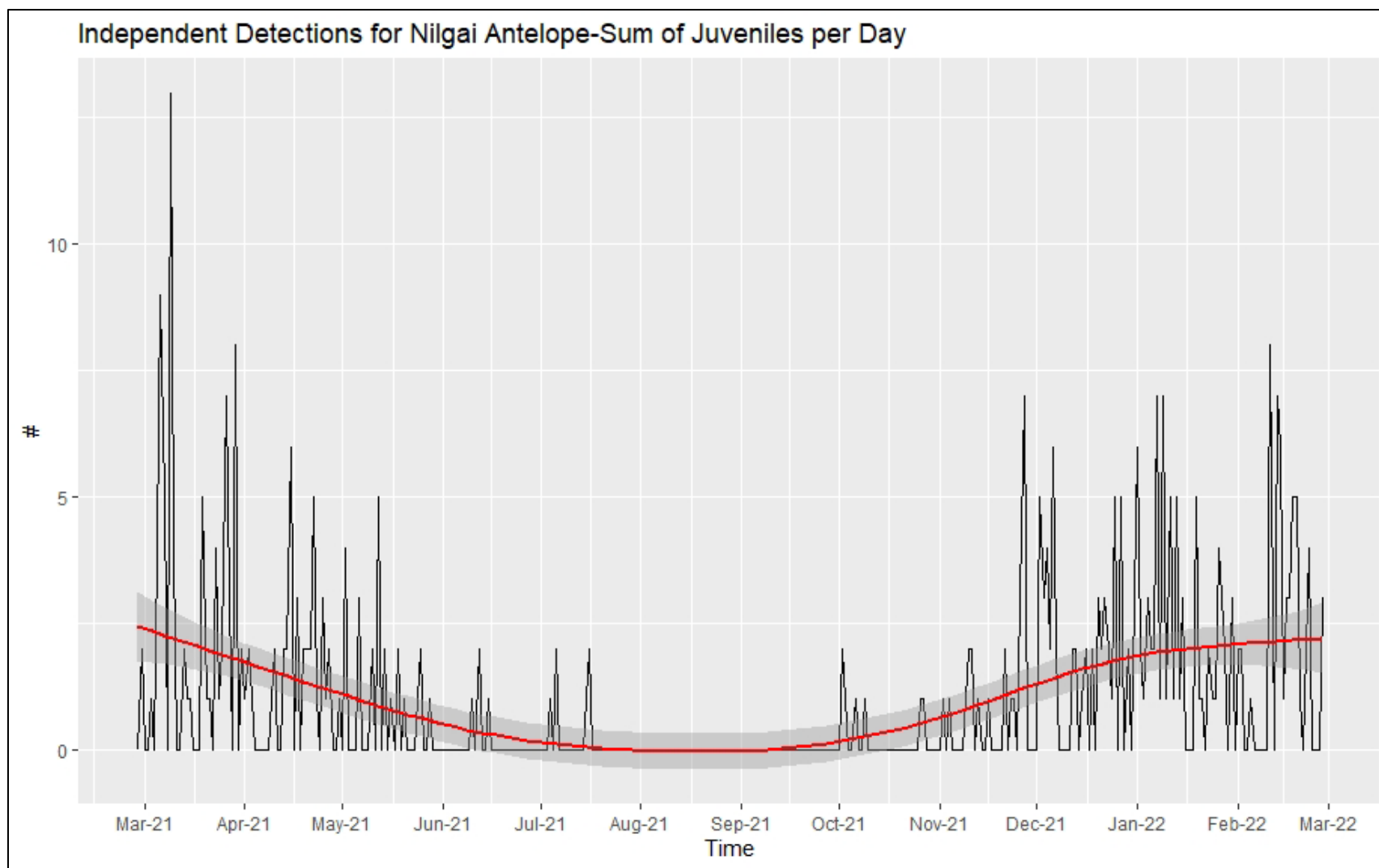


Figure C-53. Independent detections of nilgai antelope: Sum of juveniles per day (2/27/2021–2/27/2022).

Other Wildlife Species

Other wildlife species were detected less frequently compared to nilgai antelope, and detailed analysis was limited by low sample sizes (Table C-3). Time series analysis of the six most commonly detected species was conducted, with the exclusion of species for which higher numbers of independent detection events were attributed to a single location within a short period of time. Analyzed species include feral hog, collared peccary (javelina), raccoon, bobcat, coyote, and white-tailed deer in order of decreasing independent detection events.

Table C-3. Summary of variables per species and locations.

Location	Species	Sum of Total Individuals	Sum of Total Adults	Sum of Total Juveniles	Sum of Total Subadults	Sum of Total Females	Sum of Total Males	Sum of Adult Females	Sum of Adult Males	Sum of Detections
E4	American Coot	2	2	0	0	0	0	0	0	2
E4	Black-bellied Whistling Duck	10	3	7	0	0	0	0	0	2
LS_4	Black-bellied Whistling Duck	4	4	0	0	0	0	0	0	2
B3	black-tailed jackrabbit	2	2	0	0	0	0	0	0	2
E4	Blue-winged Teal	5	5	0	0	0	0	0	0	2
B3	bobcat	6	6	0	0	0	0	0	0	6
D4	bobcat	6	6	0	0	0	0	0	0	6
E2	bobcat	2	1	0	1	0	0	0	0	1
LS_7	bobcat	1	1	0	0	0	0	0	0	1
B3	collared peccary	12	10	2	0	0	0	0	0	5
D4	collared peccary	2	2	0	0	0	0	0	0	2
E2	collared peccary	9	9	0	0	0	0	0	0	3
F3	collared peccary	14	14	0	0	0	0	0	0	7
E4	Common Gallinule	1	0	1	0	0	0	0	0	1
LS_4	Common Ground Dove	7	7	0	0	0	0	0	0	4
B3	coyote	4	4	0	0	0	0	0	0	4
C5	coyote	1	1	0	0	0	0	0	0	1
D4	coyote	3	3	0	0	0	0	0	0	2
D5	coyote	1	1	0	0	0	0	0	0	1
E2	coyote	1	1	0	0	0	0	0	0	1
E5	coyote	2	2	0	0	0	0	0	0	2
F2	coyote	1	1	0	0	0	0	0	0	1
K6	coyote	1	1	0	0	0	0	0	0	1
LS_4	Curve-billed Thrasher	16	16	0	0	0	0	0	0	15
B6	Domestic cow	1	1	0	0	0	1	0	1	1

Table C-3 (continued). Summary of variables per species and locations.

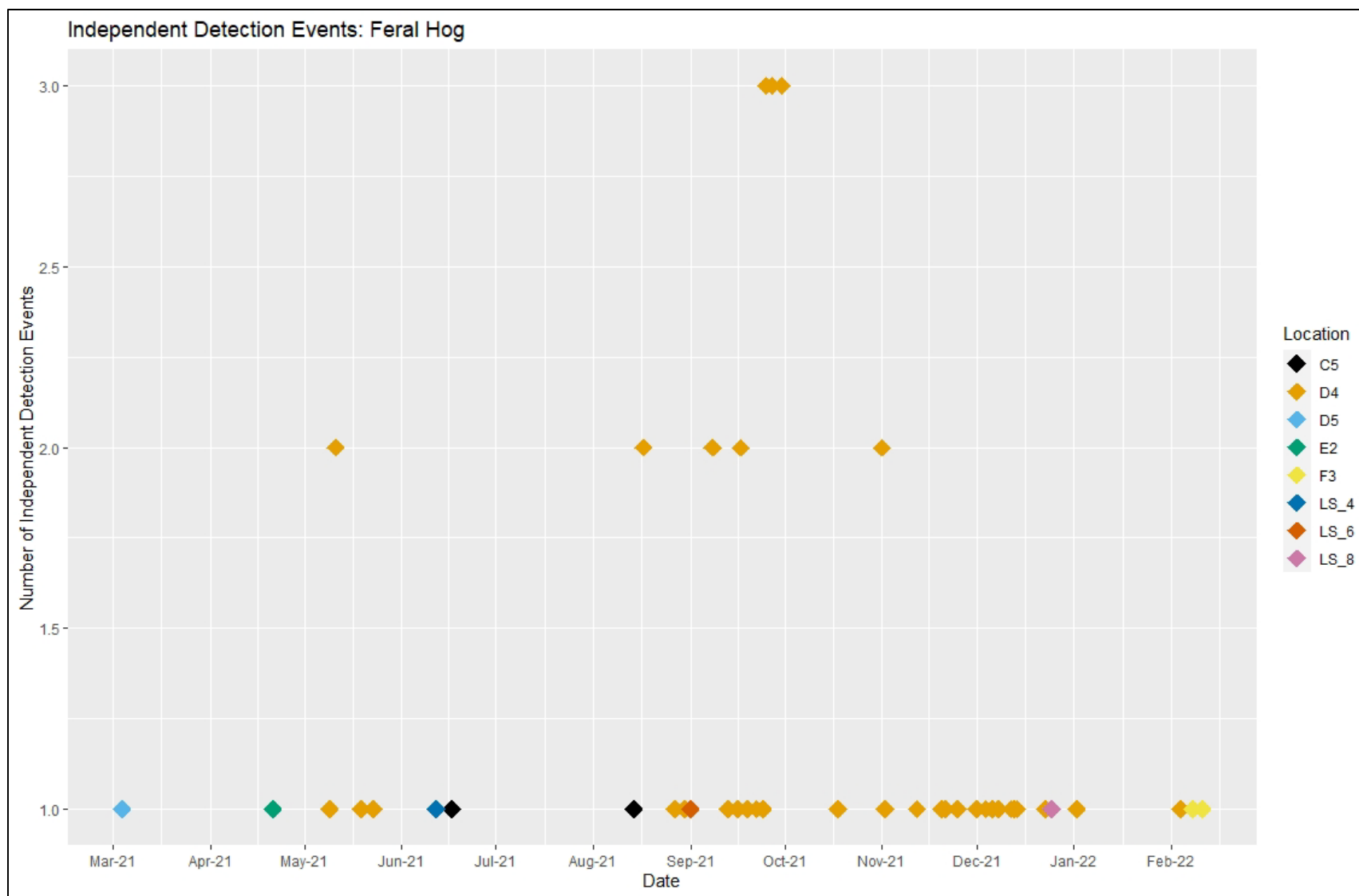
Location	Species	Sum of Total Individuals	Sum of Total Adults	Sum of Total Juveniles	Sum of Total Subadults	Sum of Total Females	Sum of Total Males	Sum of Adult Females	Sum of Adult Males	Sum of Detections
E4	Domestic cow	1	1	0	0	1	0	1	0	1
E5	Domestic cow	3	3	0	0	0	1	0	1	2
F5	Eastern Meadowlark	1	1	0	0	0	0	0	0	1
C5	feral hog	3	2	1	0	0	0	0	0	2
D4	feral hog	73	66	7	0	1	15	1	15	45
D5	feral hog	1	1	0	0	0	0	0	0	1
E2	feral hog	3	3	0	0	0	0	0	0	1
F3	feral hog	3	3	0	0	0	0	0	0	2
LS_4	feral hog	1	1	0	0	0	1	0	1	1
LS_6	feral hog	2	1	1	0	0	0	0	0	1
LS_8	feral hog	1	1	0	0	0	0	0	0	1
D4	Golden-fronted Woodpecker	1	1	0	0	0	0	0	0	1
LS_4	Great-tailed Grackle	1	1	0	0	1	0	1	0	1
D4	Groove-billed Ani	3	3	0	0	0	0	0	0	1
D4	Mottled Duck	6	0	0	0	0	0	0	0	1
LS_4	Mourning Dove	20	20	0	0	0	0	0	0	14
D4	nine-banded armadillo	6	6	0	0	0	0	0	0	6
B6	raccoon	1	1	0	0	0	0	0	0	1
D4	raccoon	20	18	0	2	0	0	0	0	14
F3	raccoon	3	2	0	1	0	0	0	0	1
LS_7	raccoon	2	2	0	0	0	0	0	0	1
D4	Red-tailed Hawk	1	1	0	0	0	0	0	0	1
L5	southern plains woodrat	1	0	0	0	0	0	0	0	1
LS_4	Turkey Vulture	1	1	0	0	0	0	0	0	1
B3	Virginia opossum	1	1	0	0	0	0	0	0	1

Table C-3 (continued). Summary of variables per species and locations.

Location	Species	Sum of Total Individuals	Sum of Total Adults	Sum of Total Juveniles	Sum of Total Subadults	Sum of Total Females	Sum of Total Males	Sum of Adult Females	Sum of Adult Males	Sum of Detections
LS_7	Virginia opossum	1	0	0	0	0	0	0	0	1
B2	white-tailed deer	1	1	0	0	0	1	0	1	1
B3	white-tailed deer	1	1	0	0	0	1	0	1	1
B6	white-tailed deer	2	2	0	0	0	1	0	1	2
D5	white-tailed deer	1	1	0	0	0	1	0	1	1
F2	white-tailed deer	2	2	0	0	0	2	0	2	2
LS_8	white-tailed deer	1	1	0	0	0	1	0	1	1
LS_4	White-tailed Hawk	2	2	0	0	0	0	0	0	1

Time Series: Independent Detection Events per Species and Location

Number of independent detection events per species (feral hog, collared peccary (javelina), raccoon, bobcat, coyote, and white-tailed deer) throughout the study duration for all locations (Figures C-54 to C-59).



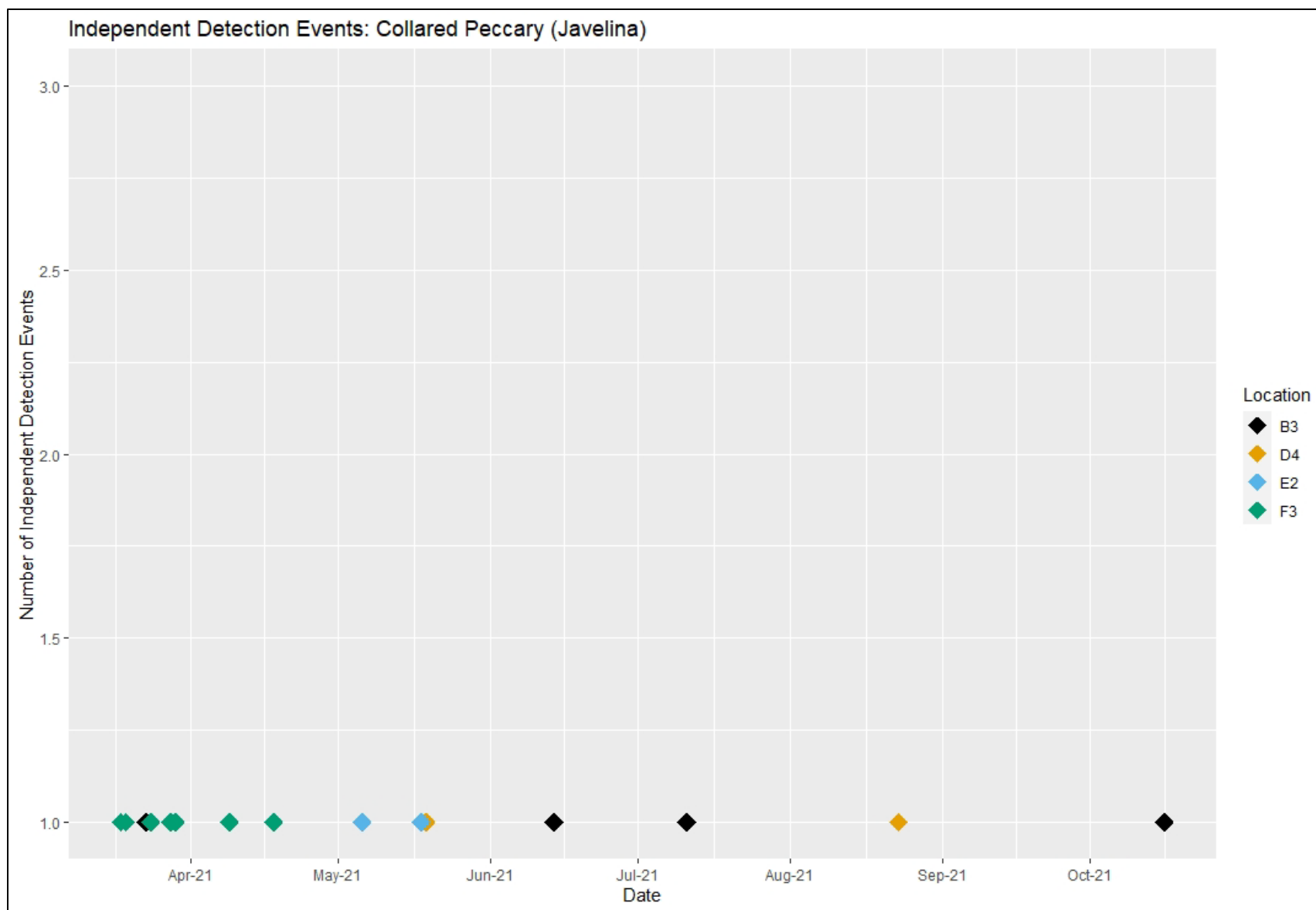


Figure C-55. Positive independent detections: Collared peccary (javelina).

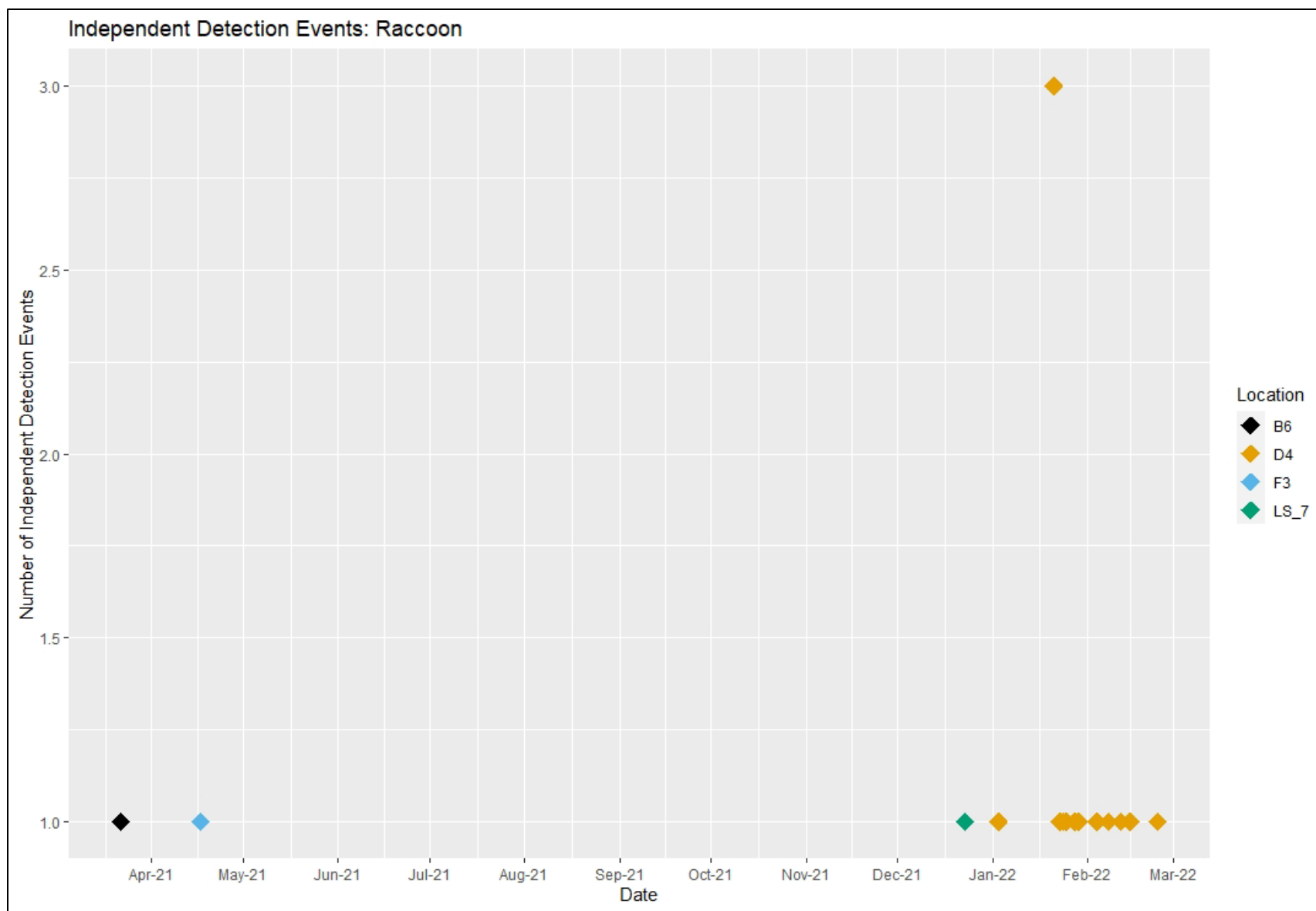


Figure C-56. Positive independent detections: Raccoon.

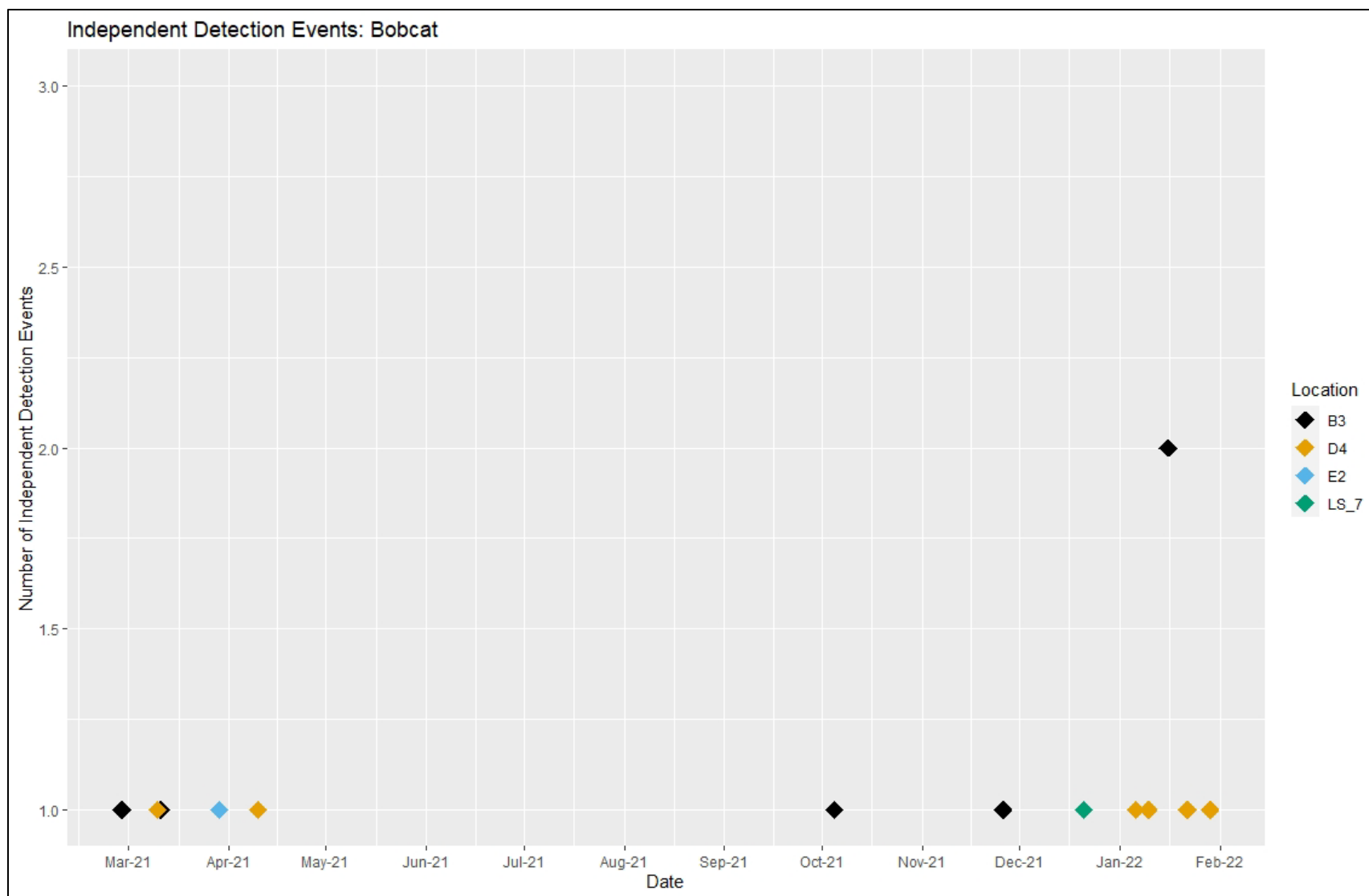


Figure C-57. positive independent detections: Bobcat.

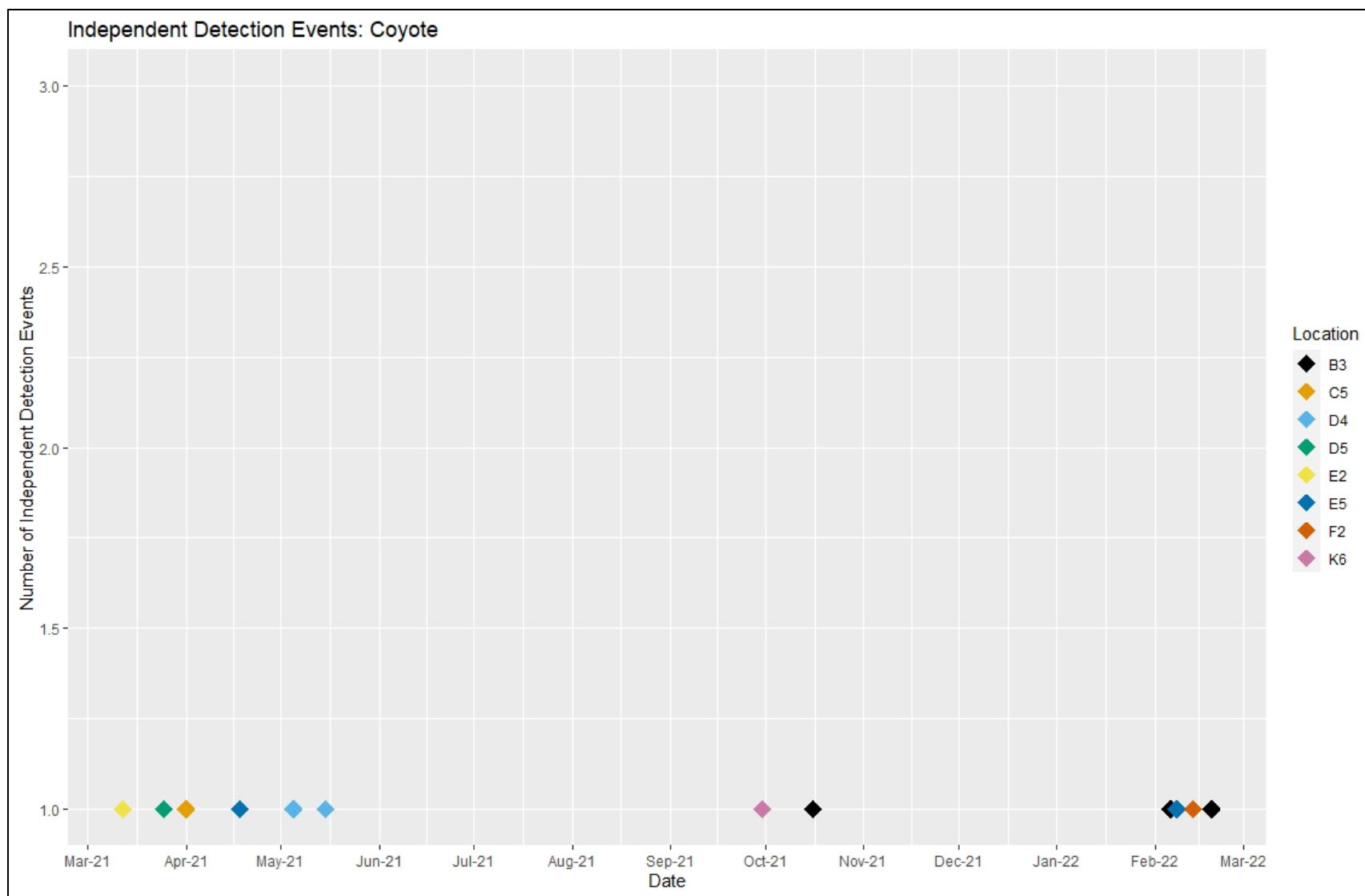


Figure C-58. Positive independent detections: Coyote.

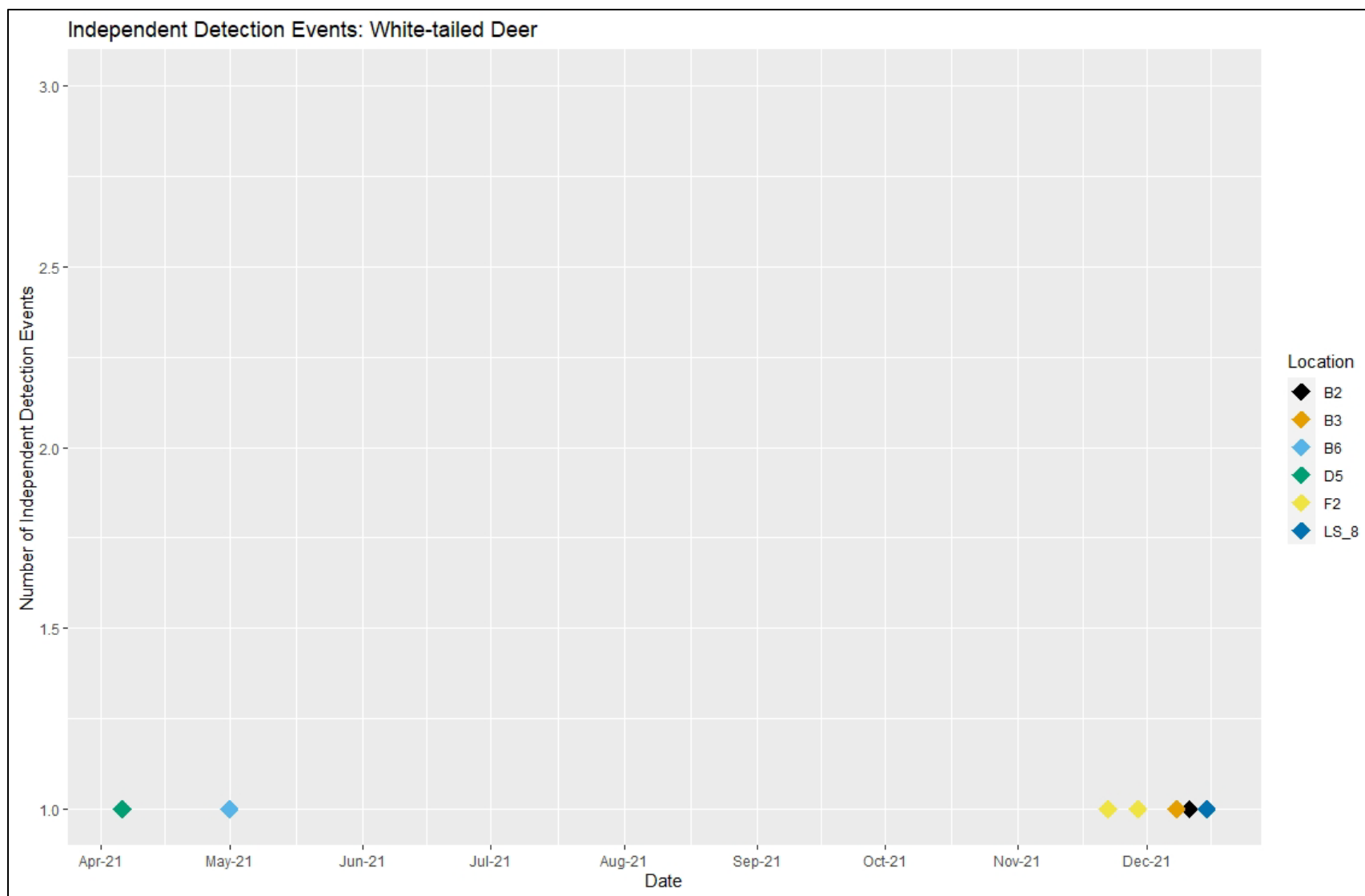


Figure C-59. Positive Independent Detections: white-tailed deer.

Appendix D—Site Covariate Results

This appendix provides site covariates values for all data collection sites including a summary list of results for vegetation, woody plant cover and structure, and inundation (Tables D-1 to D-8, and Figures D-1 to D-12). All species represented within figures are the two most dominant key species per each vegetation category as defined by the vegetation survey protocol for this project. Relative species composition is composed of all key species documented within a given survey plot adding up to 100%. Plot composition includes bare ground, water (if present), and relative percent cover of key species, adding up to greater than 100% percent cover where bare ground or water increase total coverage values.

Vegetation

Tables

Table D-1. Vegetation species observed within study area.

Species Code	Common Name	Scientific Name
2FORB	UNKNOWN FORB (USDA CODE)	NA
2SUBS	UNKNOWN SUBSHRUB (USDA CODE)	NA
2GRAM	UNKNOWN GRAMINOID (USDA CODE)	NA
ABUT1	Indian mallow	<i>Abutilon spp.</i>
ACTE4	triangle cactus	<i>Acanthocereus tetragonus</i>
ATCR2	crested saltbush	<i>Atriplex cristata</i>
ATMA	Matamoros saltbush	<i>Atriplex matamorensis</i>
BG	Bare Ground (Bare Soil)	NA
BOFR	bushy seaside tansy	<i>Borrchia frutescens</i>
CHCA6	Paraguayan windmill grass	<i>Chloris canterai</i>
CHCI	fringed windmill grass	<i>Chloris ciliata</i>
CHOD	Siam weed, Jack in the bush	<i>Chromolaena odorata</i>
DIAN	Kleberg's bluestem	<i>Dichanthium annulatum</i>
DIAR5	Angleton bluestem	<i>Dichanthium aristatum</i>
ERPS80	perennial cupgrass	<i>Eriochloa pseudoacrotricha</i>
ERSE5	Texas cupgrass	<i>Eriochloa sericea</i>
FLIN2	pink thoroughwort	<i>Fleischmannia incarnata</i>
JUNCUS	Juncus	<i>Juncus spp.</i>
KOSP	crown of thorns	<i>Koeberlinia spinosa</i>
LENE2	Nealley's sprangletop	<i>Leptochloa nealleyi</i>
LT	Litter	NA
LYBE	Berlandier's wolfberry	<i>Lycium berlandieri</i>
MAAM	Indian Valley false mallow	<i>Malvastrum americanum</i>
MAPH	Florida mayten	<i>Maytenus phyllanthoides</i>

Table D-1 (continued). Vegetation species observed within study area.

Species Code	Common Name	Scientific Name
NYMPH	waterlily	<i>Nymphaea spp.</i>
OPENL	Texas pricklypear	<i>Opuntia engelmannii</i>
PAAC3	Mexican Palo Verde, Jerusalem thorn	<i>Parkinsonia aculeata</i>
PANIC	panicgrass	<i>Panicum (genus)</i>
PECI	buffelgrass	<i>Pennisetum ciliare</i>
PRGL2	honey mesquite	<i>Prosopis glandulosa</i>
PRREC	tornillo	<i>Prosopis reptans var. cinerascens</i>
RAPH2	camphor daisy	<i>Rayjacksonia phyllocephala</i>
RK	Rock	NA
SAGGI	Arrowhead	<i>Sagittaria spp.</i>
SETAR	bristlegrass	<i>Setaria spp.</i>
SICE2	saffron plum	<i>Sideroxylon celastrinum</i>
SOEL	silverleaf nightshade	<i>Solanum elaeagnifolium</i>
SPORO	dropseed	<i>Sporobolus spp.</i>
SPSP	gulf cordgrass	<i>Spartina spartinae</i>
SUAED	seepweed	<i>Suaeda spp.</i>
URMA3	guineagrass	<i>Urochloa maxima</i>
VAFA	sweet acacia	<i>Vachellia farnesiana</i>
VEHA	Texas vervain	<i>Verbena halei</i>
WT	Water	NA
YUTR	Spanish dagger, palma pita	<i>Yucca treculeana</i>
ZAFA	Lime pricklyash	<i>Zanthoxylum fagara</i>
ZIOB	Lotebush	<i>Ziziphus obtusifolia</i>

Table D-2. Vegetation species occurrence by native status: Camera trap stations.

Species Code	Introduced	Introduced, Native	Native	Unknown	Total Occurrences	Percent of Total Occurrences
2GRAM	0	0	0	2	2	2.35
BOFR	0	0	12	0	12	14.12
CHCA6	10	0	0	0	10	11.76
ERSE5	0	0	1	0	1	1.18
FLIN2	0	0	1	0	1	1.18
JUNCUS	0	0	0	2	2	2.35
LENE2	0	0	1	0	1	1.18
MAAM	0	0	1	0	1	1.18
NYMPH	0	0	0	1	1	1.18
OPENL	0	0	4	0	4	4.71
PAAC3	0	0	4	0	4	4.71
PECI	2	0	0	0	2	2.35
PRGL2	0	0	9	0	9	10.59
PRREC	0	0	4	0	4	4.71
RAPH2	0	0	1	0	1	1.18
SAGGI	0	0	0	2	2	2.35
SETAR	0	0	0	1	1	1.18
SICE2	0	0	1	0	1	1.18
SOEL	0	0	1	0	1	1.18
SPSP	0	0	9	0	9	10.59
SUAED	0	1	0	0	1	1.18
URMA3	3	0	0	0	3	3.53
VAFA	0	0	2	0	2	2.35
VEHA	0	0	1	0	1	1.18
YUTR	0	0	1	0	1	1.18
ZAFA	0	0	4	0	4	4.71
ZIOB	0	0	4	0	4	4.71
Total Species	3	1	18	5	27	n/a
Total Occurrences	15	1	61	8	85	100.00
Percent of Total Occurrences	17.65	1.18	71.76	9.41	100.00	100.00

Table D-3. Vegetation species occurrence by native status: latrine site stations.

Species Code	Introduced	Introduced, Native	Native	No Status	Unknown	Total Occurrences	Percent of Total Occurrences
BOFR	0	0	2	0	0	2	6.06
CHCA6	6	0	0	0	0	6	18.18
MAAM	0	0	1	0	0	1	3.03
OPENL	0	0	6	0	0	6	18.18
PECI	2	0	0	0	0	2	6.06
PRGL2	0	0	5	0	0	5	15.15
PRREC	0	0	2	0	0	2	6.06
SETAR	0	0	0	0	1	1	3.03
SICE2	0	0	1	0	0	1	3.03
SUAED	0	1	0	0	0	1	3.03
URMA3	2	0	0	0	0	2	6.06
YUTR	0	0	1	0	0	1	3.03
ZIOB	0	0	3	0	0	3	9.09
Total Species	3	1	8	0	1	13	n/a
Total Occurrences	10	1	21	0	1	33	100.00
Percent of Total Occurrences	30.30	3.03	63.64	0.00	3.03	100.00	100.00

Table D-4. Summary of grazed vegetation by native status (all locations).

Location	Species Code	Common Name	Scientific Name	Native Status	Total Number of Species Occurrences	Percent of Species Occurrences Grazed
B2, E5, F5, LS_1, LS_2, LS_3	CHCA6	Paraguayan windmill grass	<i>Chloris canterai</i>	Introduced	16	37.50
E5	2GRAM	Unknown graminoid	n/a	Unknown	2	50.00
LS_1	PECI	buffelgrass	<i>Pennisetum ciliare</i>	Introduced	4	25.00
C5, E6	PRGL2	honey mesquite	<i>Prosopis glandulosa</i>	Native	14	14.30
D4, F3, LS_3	URMA3	guineagrass	<i>Urochloa maxima</i>	Introduced	5	60.00

Table D-5. Relative percent cover of key species by camera trap station (30m buffer).

Location	Species Code	Relative Percent Cover (30m buffer)*
B2	CHCA6	60.00
	PRGL2	40.00
B3	CHCA6	40.00
	OPENL	10.00
	PRGL2	20.00
	URMA3	10.00
	ZAFA	20.00
B6	2GRAM	20.00
	BOFR	10.00
	PAAC3	30.00
	PRGL2	20.00
	SAGGI	20.00
C5	CHCA6	20.00
	MAAM	10.00
	PRGL2	20.00
	SPSP	40.00
	VAFA	10.00
D4	JUNCUS	10.00
	PAAC3	20.00
	PRGL2	20.00
	SAGGI	30.00
	URMA3	20.00
D5	BOFR	10.00
	CHCA6	20.00
	LENE2	20.00
	SPSP	40.00
	VAFA	10.00
E2	BOFR	10.00
	CHCA6	20.00
	PECI	10.00
	PRGL2	40.00
	SETAR	20.00

* Relative percent cover is comprised of the two dominant key species per each vegetation category (see methods for full definition) only and does not represent a full inventory of species potentially present at each location

Table D-5 (continued). Relative percent cover of key species by camera trap station (30m buffer).

Location	Species Code	Relative Percent Cover (30m buffer)*
E4	BOFR	20.00
	JUNCUS	30.00
	NYMPH	20.00
	PAAC3	30.00
E5	2GRAM	30.00
	BOFR	10.00
	CHCA6	40.00
	OPENL	10.00
	ZAFA	10.00
E6	BOFR	10.00
	PRGL2	20.00
	SPSP	60.00
	VEHA	10.00
F2	BOFR	10.00
	CHCA6	50.00
	OPENL	10.00
	PECI	30.00
F3	CHCA6	20.00
	PAAC3	10.00
	PRGL2	40.00
	SICE2	10.00
	URMA3	20.00
F5	CHCA6	80.00
	OPENL	10.00
	ZIOB	10.00
G5	BOFR	40.00
	CHCA6	20.00
	ERSE5	30.00
	PRREC	10.00
H5	BOFR	10.00
	FLIN2	10.00
	PRREC	10.00
	SOEL	10.00
	SPSP	60.00

* Relative percent cover is comprised of the two dominant key species per each vegetation category (see methods for full definition) only and does not represent a full inventory of species potentially present at each location

Table D-5 (continued). Relative percent cover of key species by camera trap station (30m buffer).

Location	Species Code	Relative Percent Cover (30m buffer)*
I5	BOFR	20.00
	SPSP	60.00
	YUTR	10.00
	ZIOB	10.00
K5	SPSP	80.00
	ZAFA	10.00
	ZIOB	10.00
K6	PRREC	10.00
	RAPH2	10.00
	SPSP	80.00
L5	BOFR	10.00
	SPSP	70.00
	ZAFA	10.00
	ZIOB	10.00
M6	BOFR	20.00
	PRREC	5.00
	SPSP	60.00
	SUAED	15.00

* Relative percent cover is comprised of the two dominant key species per each vegetation category (see methods for full definition) only and does not represent a full inventory of species potentially present at each location

Table D-6. Relative percent cover of key species by latrine station (30m buffer).

Location	Species Code	Relative Percent Cover (30m buffer)*
LS_1	CHCA6	40.00
	OPENL	20.00
	PECI	30.00
	ZIOB	10.00
LS_2	BOFR	10.00
	CHCA6	70.00
	OPENL	10.00
	PRREC	10.00
LS_3	BOFR	20.00
	CHCA6	60.00
	OPENL	10.00
	URMA3	10.00
LS_4	OPENL	20.00
	PRGL2	30.00
	PRREC	10.00
	SUAED	40.00
LS_5	CHCA6	50.00
	PECI	10.00
	PRGL2	20.00
	YUTR	10.00
	ZIOB	10.00
LS_6	CHCA6	40.00
	MAAM	10.00
	OPENL	20.00
	PRGL2	20.00
	SETAR	10.00
LS_7	CHCA6	20.00
	PRGL2	40.00
	SICE2	20.00
	ZIOB	20.00
LS_8	OPENL	20.00
	PRGL2	50.00
	URMA3	30.00

* Relative percent cover is comprised of the two dominant key species per each vegetation category (see methods for full definition) only and does not represent a full inventory of species potentially present at each location.

Figures

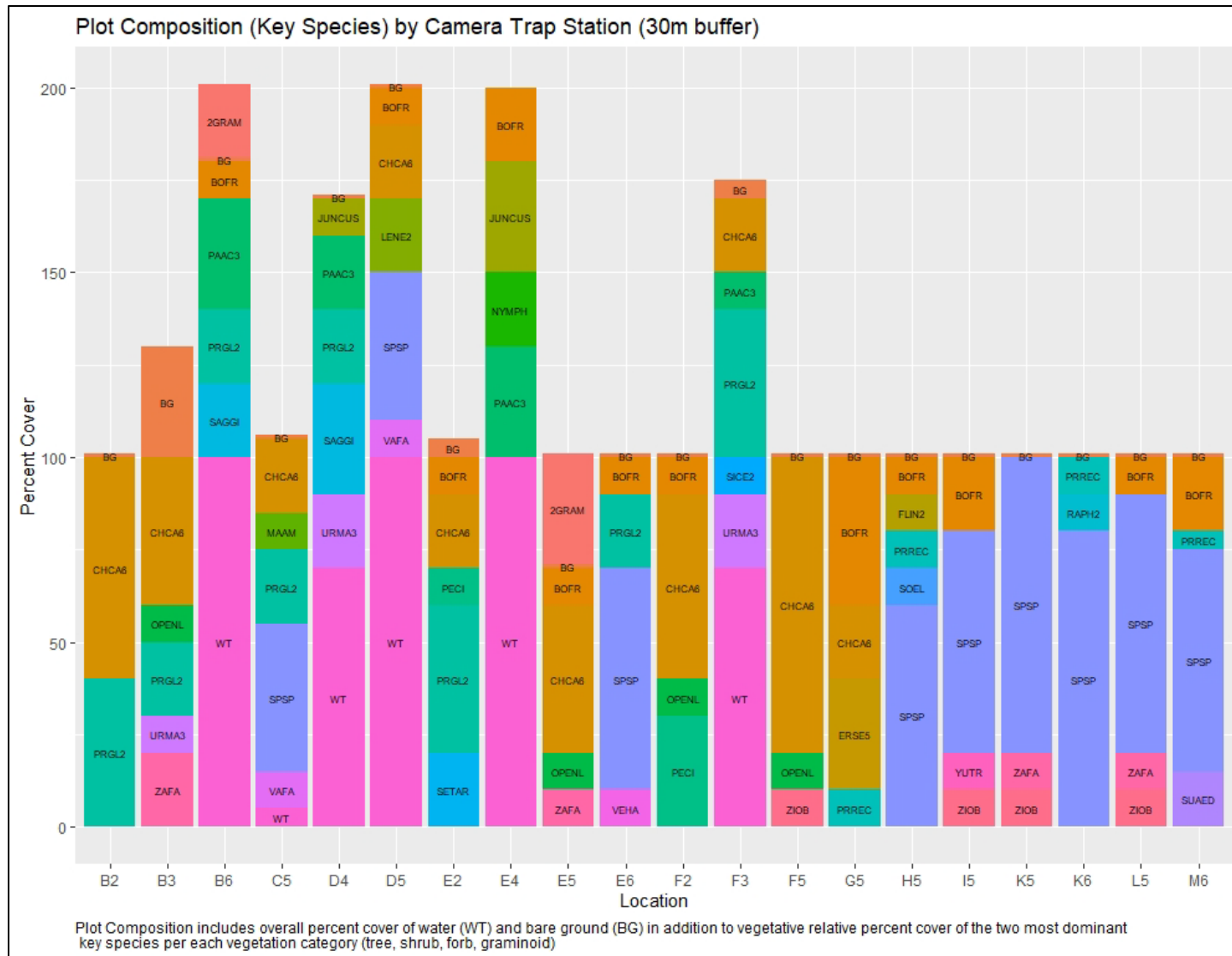


Figure D-1. Plot composition (key species) by camera trap station (30m buffer).



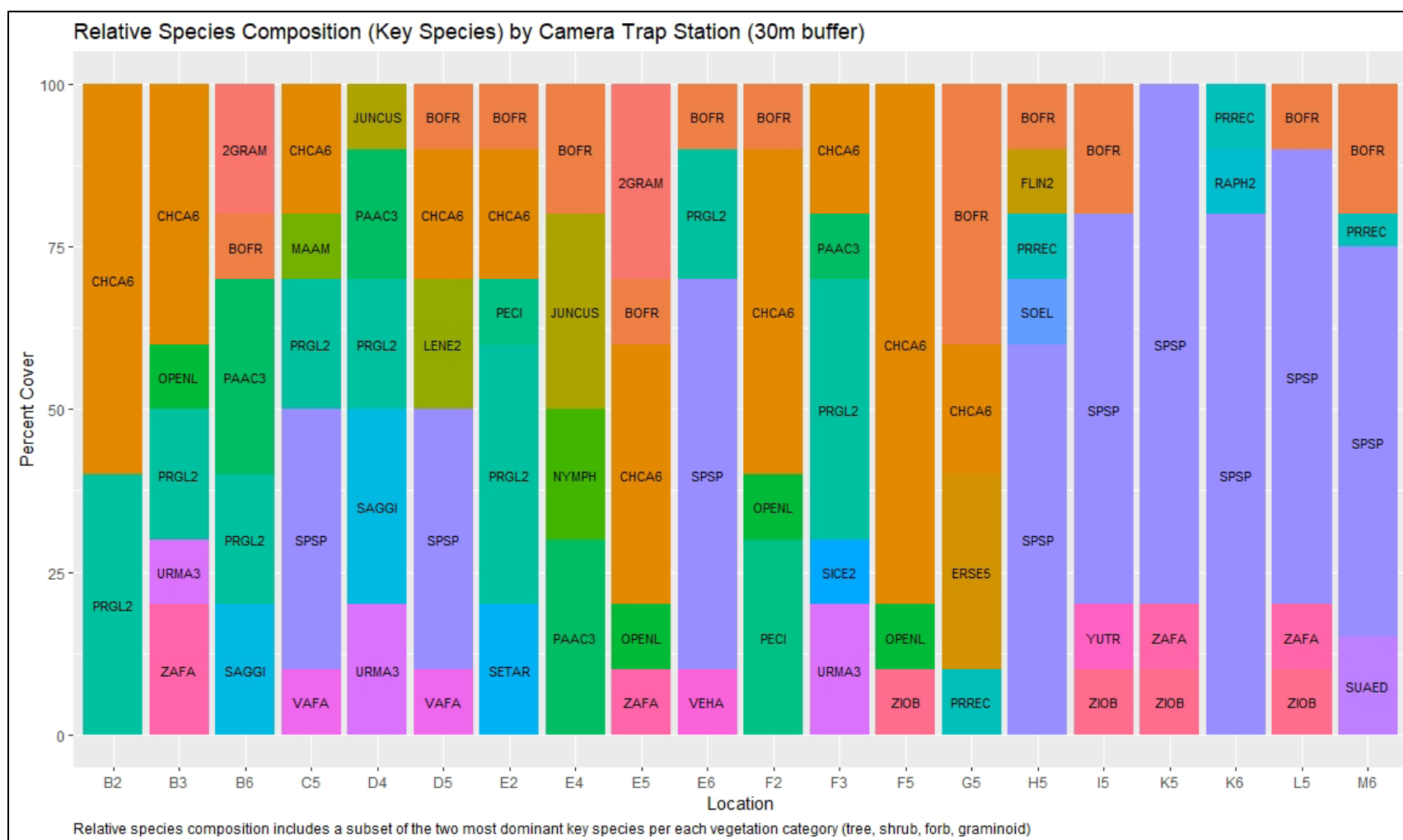


Figure D-3. Relative species composition (key species) by camera trap station (30m buffer).

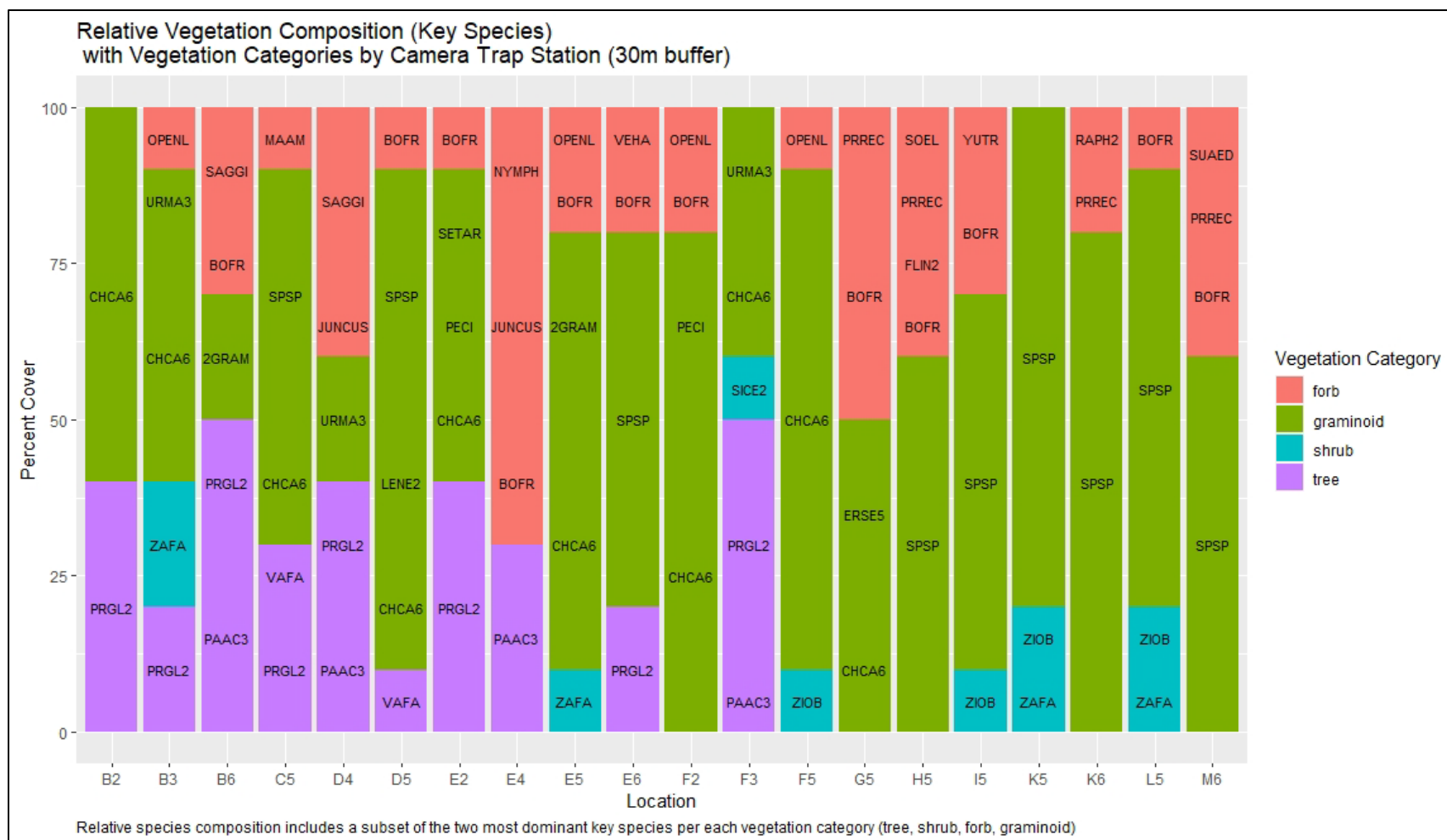


Figure D-4. Relative vegetation composition (key species) with vegetation categories by camera trap station (30m buffer).

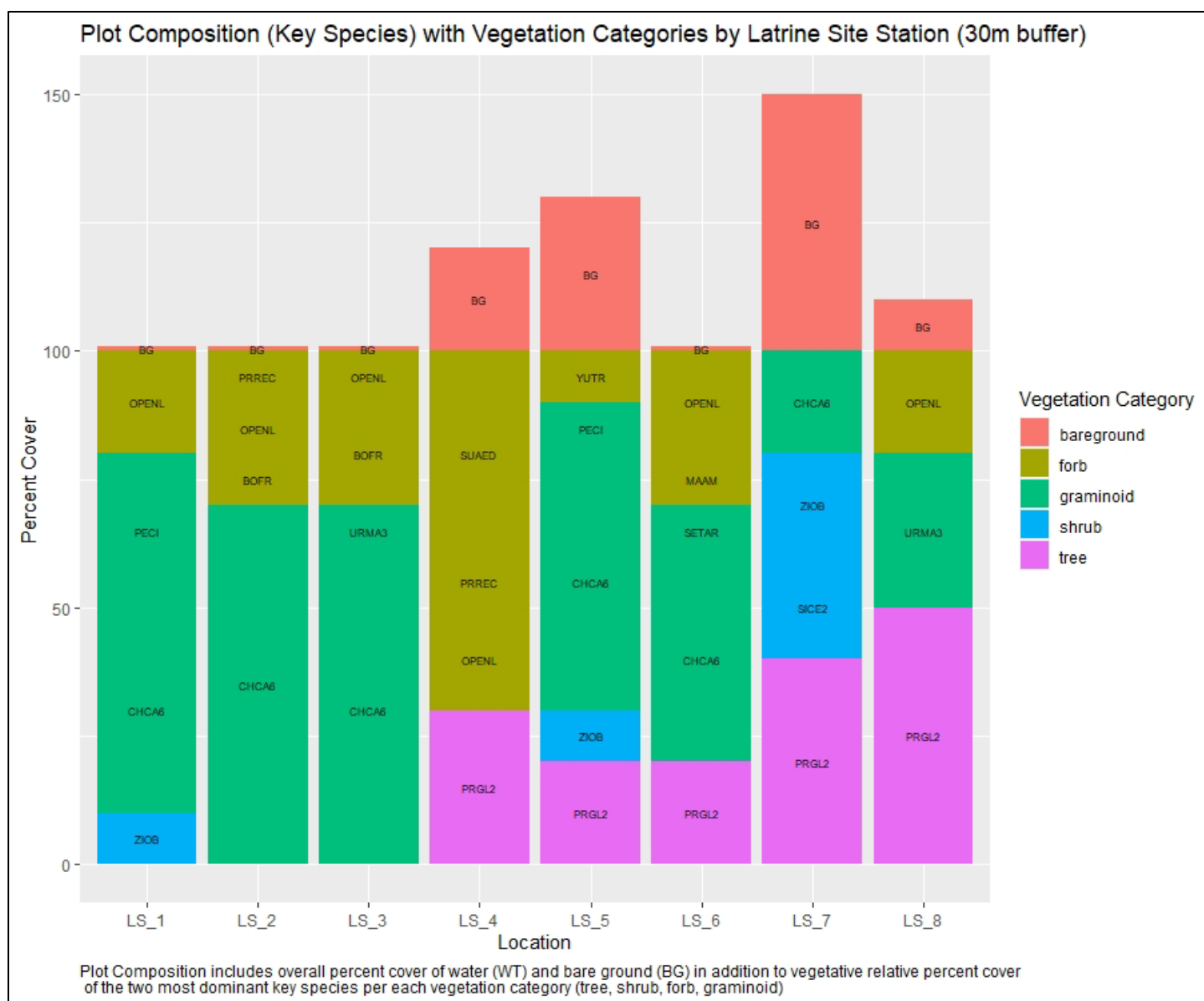


Figure D-6. Plot composition (key species) with vegetation categories by latrine site station (30m buffer).

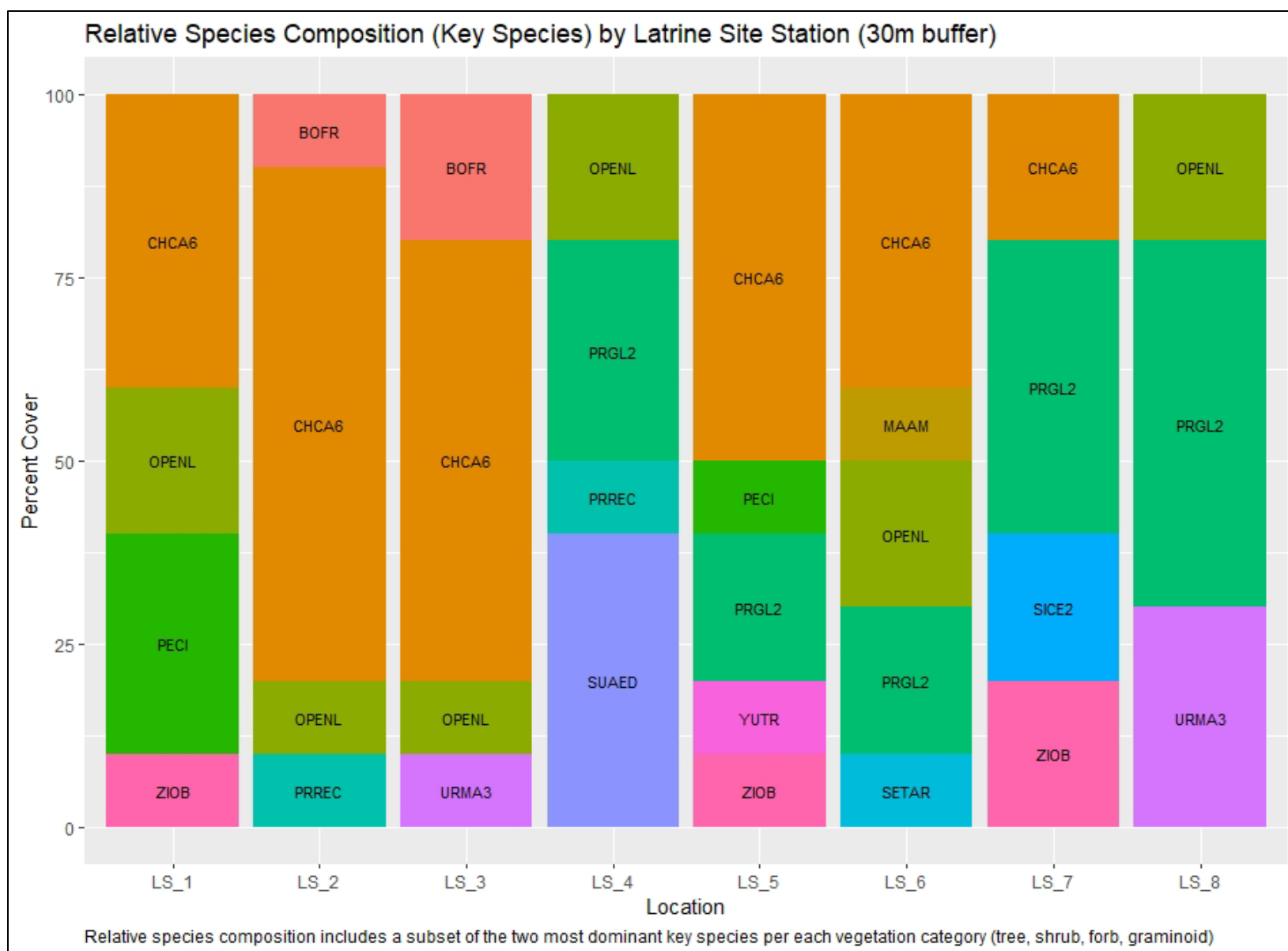


Figure D-7. Relative species composition (key species) by latrine site station (30m buffer).

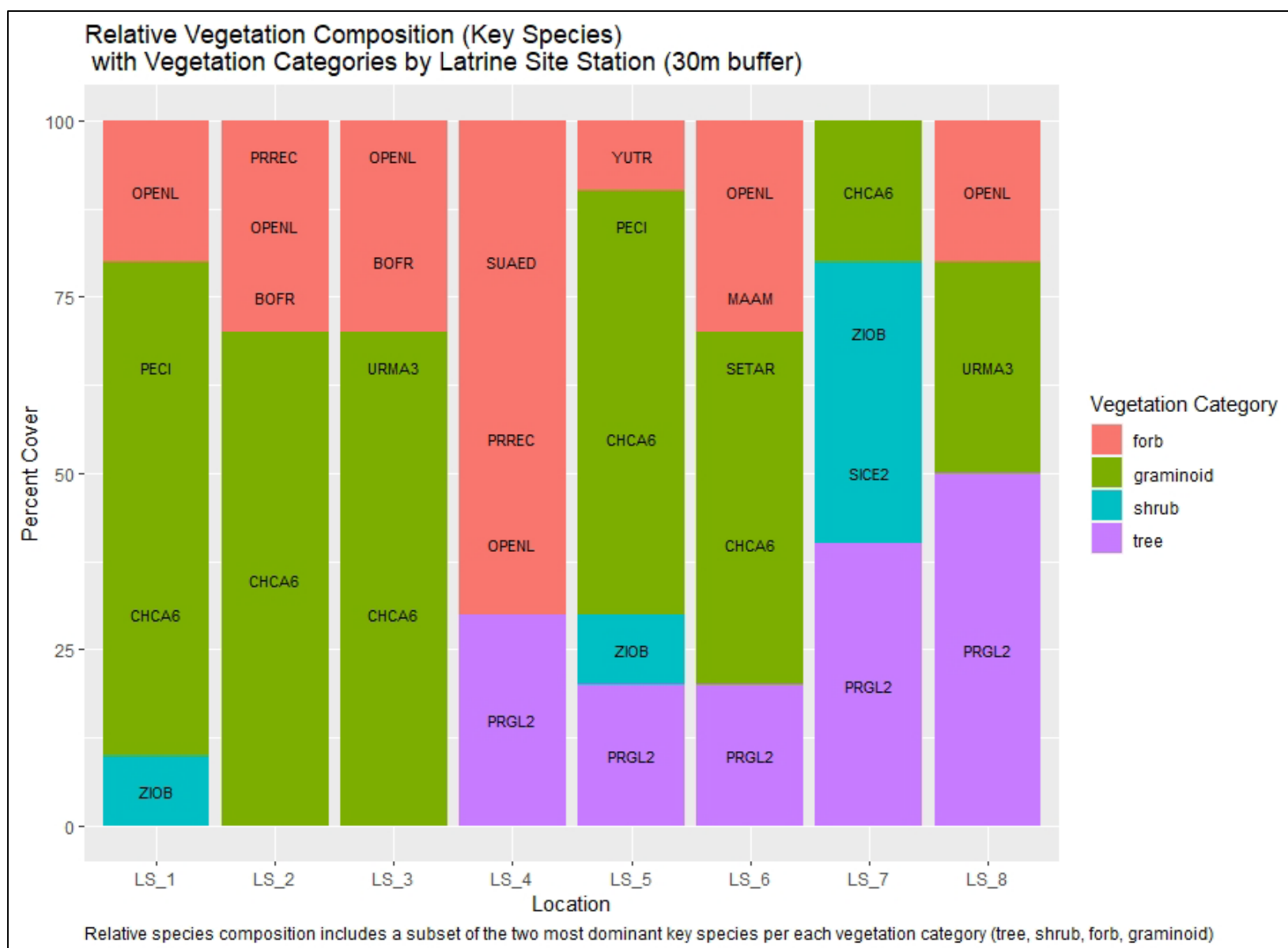


Figure D-8. relative vegetation composition (key species) with vegetation categories by latrine site station (30m buffer).

Woody Plant Cover and Structure

Tables

Table D-7. Summary values for woody plant cover and structure: Cover type (90m buffer).

Woody Plant Cover and Structure Cover Type	Variable	Camera Trap Stations		Latrine Site Stations	
		Square Meters	Percent Cover (90m buffer)	Square Meters	Percent Cover (90m buffer)
Tall Overstory, Closed Understory (TOCU)	min	0.000	0.000	0.000	0.000
	max	14771.039	58.000	19724.396	78.000
	range	14771.039	58.000	19724.396	78.000
	mean	938.062	3.650	3319.437	13.125
Tall Overstory, Open Understory (TOOU)	min	0.000	0.000	0.000	0.000
	max	24969.126	98.000	21237.921	83.000
	range	24969.126	98.000	21237.921	83.000
	mean	7477.990	29.400	9001.734	35.250
Mixed Vegetation Height (MVH)	min	0.000	0.000	0.000	0.000
	max	21464.545	84.000	11108.631	44.000
	range	21464.545	84.000	11108.631	44.000
	mean	2061.066	8.100	2764.005	10.875
No Overstory (NO)	min	43.813	0.000	39.766	0.000
	max	25450.000	100.000	25450.000	100.000
	range	25406.187	100.000	25410.234	100.000
	mean	14972.882	58.750	10364.823	40.625

Figures

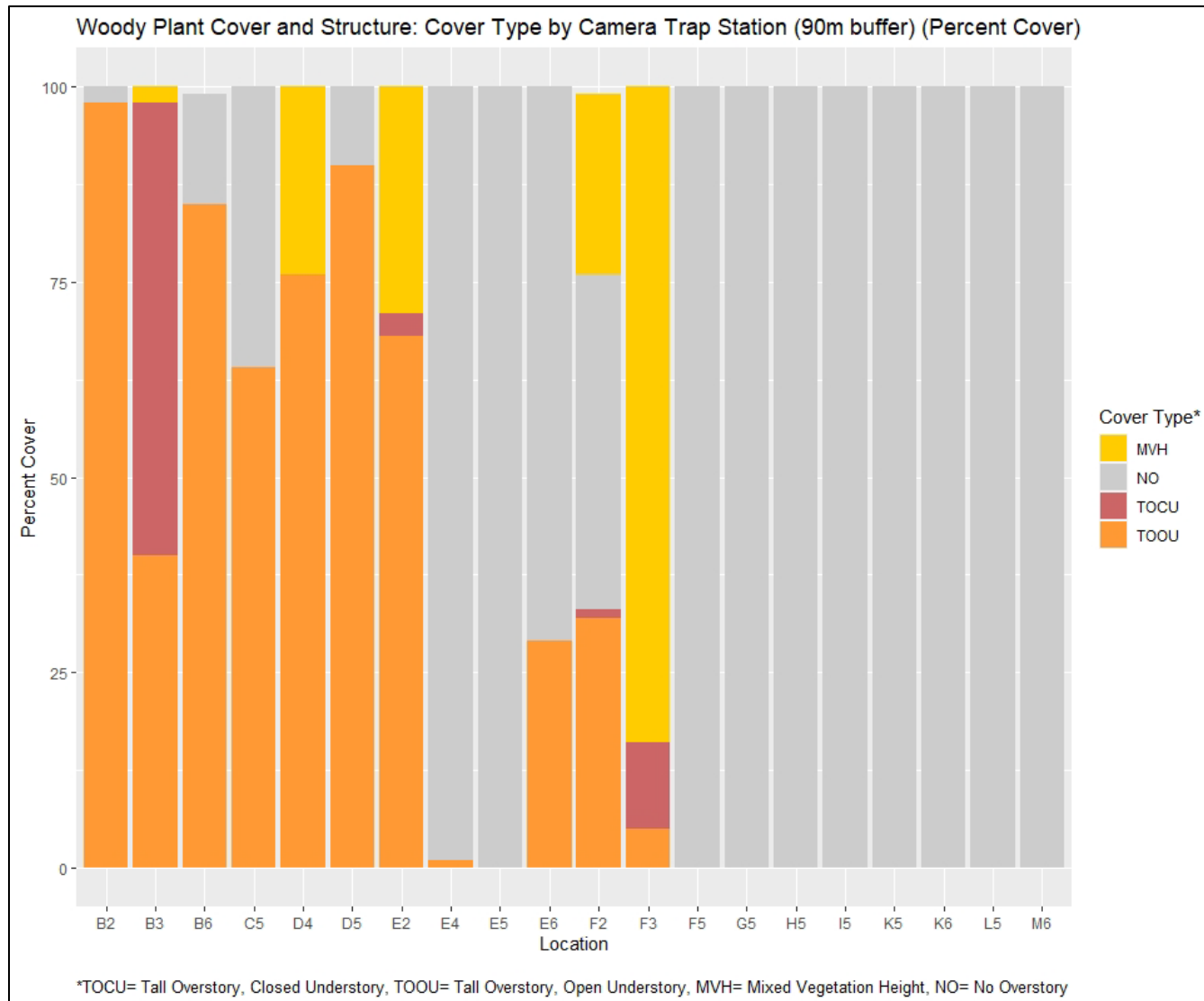


Figure D-9. Woody plant cover and structure: Cover type by camera trap station (90m buffer) (percent cover).

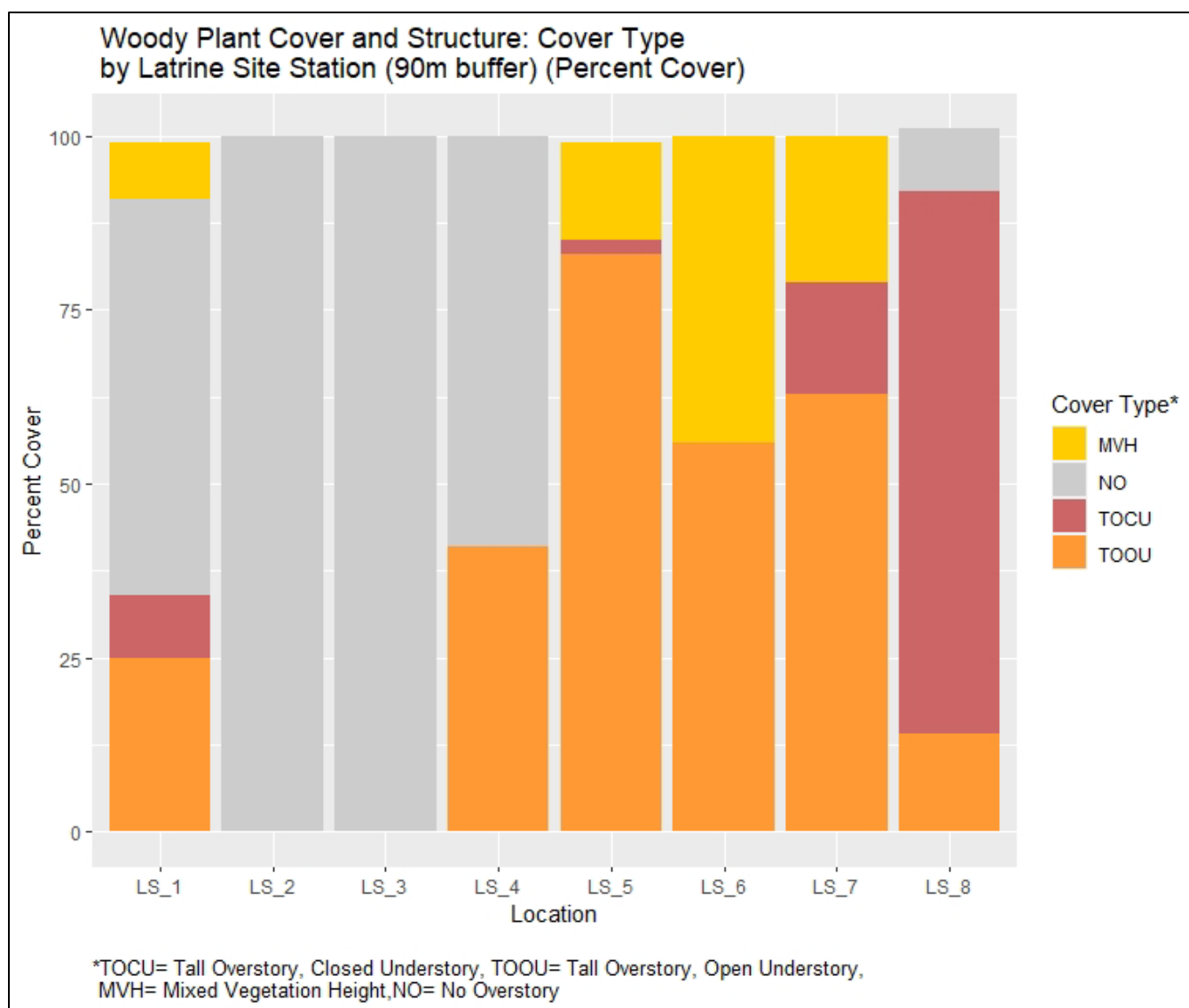


Figure D-10. Woody plant cover and structure: Cover type by latrine site station (90m buffer) (percent cover).

Inundation

Tables

Table D-8. Summary Values for Inundation by Location Type (90m buffer): March 2021-March 2022.

Station Type	Variable	March 2021 (square meters)	March 2021 (percent cover, 90m buffer)	March 2022 (square meters)	March 2022 (percent cover, 90m buffer)
Camera Trap	min	0.000	0.000	0.000	0.000
	max	6333.336	24.888	23119.710	90.855
	range	6333.336	24.888	23119.710	90.855
	mean	480.160	1.887	2999.330	11.787
Latrine Site	min	0.000	0.000	0.000	0.000
	max	5313.527	20.881	8138.235	31.981
	range	5313.527	20.881	8138.235	31.981
	mean	1463.952	5.753	3156.045	12.402

Figures

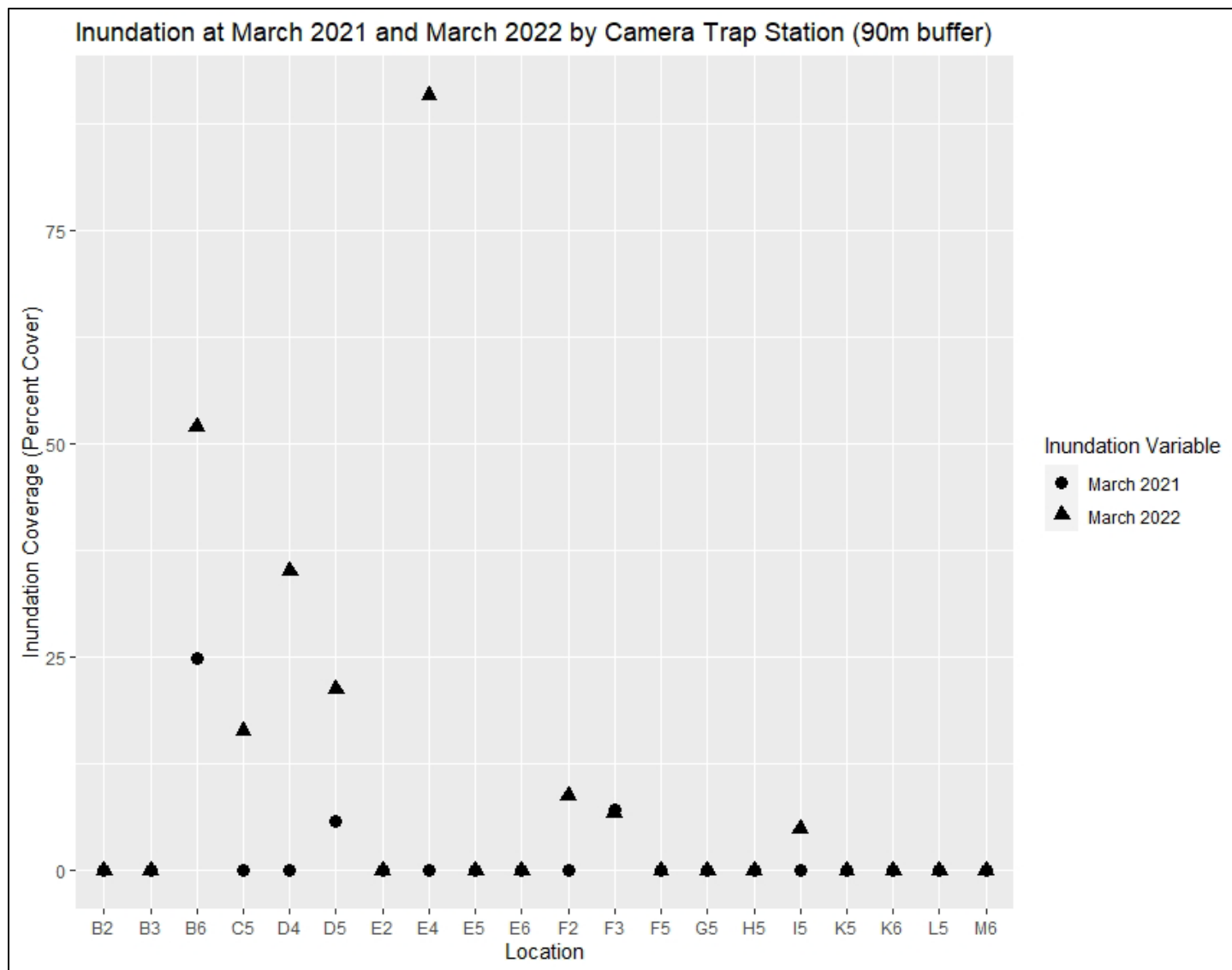


Figure D-11. Inundation at March 2021 and March 2022 by camera trap station (90m buffer).

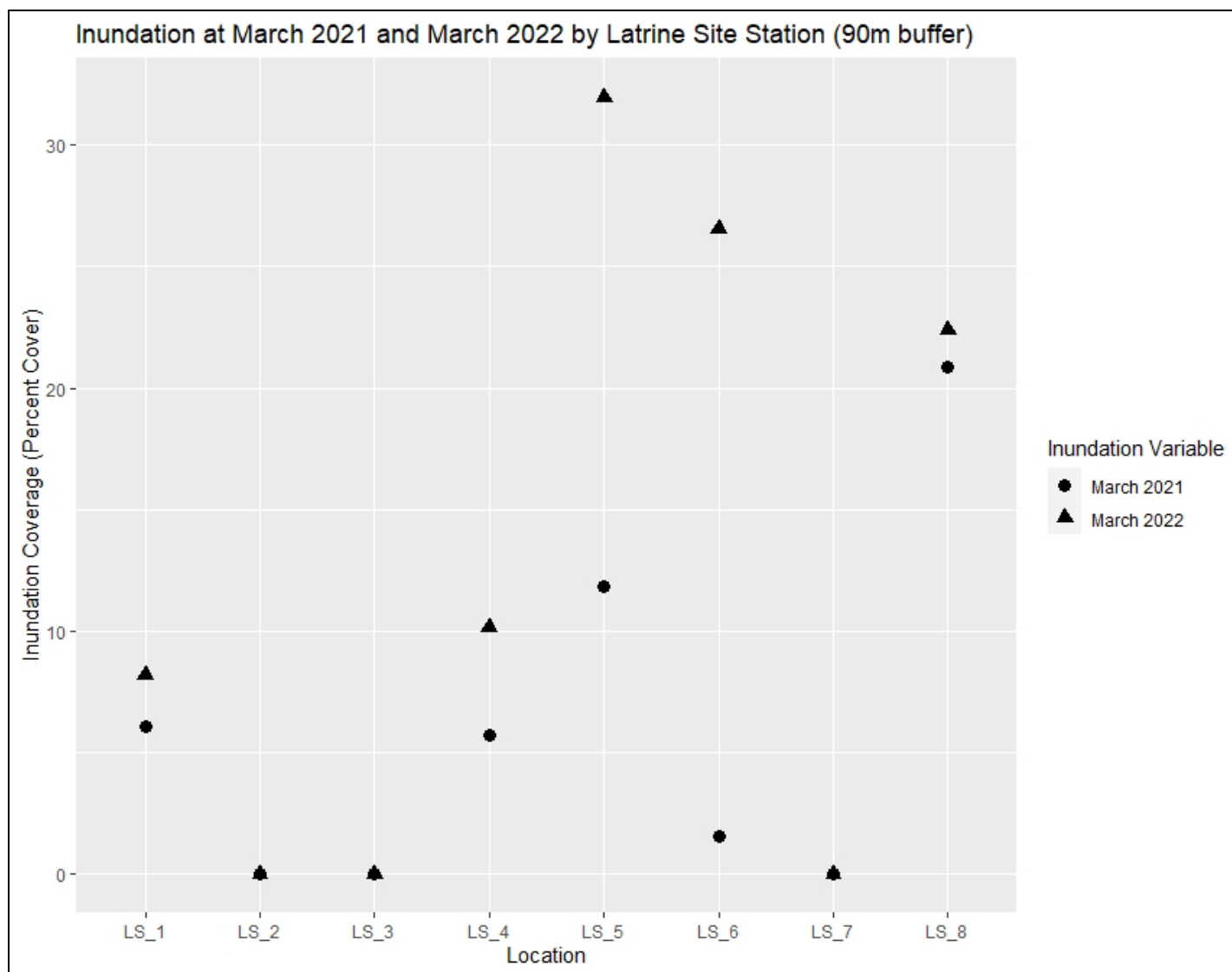


Figure D-12. Inundation at March 2021 and March 2022 by latrine site station (90m buffer).

Appendix E—Regression Analysis Results

Summary tables detailing all tested covariates and simple linear regression analysis results with significant correlations ($\Pr(>|t|) \leq .1$) for nilgai antelope at camera trap stations (Tables E-1 to E-2). Limited sample sizes for all other wildlife species precluded meaningful linear regression analyses such that solely nilgai antelope were analyzed.

Table E-1. List of Covariates tested by simple linear regression analysis (n=57).

Category	Variable
Woody Plant Cover & Structure (90 m buffer)	Percent Cover Tall Overstory, Closed Understory
	Percent Cover Tall Overstory, Open Understory
	Percent Cover Mixed Vegetation Height
	Percent Cover No Overstory
Species Proportion per Native & Grazing Categories	Introduced Proportion
	Introduced Native Proportion
	NA Proportion
	Native Proportion
	No Status Proportion
	No Grazing Proportion
	NA Grazing Proportion
Vegetation Categories-Relative Composition (Percent Cover)	Yes Grazing Proportion
	Total Water Cover
	Total Vegetation Cover
	Bare Ground (BG) Percent Cover
	Forb Percent Cover
	Shrub Percent Cover
	Tree Percent Cover
Vegetation Species-Relative Composition of Key Species (Percent Cover)	Water Percent Cover
	BARE GROUND (BG)
	BOFR
	CHCA6
	ERSE5
	FLIN2
	JUNCUS
	LENE2
	MAAM
	NYMPH
	OPENL
	PAAC3

Table E-1 (continued). List of Covariates tested by simple linear regression analysis (n=57).

Category	Variable
Vegetation Species-Relative Composition of Key Species (Percent Cover) (continued)	PECI
	PRGL2
	PRREC
	RAPH2
	SAGGI
	SETAR
	SICE2
	SOEL
	SPSP
	SUAED
	URMA3
	VAFA
	VEHA
	WATER (WT)
	2GRAM
Sum of Independent Detection Events per Sex and Age Classes (Nilgai Antelope)	Sum of Total Juveniles
	Sum of Total Subadults
	Sum of Total Females
	Sum of Total Individuals
	Sum of Total Adults
	Sum of Total Males
	Sum of Total Adult Females
	Sum of Total Detections
Other	Altitude

Table E-2. Significant regression analysis results.

Dependent Variable	Independent Variable	Estimate ¹	Standard Error ²	t-value ³	Pr(> t) ⁴	Significance Level ⁵
Sum of Adult Females	Sum.of.Total.Females	0.84783	0.02487	34.09	2.00E-16	***
	Sum.of.Detections	0.8458	0.0569	14.865	1.50E-11	***
	Sum.of.Total.Adults	0.44406	0.04288	10.356	5.20E-09	***
	Sum.of.Total.Juveniles	4.0887	0.3961	10.322	5.47E-09	***
	Sum.of.Total.Individuals	0.28999	0.02912	9.958	9.52E-09	***
	Sum.of.Total.Subadults	0.9871	0.1498	6.588	3.46E-06	***
	Sum.of.Adult.Males	0.835	0.19	4.394	0.00035	***
	Sum.of.Total.Males	0.5432	0.1387	3.916	0.00101	**
	OPENL	12.85	3.291	3.904	0.001039	**
	Introduced_Proportion	285.89	73.83	3.872	0.00112	**
	CHCA6	2.14	0.579	3.697	0.00165	**
	YesGrazing_Proportion	347.44	100.47	3.458	0.00281	**
	Native_Proportion	-181.48	68.19	-2.661	0.015898	*
	NoGrazing_Proportion	-208.66	86.64	-2.408	0.027	*
	SPSP	-1.1714	0.4988	-2.348	0.0305	*
	2GRAM	4.857	2.034	2.388	0.028106	*
	PRREC	-8.268	4.525	-1.827	0.0843	ns

¹ Estimate represents the estimated coefficient.

² Standard error is the standard error of the coefficient.

³ t-value is the t-statistic for the predictor variable calculated by dividing the Estimate by the Standard Error.

⁴ p-value corresponds to the t-statistic significance with an alpha level of $\alpha = .05$ used to determine significance.

⁵ Significance level indicator used to visually distinguish varying values of p-values: ns2 = 0.1–1, ns = 0.05–0.1, * = 0.01–0.05, ** = 0.001–0.01, and *** = 0–0.001.

Table E-2 (continued). Significant regression analysis results.

Dependent Variable	Independent Variable	Estimate ¹	Standard Error ²	t-value ³	Pr(> t) ⁴	Significance Level ⁵
Sum of Adult Males	Sum.of.Total.Males	0.68352	0.02219	30.81	2.00E-16	***
	Sum.of.Total.Subadults	0.94847	0.08285	11.448	1.07E-09	***
	Sum.of.Total.Adults	0.38096	0.03786	10.062	8.12E-09	***
	Sum.of.Total.Individuals	0.24986	0.02508	9.964	9.44E-09	***
	Sum.of.Detections	0.6258	0.1007	6.211	7.33E-06	***
	Sum.of.Total.Females	0.5341	0.1194	4.474	0.000293	***
	Sum.of.Adult.Females	0.61978	0.14105	4.394	0.00035	***
	Sum.of.Total.Juveniles	2.4643	0.6844	3.6	0.00205	**
	CHCA6	1.5622	0.5497	2.842	0.0108	*
	YesGrazing_Proportion	257.46	93.74	2.747	0.0133	*
	OPENL	8.406	3.305	2.543	0.0204	*
	SPSP	-0.8415	0.4494	-1.873	0.077466	ns
	Introduced_Proportion	142.86	79.26	1.802	0.0883	ns
Sum of Adults	Sum.of.Total.Individuals	0.65505	0.01144	57.241	2.00E-16	***
	Sum.of.Total.Subadults	2.3572	0.1545	15.259	9.68E-12	***
	Sum.of.Detections	1.7583	0.1221	14.404	2.54E-11	***
	Sum.of.Adult.Females	1.9283	0.1862	10.356	5.20E-09	***
	Sum.of.Total.Females	1.6455	0.1602	10.27	5.92E-09	***
	Sum.of.Adult.Males	2.2287	0.2215	10.062	8.12E-09	***

¹ Estimate represents the estimated coefficient.

² Standard error is the standard error of the coefficient.

³ t-value is the t-statistic for the predictor variable calculated by dividing the Estimate by the Standard Error.

⁴ p-value corresponds to the t-statistic significance with an alpha level of $\alpha = .05$ used to determine significance.

⁵ Significance level indicator used to visually distinguish varying values of p-values: ns² = 0.1–1, ns = 0.05–0.1, * = 0.01–0.05, ** = 0.001–0.01, and *** = 0–0.001.

Table E-2 (continued). Significant regression analysis results.

Dependent Variable	Independent Variable	Estimate ¹	Standard Error ²	t-value ³	Pr(> t) ⁴	Significance Level ⁵
Sum of Adults (continued)	Sum.of.Total.Males	1.5007	0.1721	8.721	7.02E-08	***
	Sum.of.Total.Juveniles	7.928	1.106	7.169	1.13E-06	***
	CHCA6	4.446	1.209	3.676	0.00173	**
	YesGrazing_Proportion	718.82	210.36	3.417	0.00307	**
	OPENL	24.544	7.308	3.359	0.0035	**
	Introduced_Proportion	505.41	170.87	2.958	0.00842	**
	SPSP	-2.339	1.052	-2.223	0.0393	*
	NoGrazing_Proportion	-393	185.8	-2.115	0.04865	*
	Native_Proportion	-306.4	151.4	-2.024	0.05805	ns
Sum of Detections	Sum.of.Adult.Females	1.09322	0.07354	14.865	1.50E-11	***
	Sum.of.Total.Adults	0.52333	0.03633	14.404	2.54E-11	***
	Sum.of.Total.Individuals	0.34063	0.02623	12.99	1.40E-10	***
	Sum.of.Total.Females	0.91446	0.07718	11.849	6.19E-10	***
	Sum.of.Total.Subadults	1.1817	0.1463	8.079	2.13E-07	***
	Sum.of.Total.Juveniles	4.3587	0.5897	7.392	7.41E-07	***
	Sum.of.Total.Males	0.7154	0.1327	5.39	4.02E-05	***
	Introduced_Proportion	338.96	80.81	4.194	0.000545	***
	CHCA6	2.5081	0.6425	3.904	0.00104	**
	OPENL	14	3.869	3.619	0.001964	**
	YesGrazing_Proportion	390.57	115.06	3.394	0.00323	**

¹ Estimate represents the estimated coefficient.

² Standard error is the standard error of the coefficient.

³ t-value is the t-statistic for the predictor variable calculated by dividing the Estimate by the Standard Error.

⁴ p-value corresponds to the t-statistic significance with an alpha level of $\alpha = .05$ used to determine significance.

⁵ Significance level indicator used to visually distinguish varying values of p-values: ns = 0.1–1, ns = 0.05–0.1, * = 0.01–0.05, ** = 0.001–0.01, and *** = 0–0.001.

Table E-2 (continued). Significant regression analysis results.

Dependent Variable	Independent Variable	Estimate¹	Standard Error²	t-value³	Pr(> t)⁴	Significance Level⁵
Sum of Detections (continued)	Native_Proportion	-226.78	74.28	-3.053	0.006845	**
	SPSP	-1.4961	0.5438	-2.751	0.0131	*
	NoGrazing_Proportion	-227.92	99.72	-2.286	0.03462	*
Sum of Individuals	Sum.of.Total.Adults	1.51826	0.02652	57.241	2.00E-16	***
	Sum.of.Total.Subadults	3.6389	0.1874	19.416	1.61E-13	***
	Sum.of.Detections	2.6526	0.2043	12.986	1.40E-10	***
	Sum.of.Total.Females	2.5065	0.2432	10.307	5.59E-09	***
	Sum.of.Adult.Males	3.388	0.34	9.964	9.44E-09	***
	Sum.of.Adult.Females	2.9187	0.2931	9.958	9.52E-09	***
	Sum.of.Total.Males	2.2996	0.2546	9.031	4.19E-08	***
	Sum.of.Total.Juveniles	12.167	1.644	7.4	7.30E-07	***
	CHCA6	6.955	1.802	3.859	0.00115	**
	YesGrazing_Proportion	1111.47	316.96	3.507	0.00252	**
	OPENL	38.25	10.96	3.491	0.00261	**
	Introduced_Proportion	777.52	258.8	3.004	0.00761	**
	SPSP	-3.59	1.599	-2.246	0.0375	*
	NoGrazing_Proportion	-613.3	281.1	-2.182	0.04263	*
Sum of Juveniles	Sum.of.Total.Females	0.17952	0.01687	10.64	3.41E-09	***
	Sum.of.Adult.Females	0.20923	0.02027	10.322	5.47E-09	***
	Sum.of.Total.Individuals	0.061859	0.008359	7.4	7.30E-07	***

¹ Estimate represents the estimated coefficient.

² Standard error is the standard error of the coefficient.

³ t-value is the t-statistic for the predictor variable calculated by dividing the Estimate by the Standard Error.

⁴ p-value corresponds to the t-statistic significance with an alpha level of $\alpha = .05$ used to determine significance.

⁵ Significance level indicator used to visually distinguish varying values of p-values: ns² = 0.1–1, ns = 0.05–0.1, * = 0.01–0.05, ** = 0.001–0.01, and *** = 0–0.001.

Table E-2 (continued). Significant regression analysis results.

Dependent Variable	Independent Variable	Estimate ¹	Standard Error ²	t-value ³	Pr(> t) ⁴	Significance Level ⁵
Sum of Juveniles (continued)	Sum.of.Detections	0.17257	0.02335	7.392	7.41E-07	***
	Sum.of.Total.Adults	0.09342	0.01303	7.169	1.13E-06	***
	Sum.of.Total.Subadults	0.20873	0.03871	5.392	4.00E-05	***
	CHCA6	0.5278	0.1212	4.353	0.000383	***
	Introduced_Proportion	67.346	16.103	4.182	0.00056	***
	OPENL	3.0125	0.7208	4.179	0.000563	***
	Sum.of.Adult.Males	0.16989	0.04719	3.6	0.00205	**
	Sum.of.Total.Males	0.11312	0.03335	3.392	0.00325	**
	YesGrazing_Proportion	76.905	23.046	3.337	0.00367	**
	NoGrazing_Proportion	-45.1	19.87	-2.27	0.03576	*
	Native_Proportion	-31.7	16.6	-1.909	0.07229	ns
	2GRAM	0.9936	0.4732	2.100	0.05013	ns
	SPSP	-0.2162	0.1185	-1.825	0.084628	ns
	PRREC	-1.83	1.028	-1.781	0.09176	ns
Sum of Subadults	Sum.of.Total.Individuals	0.26228	0.01351	19.416	1.61E-13	***
	Sum.of.Total.Adults	0.39379	0.02581	15.259	9.68E-12	***
	Sum.of.Total.Males	0.64364	0.05323	12.091	4.47E-10	***
	Sum.of.Adult.Males	0.927	0.08098	11.45	1.07E-09	***
	Sum.of.Detections	0.6633	0.0821	8.079	2.13E-07	***
	Sum.of.Total.Females	6.26E-01	8.73E-02	7.17E+00	1.12E-06	***

¹ Estimate represents the estimated coefficient.

² Standard error is the standard error of the coefficient.

³ t-value is the t-statistic for the predictor variable calculated by dividing the Estimate by the Standard Error.

⁴ p-value corresponds to the t-statistic significance with an alpha level of $\alpha = .05$ used to determine significance.

⁵ Significance level indicator used to visually distinguish varying values of p-values: ns = 0.1–1, ns = 0.05–0.1, * = 0.01–0.05, ** = 0.001–0.01, and *** = 0–0.001.

Table E-2 (continued). Significant regression analysis results.

Dependent Variable	Independent Variable	Estimate ¹	Standard Error ²	t-value ³	Pr(> t) ⁴	Significance Level ⁵
Sum of Subadults (continued)	Sum.of.Adult.Females	0.7161	0.1087	6.588	3.46E-06	***
	Sum.of.Total.Juveniles	2.9591	0.5488	5.392	4.00E-05	***
	CHCA6	1.7454	0.5085	3.432	0.00297	**
	YesGrazing_Proportion	281.64	88.21	3.193	0.00504	**
	OPENL	9.631	3.059	3.148	0.00556	**
	Introduced_Proportion	182.18	73.51	2.478	0.0233	*
	SPSP	-0.9499	0.4309	-2.204	0.04075	*
	NoGrazing_Proportion	-149.76	77.17	-1.941	0.0681	ns
	Native_Proportion	-111.36	63.33	-1.758	0.09568	ns

¹ Estimate represents the estimated coefficient.

² Standard error is the standard error of the coefficient.

³ t-value is the t-statistic for the predictor variable calculated by dividing the Estimate by the Standard Error.

⁴ p-value corresponds to the t-statistic significance with an alpha level of $\alpha = .05$ used to determine significance.

⁵ Significance level indicator used to visually distinguish varying values of p-values: ns2 = 0.1–1, ns = 0.05–0.1, * = 0.01–0.05, ** = 0.001–0.01, and *** = 0–0.001.

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