

**USE OF SUPPLEMENTAL FEEDING AND DELIVERY OF ORAL
TREATMENT FOR MANAGING WILDLIFE DISEASES:
A CASE STUDY OF IVERMECTIN USE IN SOUTH TEXAS**

A Thesis

by

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ABSTRACT

Biosurveillance of zoonotic diseases of public health concern is a necessary action to protect communities and animal health from potentially life-threatening effects. Many zoonoses have a wildlife component which presents a challenge for effective delivery of treatment to prevent disease. Bovine babesiosis (cattle fever) caused by infection with *Babesia bovis* or *B. bigemina* and vectored by two species of ticks, *Rhipicephalus microplus* and *R. annulatus*, had devastating impacts on the United States cattle industry in the late 1800's and the first half of the 20th century. Due to the continued presence of cattle fever ticks along the Texas-Mexico border and occasional outbreaks recorded beyond the permanent quarantine zone, treatment programs targeting wildlife, which also can be hosts in addition to cattle, are now being implemented. The use of corn treated with ivermectin, an anti-parasitic agent effective at killing fever ticks, has been identified as an effective method to treat white-tailed deer (*Odocoileus virginianus*) to prevent infestation with fever ticks. In Texas, many white-tailed deer populations are accustomed to consuming corn from supplemental feeders, and previous studies found feeding ivermectin treated corn is a successful method for controlling ticks on deer. Infested white-tailed deer were recently discovered in Port Mansfield, TX. However, on East Foundation's El Sauz Ranch, an adjacent property to Port Mansfield, Cattle fever ticks were not found. Therefore, as a preventative measure, ivermectin treated corn is being used to keep ticks from coming onto the property. The overall research goal is to evaluate the use of ivermectin-treated corn feeders for mitigating tick infestation. White-tailed deer were the primary target species in my study. Deer frequency and corn consumption data were collected from feeder stations utilizing infrared cameras to capture animal species and feeder visitation. The distance for 18 feeders on El Sauz Ranch relative to the study boundary fence line were categorized as near (<1.5 km), mid (1.5-2.5

km), and far (>2.5 km). Ivermectin treated corn consumption after pre-baiting for the treatment period (March-July 2020) was highest at near feeders, with an average consumption rate of 750 pounds, followed by far feeders (709 pounds) and mid feeders (629 pounds). Pre-baiting was conducted in December of 2019 and January of 2020. Due to visitation of larger male deer, it is likely that they are consuming more ivermectin corn and have a higher chance of receiving treatment for tick infestation. This study found that feed availability encouraged wildlife visitations throughout the year and pilot results suggest pre-baiting increased ivermectin treated corn consumption, which is recommended to aid in maintaining the current cattle fever tick free environment.

DEDICATION

I would like to dedicate this paper to my family. I also want to dedicate this paper to the East Foundation for allowing students such as myself the ability to pursue wildlife research in South Texas.

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I am grateful to Dr. Roel Lopez for providing guidance during this study. I also want to thank Dr. Tammi Johnson and Dr. Angela Clendenin for their guidance throughout this process. I would also like to thank Texas Animal Health Commission for providing the ivermectin corn consumption data. Finally, I would like to thank Dr. Mathew Kramm III for always pushing me forward both academically and as my father.

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INTRODUCTION

Diseases and Oral Treatments

Numerous infectious diseases remain viable and a threat to community and animal health in the United States and in many instances, free-ranging wildlife populations can serve important roles as hosts and reservoirs in the transmission cycle (Cross et al. 2007.) Wildlife can transmit disease without any influence by humans generally. While treating wildlife for diseases is challenging, current oral prophylactic treatments are readily available and have the potential to drastically reduce or even prevent diseases. Oral treatments to mitigate and treat infectious diseases have been used on a variety of wildlife and have proven to be a useful tool. Oral delivery has been used to treat for plague in black-tailed prairie dogs (*Cynomys ludovicianus*) in the mid-western United States (Creekmore et al. 2002) and in American black bears (*Ursus americanus*) to control sarcoptic mange (Wick et al. 2019). Use of baiting can serve to increase the efficacy of these oral treatments and have found success in many wildlife populations.

Baiting strategies have been implemented in South Texas to vaccinate free ranging coyotes (*Canis latrans*) for rabies (Farry et al. 1998). While rabies vaccination baits are available for other animals such as the gray fox (*Urocyon cinereoargenteus*) and raccoons (*Procyon lotor*), they must be specifically tailored towards each individual species. Based on gray foxes' preferences, dog food as well as fish meal and lard were used for the base of the rabies vaccination feed (Steelman et al. 2000). Oral rabies vaccination for wildlife in the United States has shifted to the raccoon variant while still preventing any potential re-emergence of coyotes and gray fox (Slate et al. 2009). Oral vaccinations for tuberculosis in the Australian brushtail possum (*Trichosurus vulpecula*) have been used in the endemic regions of New Zealand to prevent transmission of bovine tuberculosis (Tompkins et al. 2009). While oral treatments of

disease have been beneficial, they do not come without their challenges. Wobeser (2002) lists a set of criteria that oral treatments must meet for wide-scale distribution on wildlife populations. First, the treatment must be efficient at treating or vaccinating for a specific disease or ailment and safe for non-target animals to inadvertently ingest without lasting detrimental effects (Wobeser 2002). Second, the drug treatment must be able to withstand diverse environmental conditions. Rapid breakdown of oral medication renders the process in wildlife populations useless.

Oral treatments have not only been effective for various wildlife species but have played an important role in cervids. Cervid populations have been treated with a wide variety of oral treatments for many different reasons. White-tailed deer (*Odocoileus virginianus*) have been orally administered encapsulated diethylstilbestrol with the intent to curb overpopulation (Matschke 1977). White-tailed deer also have been treated with melatonin orally to monitor circadian rhythms in males (Bubenik and Smith 1987). Finally, red deer (*Cervus elaphus*) have been treated with orally administered copper oxide wire particles in their youth to observe growth rates (Wilson 1989).

Deer Feeders and Ivermectin

In addition to the selected medication being considered for a given treatment, delivering the medication successfully is also important in a wildlife disease mitigation program. For some species like white-tailed deer, an effective oral delivery system can include gravity feeders or mechanically dispensed feed. The ability of the feeders to deliver supplemental feed in conjunction with toxicants or medicines is popular in management programs. One issue that may occur is the potential for non-target species such as raccoons (*Procyon lotor*), feral hogs (*Sus scrofa*), avian species and other wildlife to interfere and consume supplemental feed intended for

deer (Cooper and Ginnett 2000, Rattan et al. 2010). Therefore, it is common practice to use fencing to minimize non-target species access to the treated feed. A fenced enclosure provides protection from other animals such as feral hogs and coyotes (*Canis latrans*) that could also potentially deter white-tailed deer visitation and feeder use. Another advantage of supplemental feed delivered through gravity or mechanical feeders is the option to manipulate the feed by adding protein pellets or flavor additives to increase feed attractiveness and nutrition.

Supplemental feed in combination with an acaricide such as ivermectin, can potentially serve to mitigate parasitic diseases by targeting arthropod vectors. Ivermectin is an antiparasitic agent that was introduced in the early 1980s and has been shown to be highly effective against arthropods such as cattle fever ticks (Campbell 1985). Campbell goes on to state that ivermectin can be traced in the excrement of the animals and can be administered orally or subcutaneously. Using deer feeders that have ivermectin-treated corn can provide additional benefits in a wildlife disease program. For example, when white-tailed deer seek out treated corn in feeders as their primary form of nourishment this will reduce the need to travel in search of food, further reducing the potential for transmitting vectors and infectious diseases (Garner 2001).

Pre-Baiting and Supplemental Use

There are many benefits to pre-baiting depending on overall wildlife management goals. Pre-baiting at specific locations used in conjunction with drop nets has been successful in the capture of wildlife (Silvy et al. 2020). Identification of pre-baited feed locations to lure animal species such as birds allows for successful netting and capture when individuals are in close proximity to the feed (Silvy et al. 2020). Pre-baiting for increased white-tailed deer visitation has been documented in multiple ways to include salt blocks used as an attractant during summer months or shelled corn during summer months as a supplement or in the fall as an attractant for

increased hunting success (Morgan and Dusek 1992, Naugle et al. 1995). In contrast, Edalgo and Anderson (2007) concluded that pre-baiting for small mammals did not contribute or improve capture success. Similarly, Barrett et al. (2008) examined various corn baits and determined no difference in large mammal capture success when using clover traps. The use of pre-baiting to increase the effectiveness of oral delivery treatments is poorly understood and requires further assessment.

Case Study: Cattle Fever and Ticks

Cattle fever or bovine babesiosis is an infectious disease caused by protozoan parasites of the genus *babesia*, specifically *Babesia bigemina* and *B. bovis*. In cattle, infection is generally accompanied by fever, respiratory complications, hemoglobinuria, and anemia; it is detrimental to naïve cattle (Smith and Kilborne. 1893). Bovine babesiosis is vectored by the cattle tick (*Rhipicephalus annulatus*) and southern cattle tick (*Rhipicephalus microplus*), as well as a third tick, *Rhipicephalus australis* in Australia. In South Texas, the tick vector has the potential infest and migrate on a range of wild and domestic mammals such as white-tailed deer, cattle, and other ungulates (George et al. 2002, Lohmeyer et al. 2018). The disease was considered eradicated from the U.S. by 1943, primarily via the elimination of disease vector populations, namely the cattle fever tick (*Rhipicephalus microplus* and *R. annulatus*). Eradication was achieved largely by efforts of the cattle fever tick eradication program (CFTEP) implemented by the United States Department of Agriculture (USDA) and the Texas Animal Health Commission in 1907 (Graham and Hourrigan 1977). As a result of the program, the tick eradication quarantine area (TEQA) still exists in Texas at its border with Mexico where both the tick vector and babesiosis parasites are endemic. The TEQA is a buffer zone that ranges in width from one quarter mile to 10 miles and extends for approximately 500 miles along the southern Texas to

prevent the reestablishment of fever ticks. Despite continued quarantine zones to mitigate the spread of cattle fever ticks, there has been re-emergence due to ticks being resistant to pesticides as well as changes in land use (Busch et al. 2014). Although cattle fever ticks were eradicated from the United States by 1943 (Racelis et al. 2012), the USDA Animal and Plant Health Inspection Service estimates that a resurgence of these ticks could have an economic impact exceeding \$3 billion today (USDA 2018).

While cattle are the primary hosts for cattle fever ticks, Graham et al. (1972), found mammals such as deer, nilgai (*Boselaphus tragocamelus*), and raccoons may serve as viable hosts, though they weren't preferred to their preferred host cattle, due to their ability to reach and mechanically remove ticks. This conclusion was substantiated by Cooksey et al. (1989) when she examined the contrasts between cattle and white-tailed deer as alternate hosts for cattle fever ticks. The study proposed that grooming techniques of white-tailed deer decreased the likelihood of these ticks to obtain a blood meal and complete engorgement. White-tailed deer may be suitable hosts for the fever tick, but cattle are preferred by the arthropod due to higher probability of completing the life cycle with minimal interruption from the host animal. Cooksey et al. 1989 and Cantu et al, 2007 determined both *Rhipicephalus annulatus* and *R. microplus* have been identified on white-tailed deer and other ungulates. Nilgai establishment in south Texas has complicated the mitigation of cattle fever ticks, as there are currently no USDA Cattle Fever Tick Eradication Program (CFTEP) approved methods for treatment on Nilgai (Lohmeyer et al. 2018).

Treatment of hosts, such as white-tailed deer, and the expansion of cattle fever ticks has been mitigated by effective uses of acaricide treated corn. Use of ivermectin treated corn has been shown to be an effective method to the treatment of wildlife populations including, free-

ranging and confined white-tailed deer, in minimizing tick infestations (Pound et al. 1996, Rand et al. 2000). Both studies concluded that feeding deer with ivermectin treated corn was effective in interrupting and/or reducing all life stages of ticks. Studies indicate treating white-tailed deer populations with ivermectin in co-inhabited areas with cattle should be considered as white-tailed deer can serve as a host and/or aid in transport of cattle fever ticks to other ungulates species, making eradication difficult (Kistner and Hayes 1970, Bram et al. 2002).

There is a constant threat of infestations in South Texas due to close proximity to Mexico where cattle fever ticks are endemic with potential for animal migration across the Texas border (Racelis et al. 2012). With increased acaricide resistance, tick density could remain high and increase the potential for infesting suitable hosts (Busch et al. 2014). In a recent study by Rodríguez-Vivas et al. (2013), *R. microplus* was determined to be the most economically important species of tick in Mexico. A year later, Rodríguez-Vivas et al. (2014) determined ivermectin resistant populations of *R. microplus* were identified in Mexico and Central America. Cattle fever tick populations resist to acaricides have been documented outside of the temporary eradication quarantine area (TEQA) that stretches along the Texas-Mexico border (Busch et al. 2014). De Waal and Combrink (2006) discussed the effectiveness of different tick control treatments and concluded that the use of acaricides to be the most cost-effective treatment for cattle fever. Gravity feeders designed to delivery acaricide treated corn shells to white-tailed deer have the potential to mitigate both arthropods and wildlife diseases. Based on this knowledge an outlined list of study objectives follows below.

Goals and Objectives

The overall goal of this research was to assess feeder usage and ivermectin corn consumption from feeders on East Foundation El Sauz Ranch, a property which cattle fever ticks

have never been found, in comparison to feeder usage in Port Mansfield where fever ticks have been documented in the past. The objectives of this study were to:

1. Assess feeder use and bait consumption
2. Determine wildlife feeder visitation frequency by species
3. Determine efficacy of pre-baiting to increase ivermectin corn consumption rates

STUDY AREA

The East Foundation's mission is to "promote the advancement of land stewardship through ranching, science, and education". East Foundation operates six separate ranches across South Texas that exceeds 80,937 ha, and employs ranchers, scientists, and support personnel to achieve their goals and objectives relating to land stewardship. Wildlife management plays an integral part of rangeland sustainment by using experienced ranchers working in conjunction with wildlife managers and scientists. This study was conducted on the East Foundation El Sauz Ranch, that encompasses 11,082 ha, with most of the land located in Willacy County and the northern section of the ranch located in Kennedy County, Texas (Figure 1).

Vegetation cover types on the East Foundation El Sauz are comprised primarily of grasslands and shrublands, with small patches of woodlands, wetlands, and early seral plant communities. The topography is primarily level with some rolling hills (Beasom and Scifres 1977), with honey mesquite (*Prosopis glandulosa* var. *glandulosa*) overstory, accounting for over 70% of the woody plant density. Other woody species include huisache (*Acacia farnesiana*), spiny hackberry (*Celtis pallida*), lime pricklyash (*Zan thoxylumfagara*), and bluewood (*Condalia obovate*). The soil composition at El Sauz Ranch is primarily Delfina and Lozano sandy loam.

El Sauz Ranch is home to a variety of native and non-native wildlife species such as white-tailed deer, bobcat (*Lynx rufus*), nilgai antelope (*Boselaphus tragocamelus*), and feral hogs. White-tailed deer were the primary target species of the study where annual survey data estimates white-tailed deer density to be approximately 1 deer/18 ha.

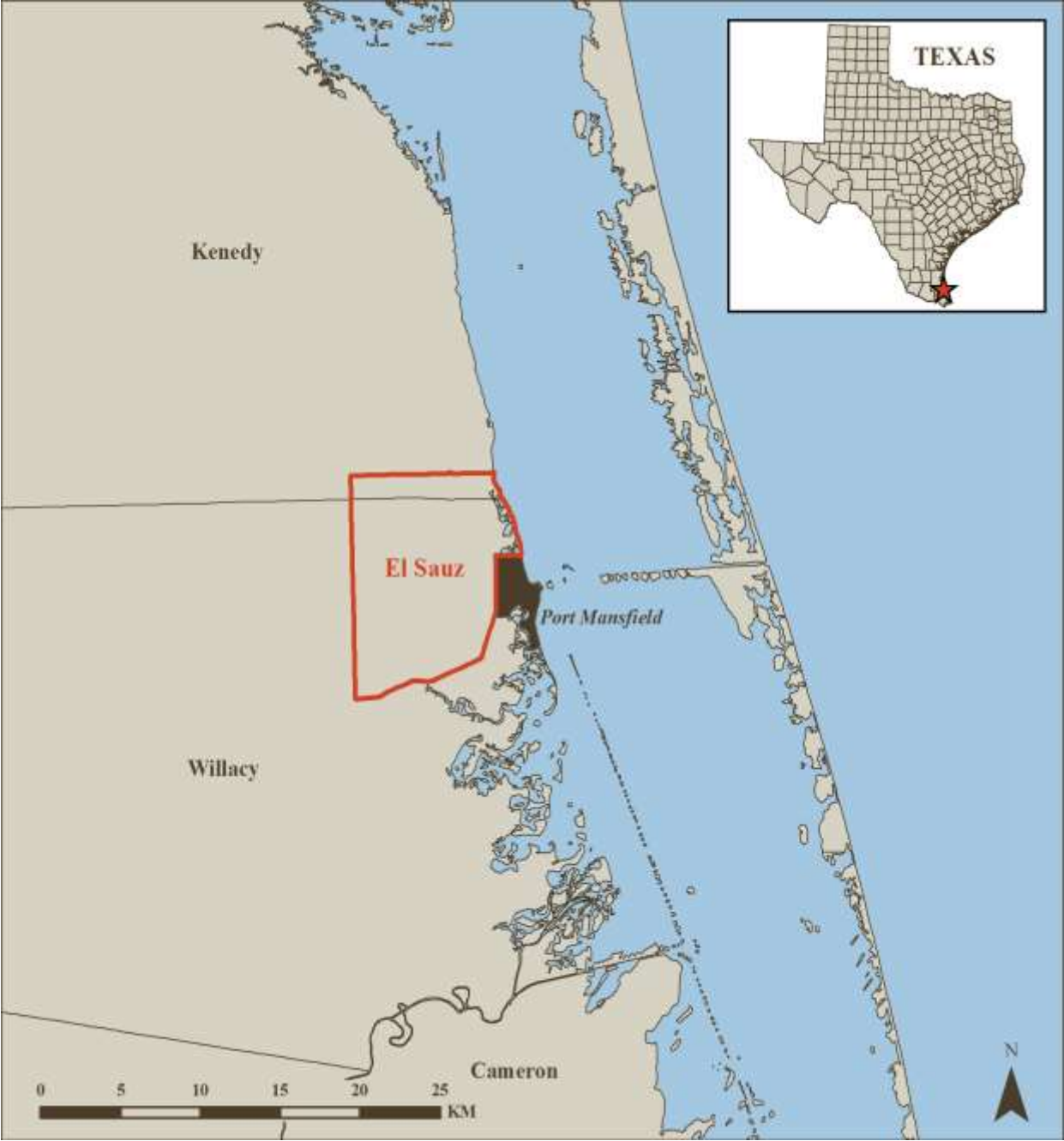


Figure 1. Study area location of El Sauz Ranch and Port Mansfield in South Texas, 2020.

METHODS

Feeder Use and Bait Consumption

Data were collected from 18 feeder stations on El Sauz Ranch targeting white-tailed deer between 9 April 2019 until 30 July 2020 (Figure 2). Feeders 227-230, 234, 236, 264 were accessible just off the entrance main road, while the remainder of the feeders were located within pasture centers. Deer feeders were maintained with shelled corn (both treated and untreated, depending on the timing of the study) throughout the period of study. Feeders were filled with ivermectin treated corn from March to July of each year and were either emptied or capped for the remainder of the year. Bait consumption was monitored through monthly checks of feeders and used to determine bait consumption trends over time.

In addition to the 18 feeders at El Sauz, three feeders at Port Mansfield also were monitored (Figure 2). All 21 feeders were Boss Buck™ gravity head feeders (GSM Outdoors, Grand Prairie, Texas), capable of holding 350-pounds of feed with three separate feed ports and were monitored with game cameras (Figure 3-4). Feed ports were at a 10-degree angle to allow for even distribution of corn and a drain hole to prevent any water from sitting in the feed (Figure 4).



Figure 2. Property boundary of El Sauz Ranch (red) and Port Mansfield (blue) with numbered deer feeders, 2020

Feeder use was monitored using infrared game cameras (Browning® Strike Force HD Pro Game Cameras, Morgan, Utah) due to their cost effectiveness in capturing photos in a variety of weather conditions (Brown and Gehrt 2009). Infrared camera technology has been implemented in wildlife studies to monitor activity for almost 50 years (Cutler and Swann 1999) and has been shown to provide quality monitoring data for wildlife research studies.

Feeder Visitation by Species

Since the development of infrared motion triggered cameras, images that were once difficult to capture or observed in certain environmental conditions can now be readily obtained (Cutler and Swann 1999). Motion triggered camera images were captured using 18 Browning® Strike Force HD Pro Game Cameras (Browning, Morgan, Utah) allowing for both day and nighttime images, set at 10-minute intervals between each capture event to minimize duplications and maintain independence between photo captures. All cameras were zip-tied to the surrounding fence enclosing each feeder station, and each camera was set three feet off the ground as the ideal height to capture images of white-tailed deer and other wildlife species (Figure 4). The game cameras were set at each feeder location throughout the duration of the study (Figure 2).



Figure 3. Browning Strike Force HD Pro trail camera used at El Sauz Ranch, 2020.



Figure 4. Deer feeder with exclusionary fence at El Sauz Ranch, 2020.

Game cameras were unaffected by weather conditions with a few exceptions where some images were hazy due to heavy fog conditions. Throughout the 15-month study, weather conditions were mostly consistent with occasional rainfall that rarely impacted game cameras continuing to take wildlife pictures. Occasionally, game cameras would be disturbed by wildlife entering and exiting the enclosure. Images captured by the infrared motion triggered game cameras were classified into groups by animal species. Species groups consisted of birds, feral hogs, raccoons, deer, and other (i.e., coyote, cattle, and nilgai). Each animal group was classified as “in” or “out” depending on whether the image captured the specific animal inside or outside feeder enclosures. Deer photo assignments were more specific with classifications of male, female, or an unknown gender, while still allowing for inside and outside differentiation. “Other” encompassed any animal that was not a species group choice. These consisted primarily of coyote, cattle, and nilgai.

Efficacy of Pre-baiting

Texas Animal Health Commission (TAHC) was responsible for the delivery and removal of ivermectin treated corn to all 18 feeders on El Sauz Ranch during the months of March to July 2019 and 2020. From August through February, the feeders on El Sauz Ranch were emptied or capped to prevent access to ivermectin treated corn. Emptied feeders allowed for pre-baiting to assess visitation rates. In December 2019, pre-baiting was conducted at four feeders (239, 241, 242, 243) with 150 pounds of untreated corn for that month. In January 2020, nine feeders were pre-baited (233, 235, 237, 238, 239, 240, 241, 242, 243), four from the previous list and an additional five new feeders. All feeders were filled with 100 pounds of untreated corn. The first four feeders (239, 241, 242, 243) received 250 pounds of untreated corn in total.

RESULTS

Feeder Use and Bait Consumption

Ivermectin treated corn consumption was monitored March-July 2019 and March-July 2020. Corn consumption data from both years allowed for preliminary pre-baiting results at half the feeder stations on El Sauz Ranch. Post hoc, deer feeders were categorized based on distance from property boundary to determine if there was differential use of feeders. Distance categories for the 18 feeders on El Sauz were: near (<1.5 km), mid (1.5-2.5 km), and far (>2.5 km) from the El Sauz property boundary (Table 1). Consumption data for 2020 shows a sizeable increase in consumption closer to the study area perimeter fence (Figure 16). Total corn consumed in 2019 was 8,835 pounds of corn combined between all distance regions. Corn consumption in 2020 totaled 12,865 pounds among the three distance regions (Figure 5). With consumption data for each individual feeder for 2019 and 2020, I was able to accurately compare and identify which distance region changed (Figures 6-7) (Table 1). Ivermectin corn consumption was highest among the near feeders with a feeder mean consumption of 685 pounds in 2019 compared to 750 pounds in 2020. Mid feeders averaged 380 pounds in 2019 while mid feeders in 2020 averaged 629 pounds (Figures 8-9).

Table 1. Ivermectin corn consumption (pounds/kilograms/feeder) from 6 March - 10 July 2019 and 6 March - 30 July 2020 on El Sauz Ranch. Feeders categorized by distance (km) to El Sauz property boundary fence line.

Feeder	Distance (km)	Distance Category*	Consumption (lbs/kg)	
			2019	2020
228	0.3	Near	600 / 272	705 / 320
229	0.3	Near	650 / 295	975 / 442
230	0.3	Near	900 / 408	825 / 374
227	0.4	Near	850 / 385	725 / 329
234	0.5	Near	900 / 408	950 / 431
237	1.0	Near	470 / 213	550 / 250
231	1.1	Near	400 / 181	645 / 293
236	1.3	Near	830 / 376	470 / 213
239	1.4	Near	560 / 254	900 / 408
238	1.6	Mid	575 / 261	1000 / 454
243	1.8	Mid	175 / 80	700 / 318
232	1.9	Mid	50 / 22	570 / 259
264	2.2	Mid	750 / 340	400 / 181
235	2.3	Mid	350 / 159	475 / 215
240	2.6	Far	0 / 0	675 / 306
233	3	Far	200 / 91	900 / 408
241	3.2	Far	225 / 102	700 / 318
242	3.7	Far	350 / 159	700 / 318

*Feeders categorized by distance (km) to El Sauz property boundary fence line. Distance categories: Near (<1.5 km), Mid (1.5-2.5 km), Far (>2.5 km).

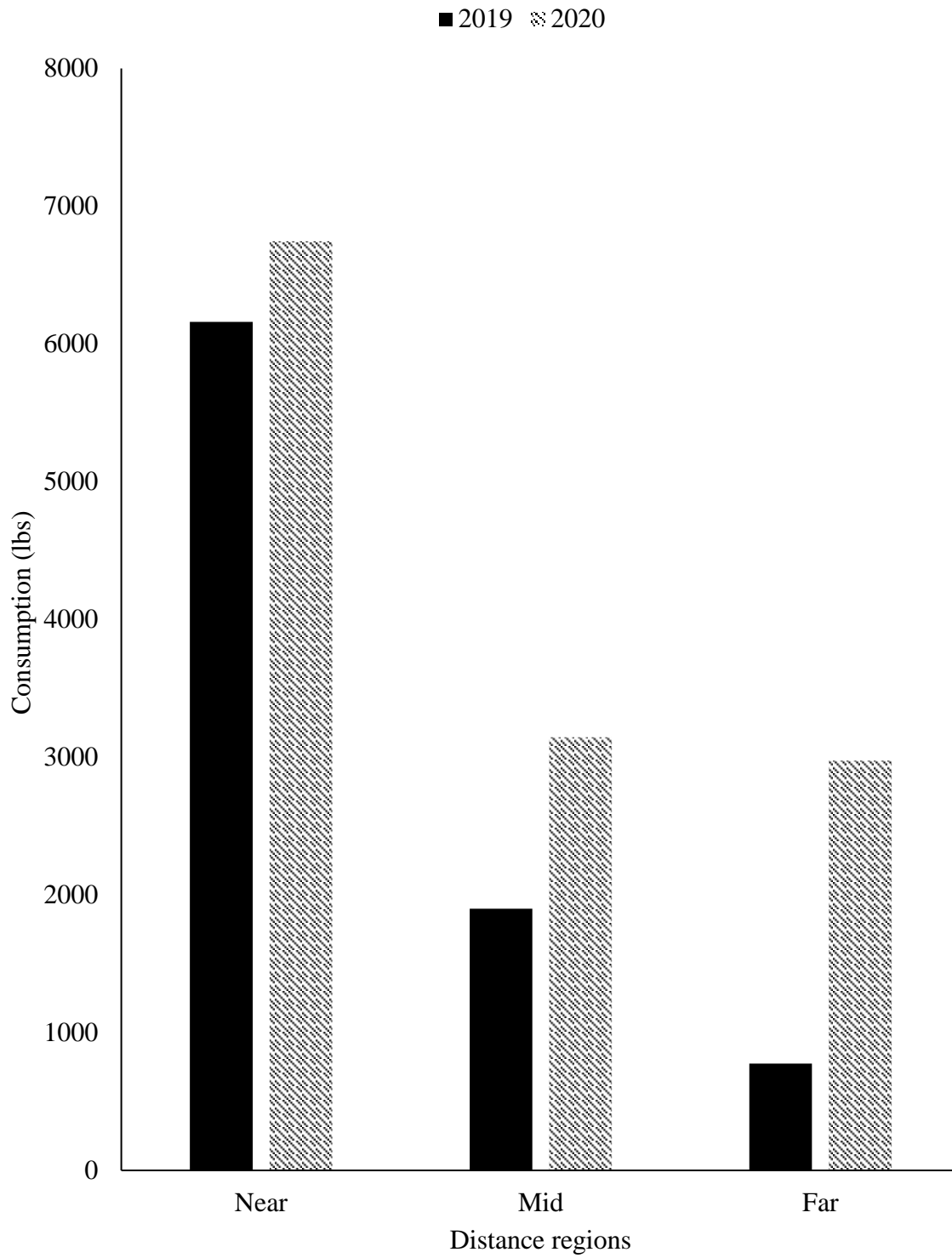


Figure 5. Ivermectin corn consumption by feeder, 2019 and 2020. El Sauz Ranch.

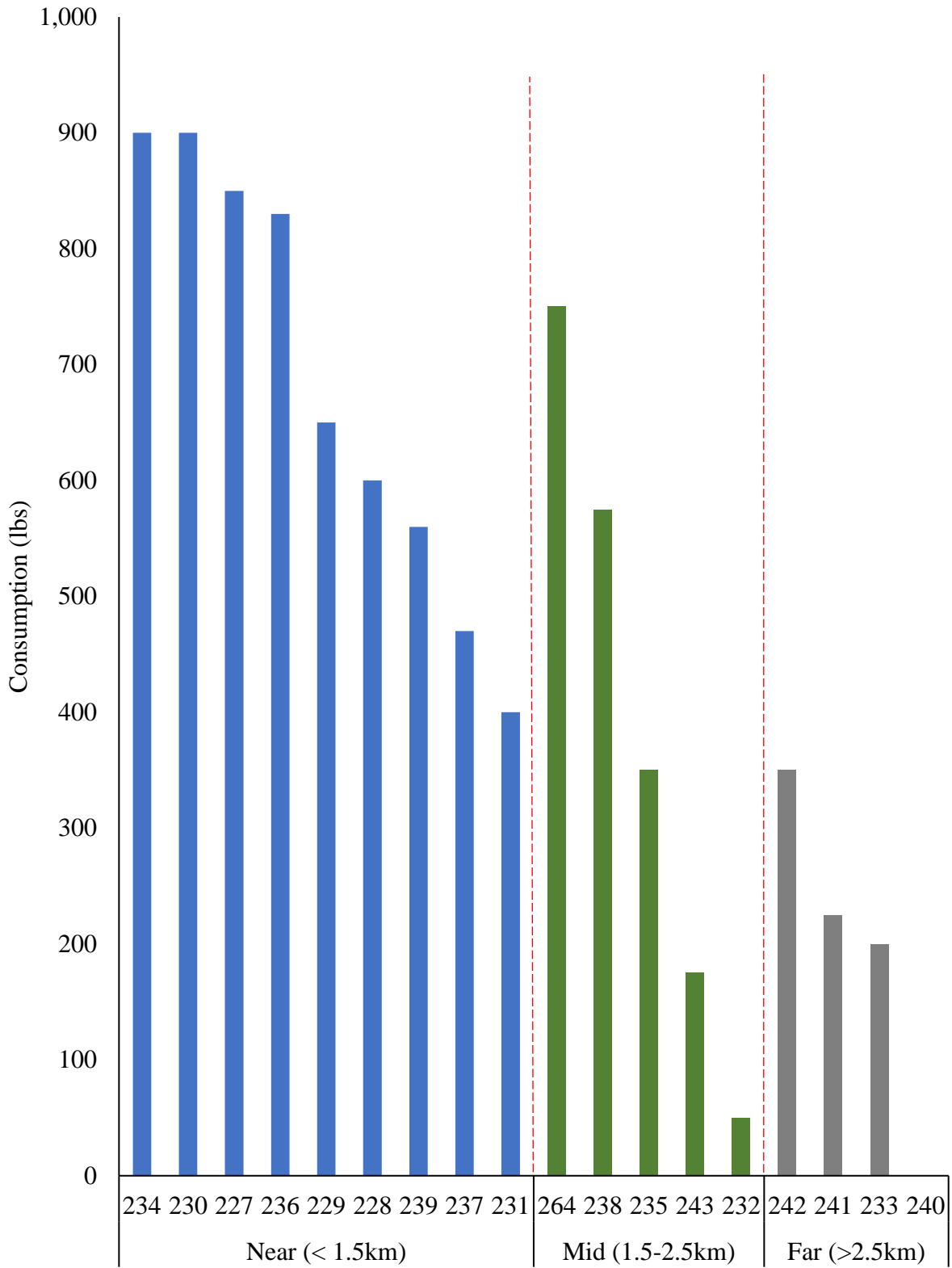


Figure 6. Total corn consumption (pounds/feeder) categorized by distance to property fence line, El Sauz Ranch from 6 March – 10 July 2019.

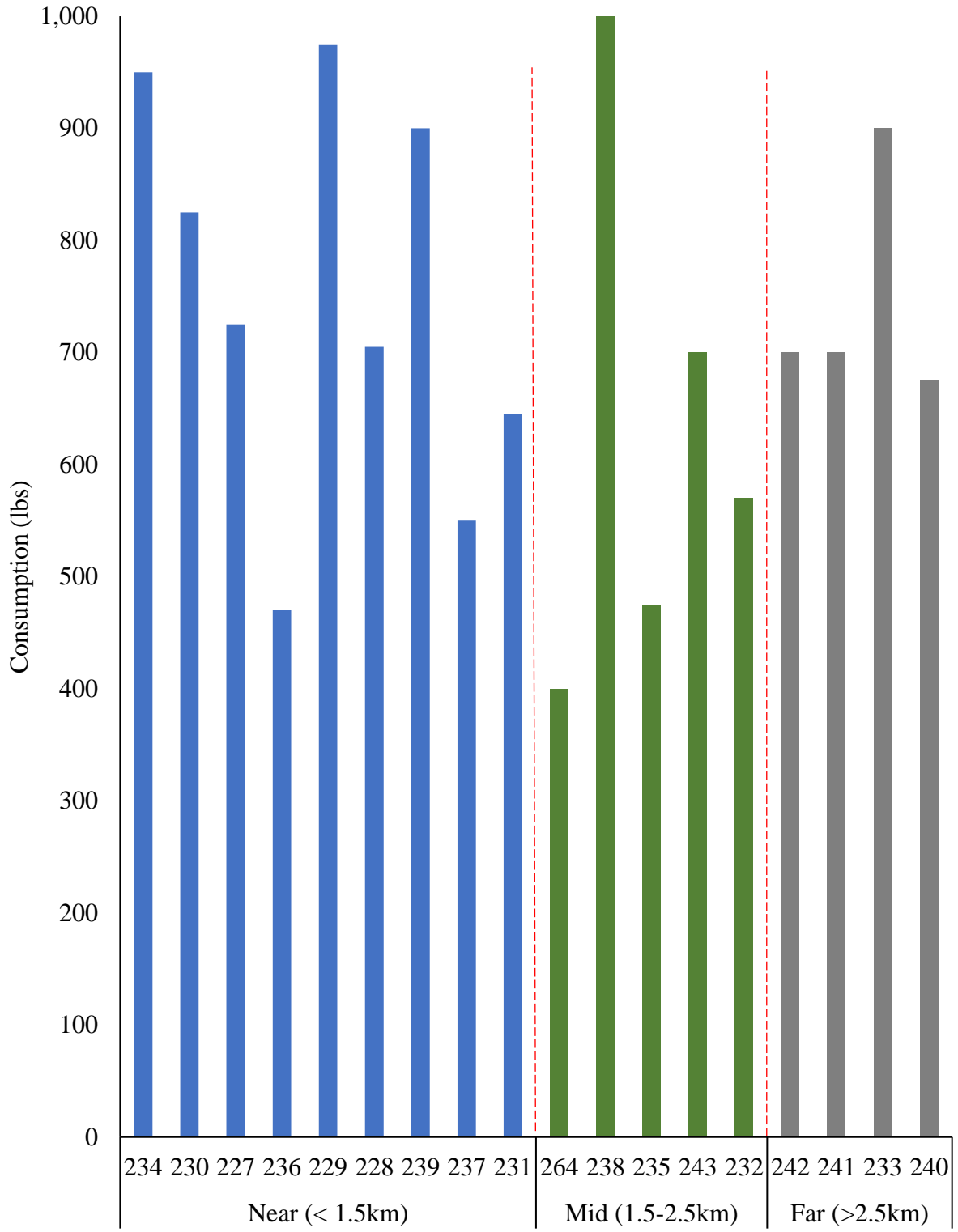


Figure 7. Total corn consumption (pounds/feeder) categorized by distance to property fence line, El Sauz Ranch, 6 March – 22 July 2020.

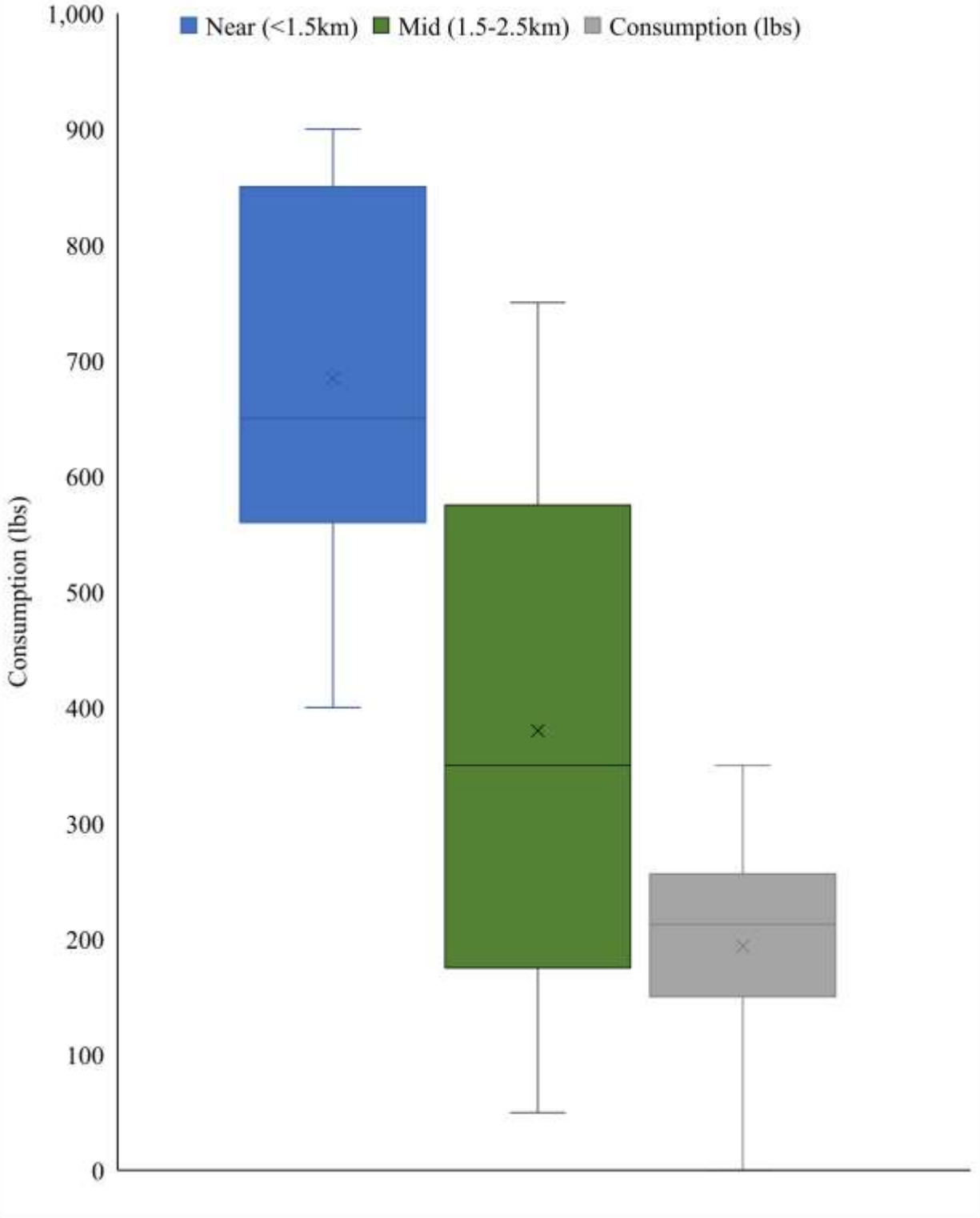


Figure 8. Box plot of total feed consumption grouped by feeder distance, El Sauz Ranch, 6 March 2019 – 10 July 2019.

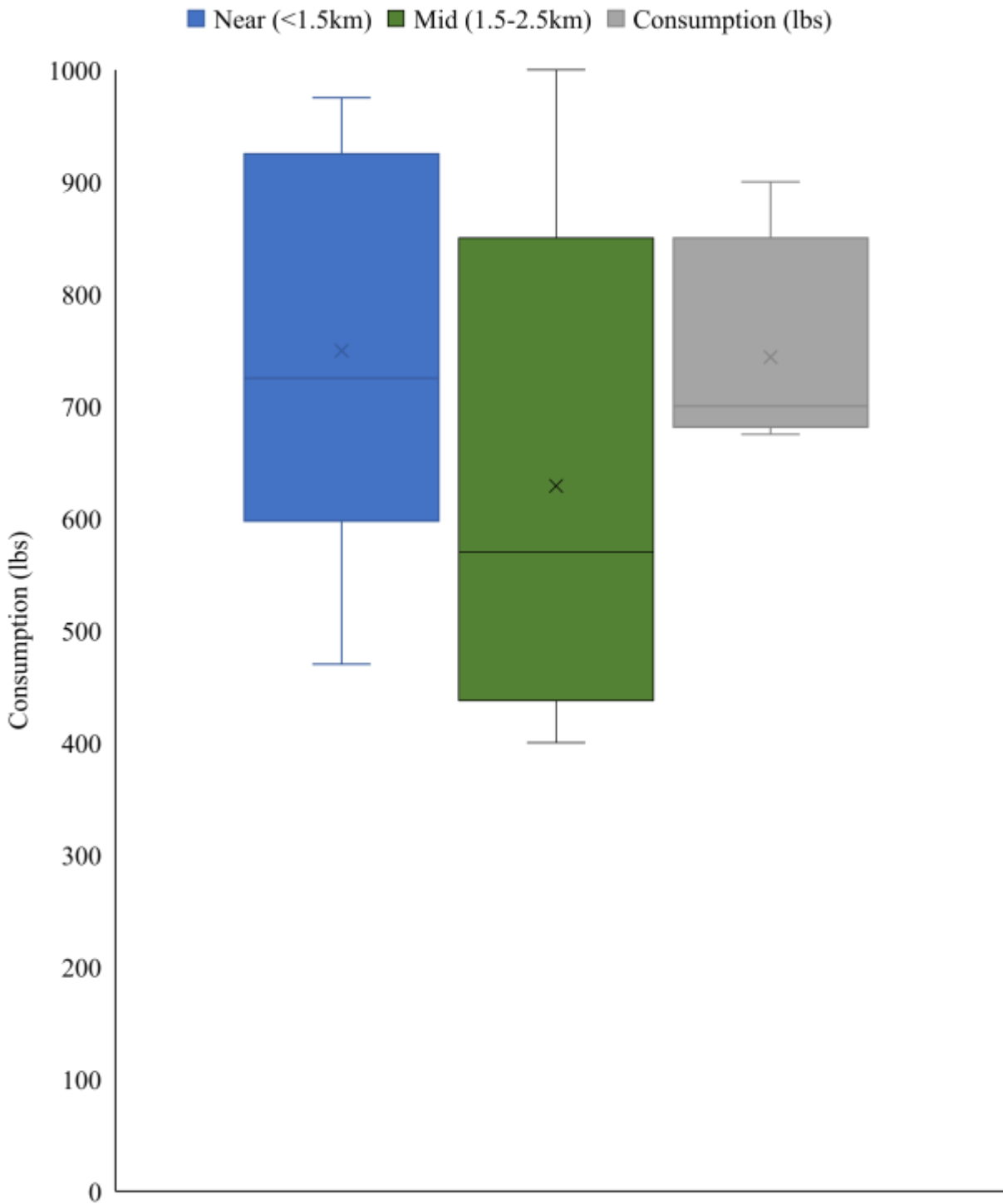


Figure 9. Box plot of total feed consumption grouped by feeder distance, El Sauz Ranch, 6 March 2020 – 22 July 2020.

Feeder Visitation by Species

Species observations from the 18 feeders on El Sauz Ranch revealed most visitations were by raccoons, birds, and male deer. Raccoons had over 15,000 visitations (Table 2) followed by various avian species (13,006 visitations) observed on or inside the feeder enclosure throughout the study. Male deer were observed more than six times more often at the feeder stations than female deer (Figures 10-12). Male deer had 11,956 visitations inside the feeder enclosures compared to 1,900 female deer visitations (Figure 14) (Table 2). In contrast, species visitations at Port Mansfield feeders were primarily avian species and white-tailed deer (Table 2). At Port Mansfield, buck visitations were 2,951 and does were 1,378 inside the feeder enclosures (Figure 13). Visitations by distance groups saw near and far feeders with the most visitations while mid feeder distance group was the least visited by wildlife (Figure 10). Non-targets made up most observed visitations on El Sauz Ranch (Figure 15). The “other” group of observations had less than 40 observations inside the feeder enclosure that were primarily coyote and bobcat. Other visitations outside the enclosure were mainly cattle, feral hogs, and nilgai. Feral hogs were seen at a relatively high rate at Port Mansfield feeders due to a breach in the fence enclosures at one site, which allowed for large groups to come inside the feeder station. While observations for groups such as raccoons, white-tailed deer, and avian species were extremely high, it is important to note the density of these species is not reflected through the observations taken at 10-minute intervals. Instead, camera data should be viewed as an index to population numbers and are relative in nature. Some species often spent over 10 minutes while feeding, which likely resulted in multiple photos of the same individual.

Table 2. Total wildlife observations (*n*, inside/outside exclusionary fence) on El Sauz Ranch and Port Mansfield feeders, 9 April 2019 – 30 July 2020.

Common Name	Scientific Name/Group	El Sauz		Port Mansfield	
		In	Out	In	Out
Bird	Avian	13,006	247	2,729	0
Female Deer	<i>Odocoileus virginianus</i>	1,900	238	1,378	3
Male Deer	<i>Odocoileus virginianus</i>	11,956	656	2,951	17
Deer Unknown	<i>Odocoileus virginianus</i>	93	156	1,152	7
Hog	Suidae	1	243	824	0
Other*	Other	38	645	26	49
Raccoon	<i>Procyon lotor</i>	15,163	23	240	0

* Includes observations of nilgai, bobcat, domestic cat, and coyote.

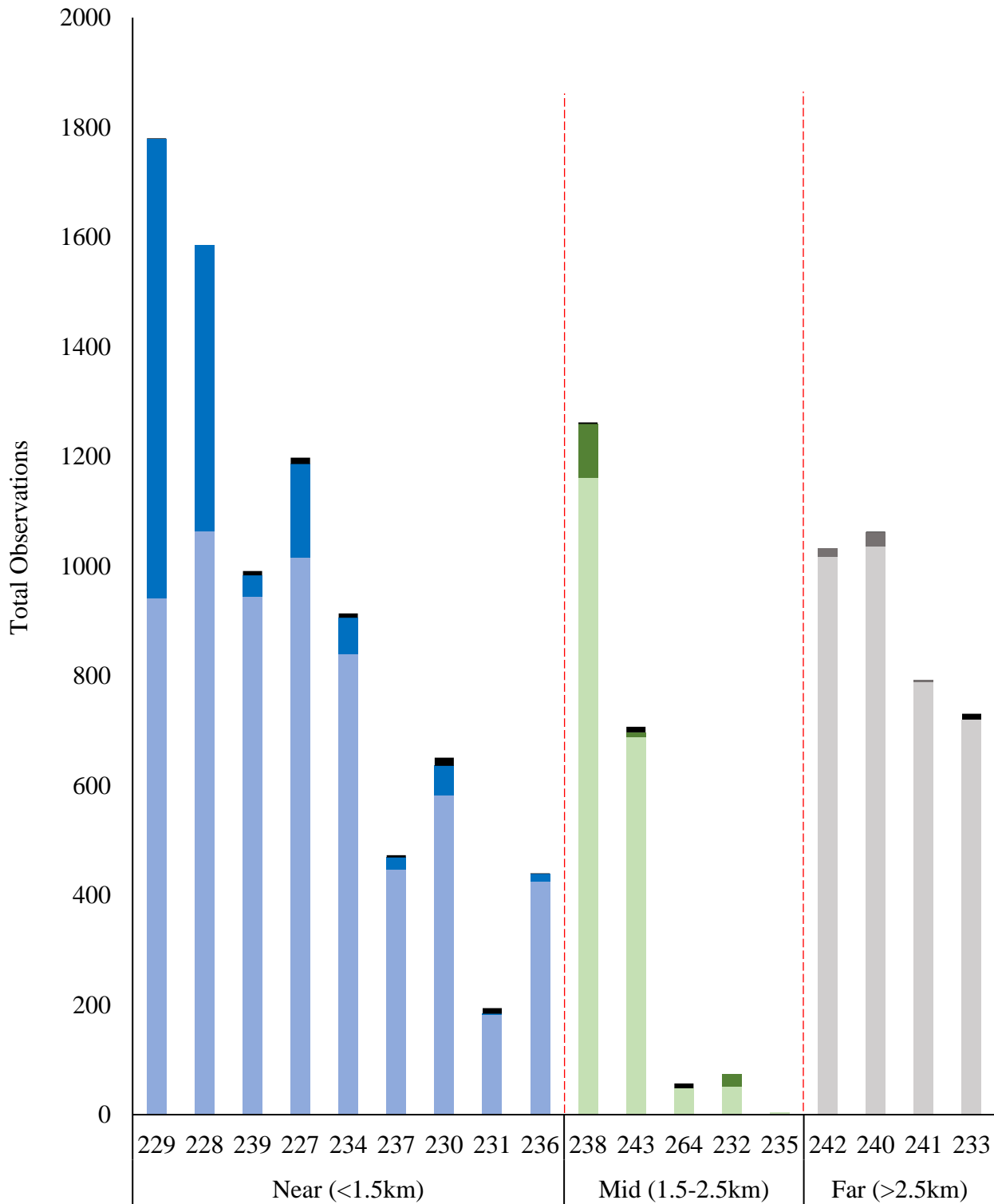


Figure 10. Total white-tailed deer observations inside exclusionary fencing by feeder ($n = 18$), gender (male = light shade, female = dark shade, unknown = black), and distance group (near, mid, and far,), El Sauz Ranch, 9 April 2019 – 30 July 2020.

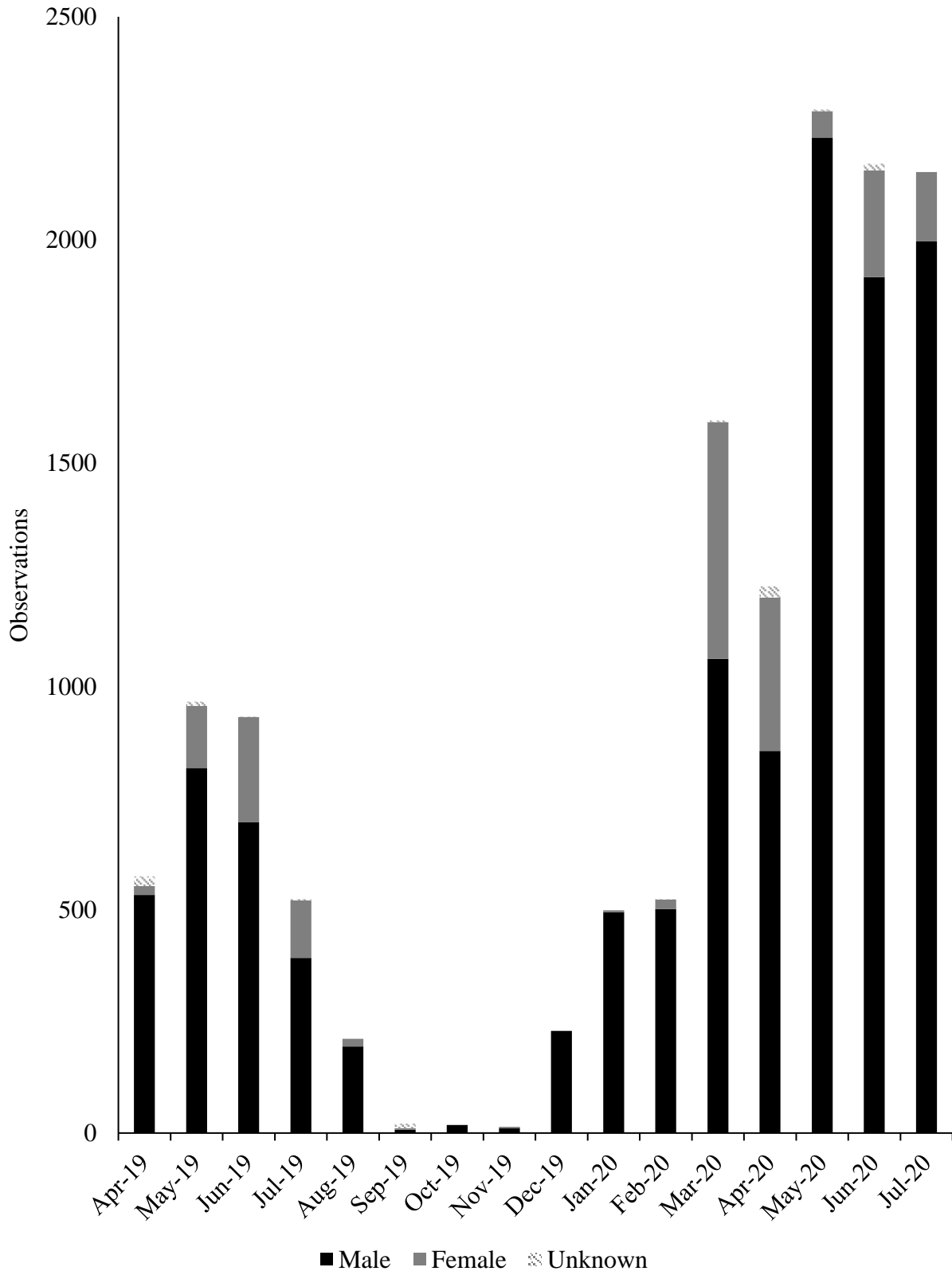


Figure 11. Deer observations by gender on El Sauz Ranch, 9 April 2019 – 30 July 2020.

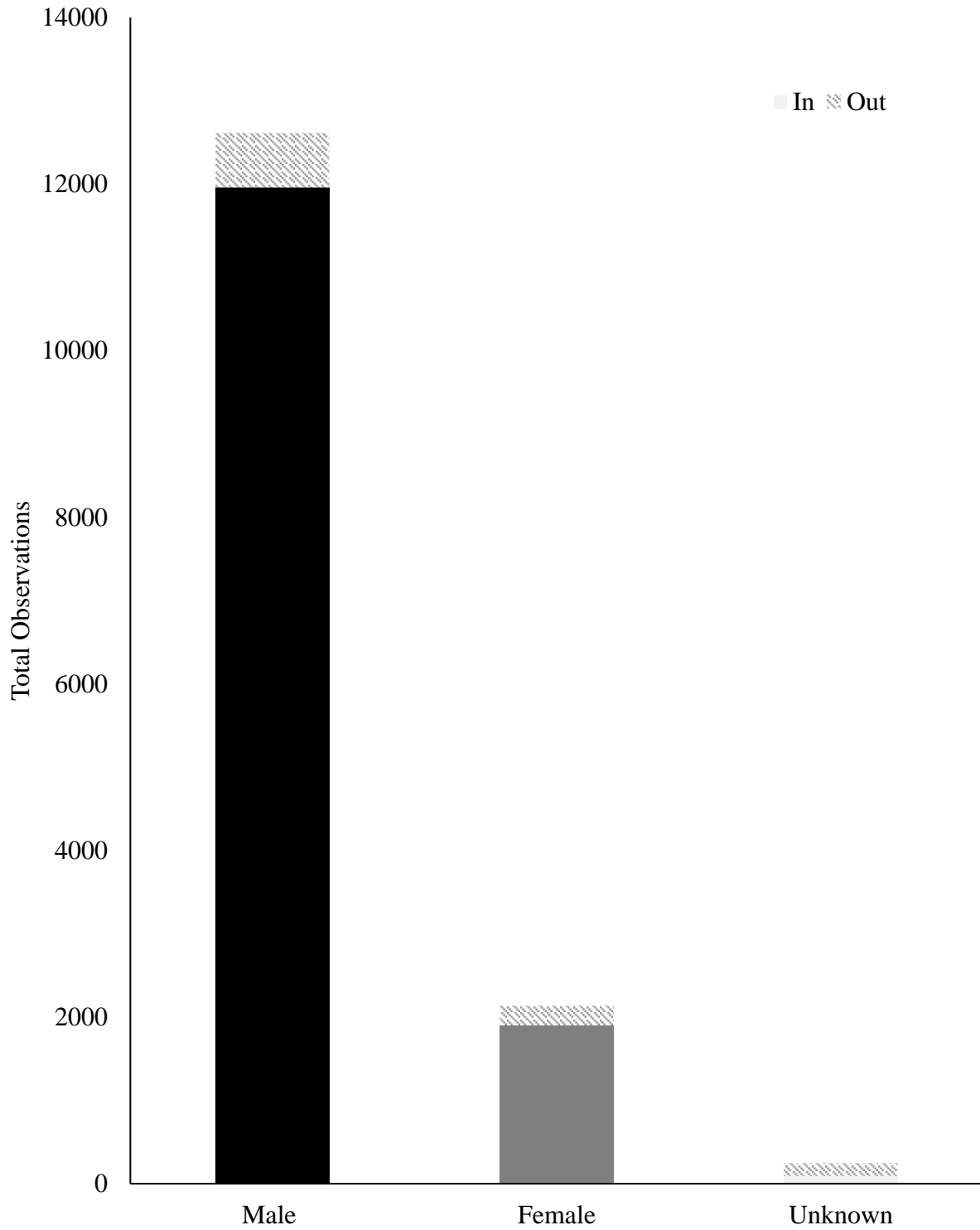


Figure 12. Total white-tailed deer observations (n , inside/outside exclusionary fencing), El Sauz Ranch, 9 April 2019 – 30 July 2020.

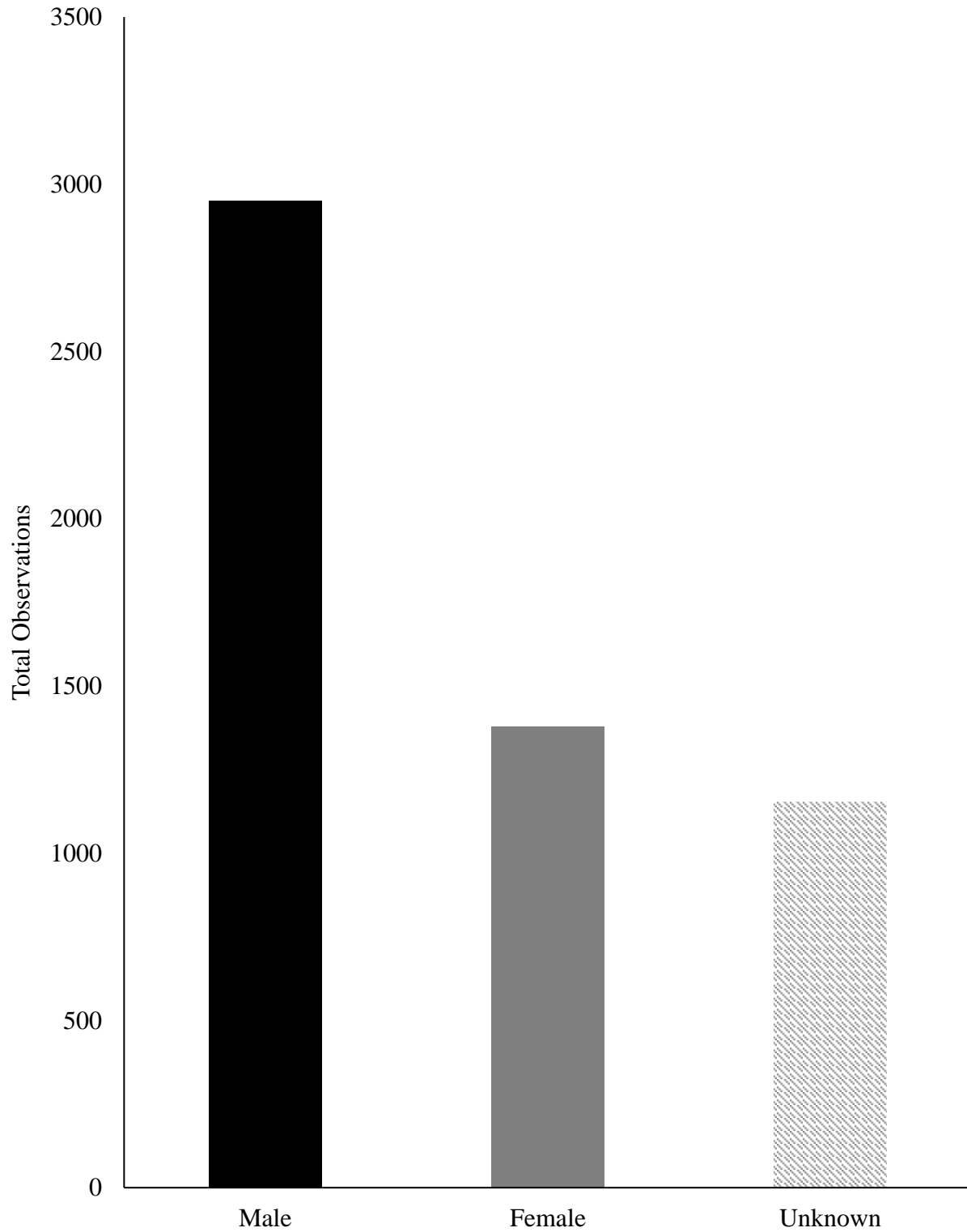


Figure 13. Port Mansfield total white-tailed deer feeder visitation inside feeder enclosure ($n = 3$), 9 April 2019 – 30 July 2020.

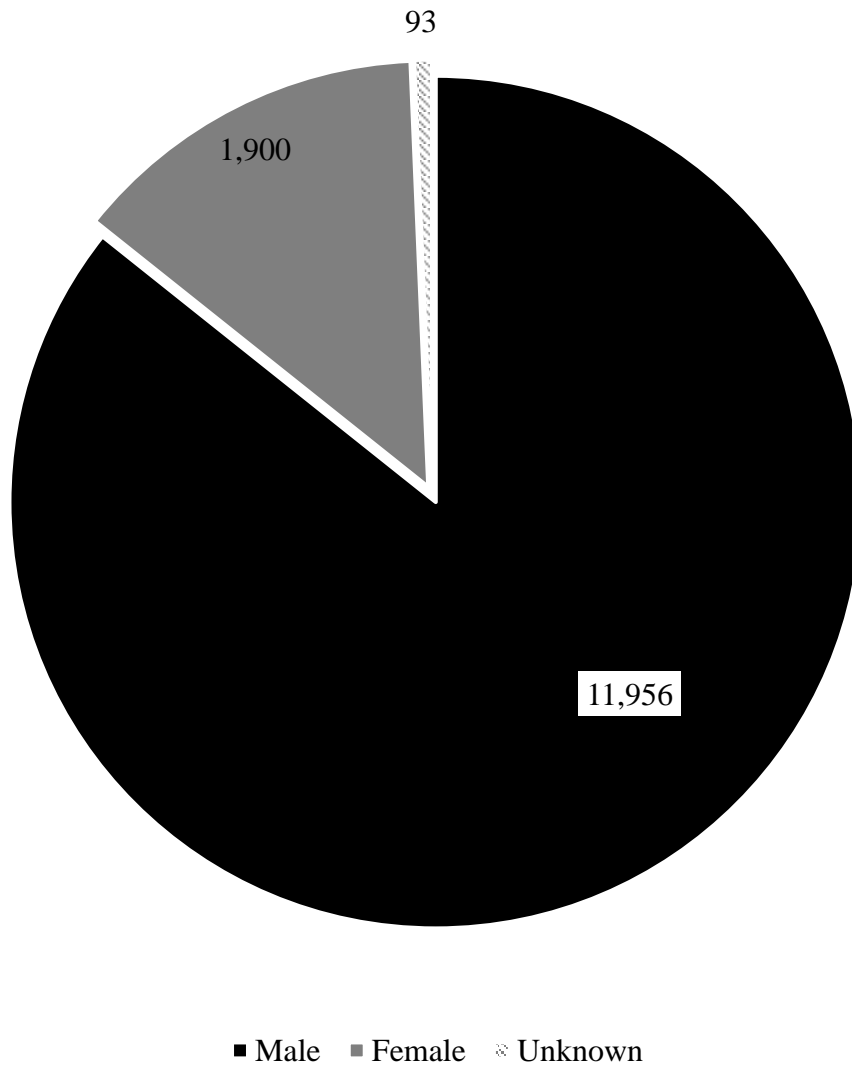


Figure 14. White-tailed deer observations by gender, El Sauz Ranch, 9 April 2019 – 30 July 2020.

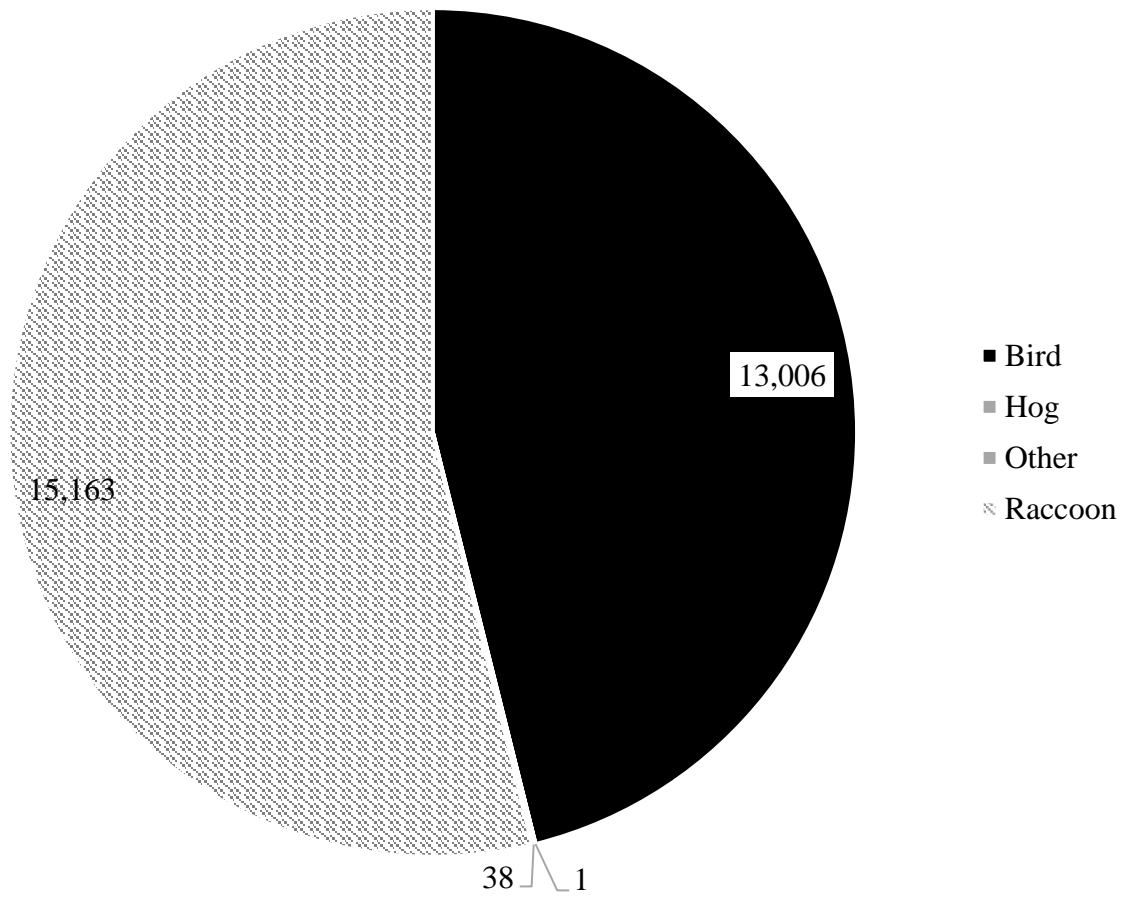


Figure 15. Non-target wildlife observations, El Sauz Ranch, 9 April 2019 – 30 July 2020.

Efficacy of Pre-baiting

Ivermectin corn consumption data (Table 1; Figure 16) suggests that pre-baiting had a positive effect on consumption levels. When pre-baiting was initiated, wildlife was able to find the feeders that had corn within a 24-hour period. Ivermectin corn consumption increased between March –July of 2019 and 2020 (Figures 16-17). High consumption feeders were primarily along the ranch boundary in 2019, however, feeders further inland on the property saw higher increases in ivermectin corn consumption (Figure 16). Pre-baited feeders made up the entirety of the far distance region, which was considered interior (Figure 17). Near distance feeders saw a slight increase in ivermectin corn consumption of 585 pounds. Near feeder's total ivermectin corn consumption for 2019 was 6,160 pounds and 6,745 pounds for 2020. Mid distance feeders saw an increase ivermectin corn consumption of 1,245 pounds between 2019 and 2020. Mid feeders mean ivermectin corn consumption for 2019 was 380 pounds of treated corn while 2020 mid mean consumption was 630 pounds per feeder. Far distance feeders saw the largest increase with almost four times the amount of ivermectin corn consumed in 2020. Ivermectin corn consumption in far feeders in 2019 was 775 pounds compared to 2,975 pounds in 2020. Far feeder mean consumption was 193 pounds in 2019 compared to 709 in 2020 (Figure 8-9). Pre-baiting saw an increase in total wildlife visitations during the month of April for both years (Figure 18). Observations for all wildlife increased after pre-baiting was implemented (Figure 19).

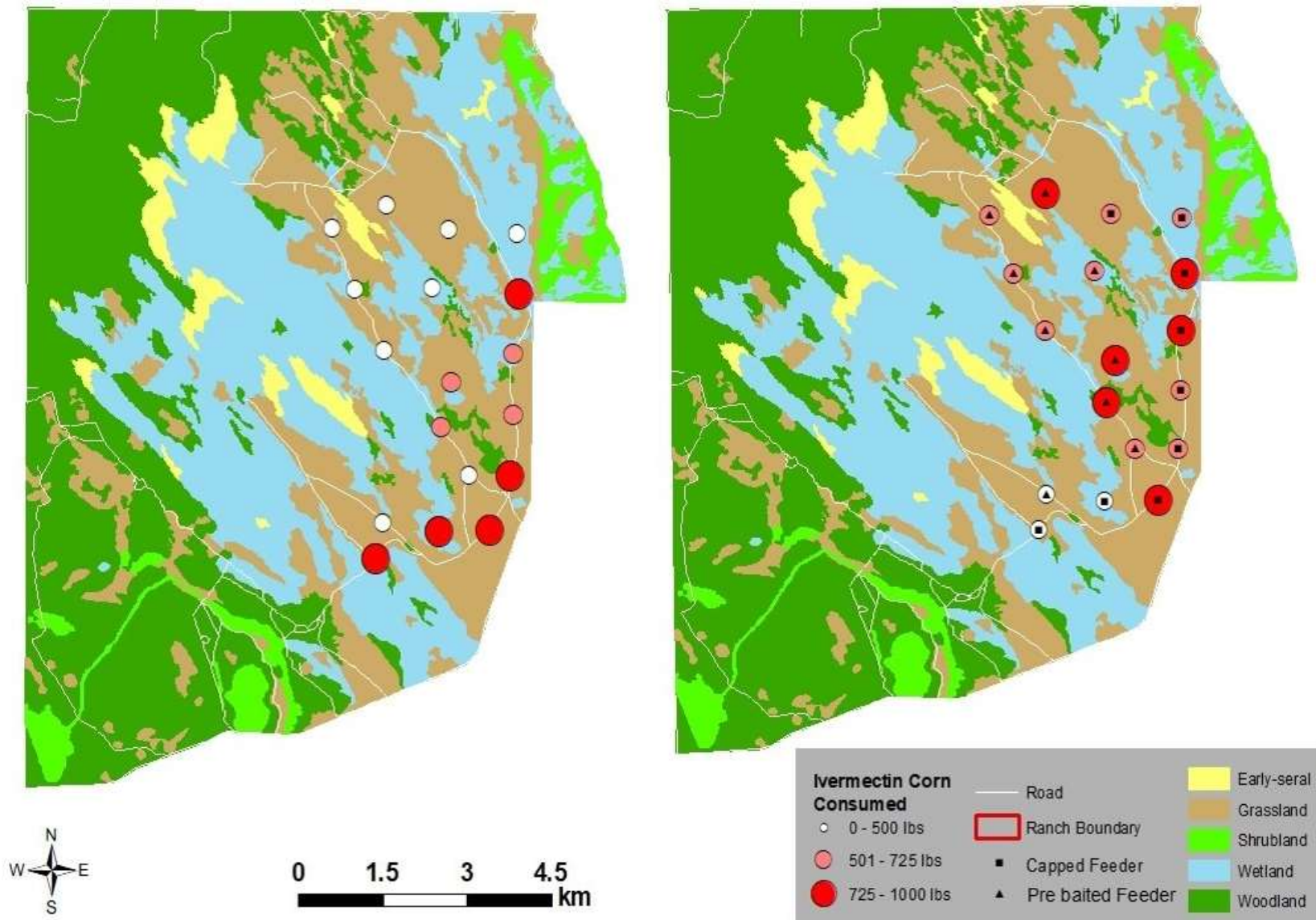


Figure 16. Ivermectin corn consumption by feeder, 2019 and 2020. El Sauz Ranch.

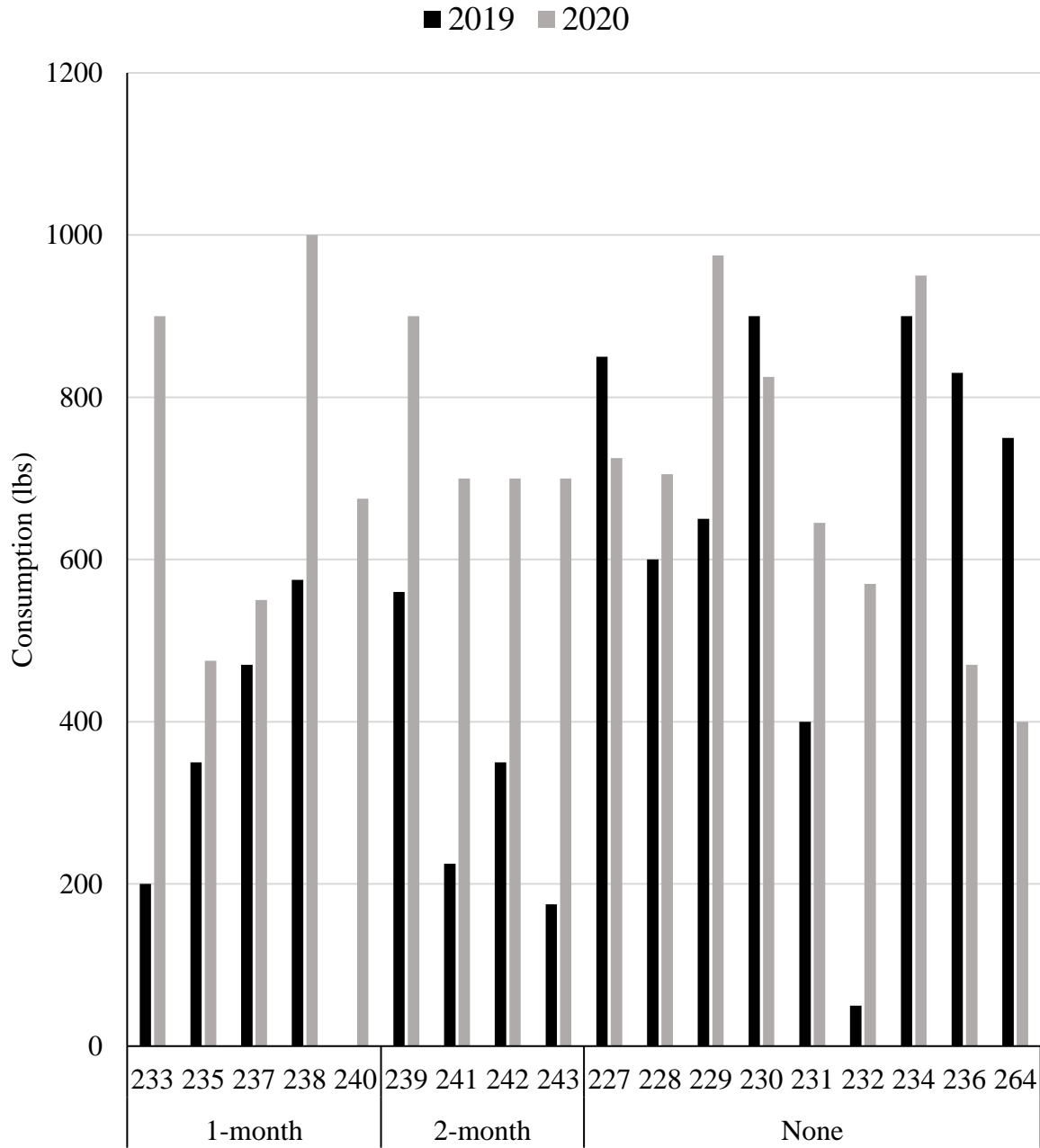
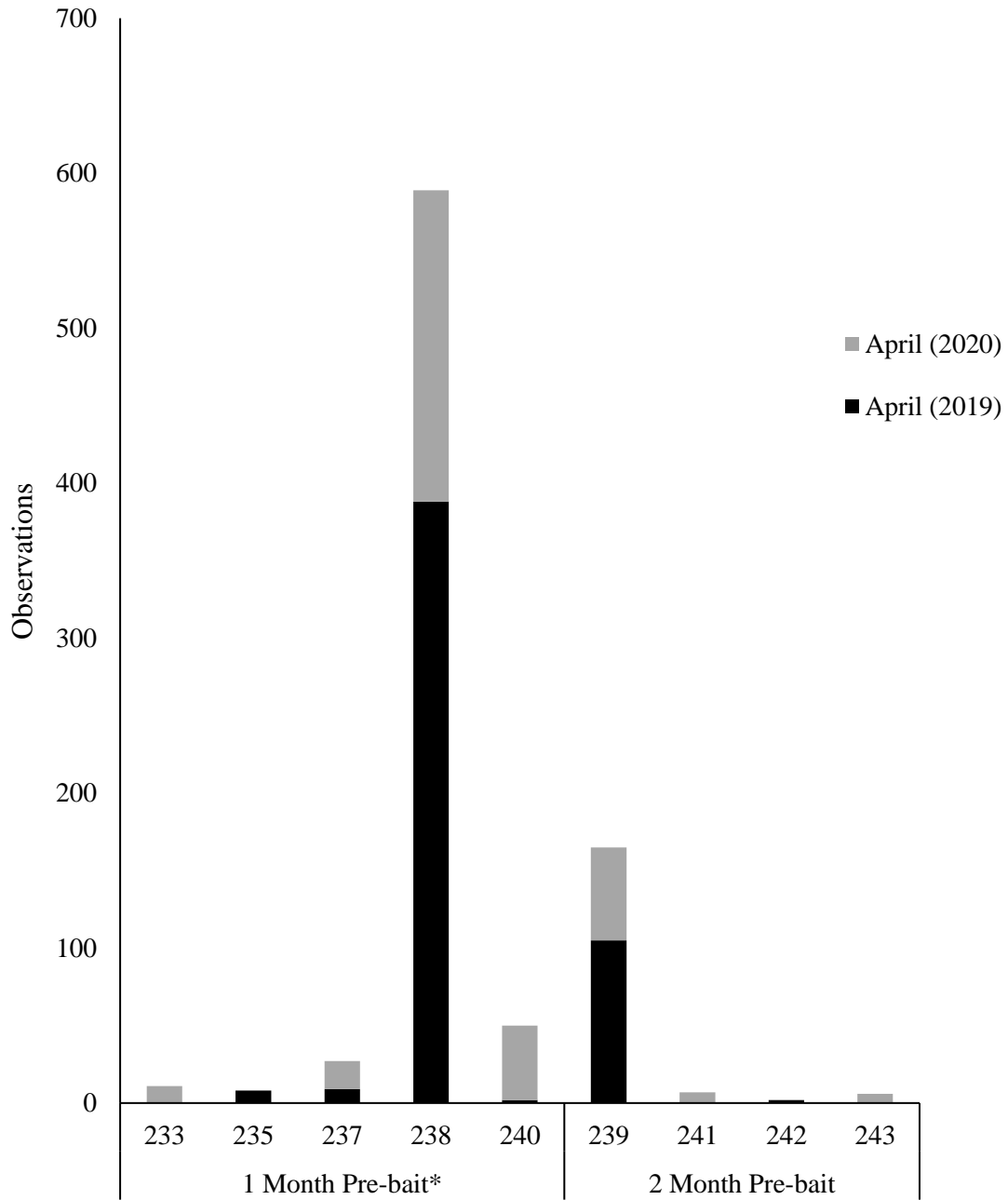


Figure 17. Pre-baited vs non pre-baited feeder consumption, March – July for 2019 and 2020.



*One-month pre-baited feeders received 100 pounds of untreated on 21 January 2020. Two-month pre-baited feeders received 250 pounds of untreated corn on 5 December 2019 and 21 January 2020
 Figure 18. Pre-baited feeder observations on El Sauz Ranch, April 2019 and 2020.

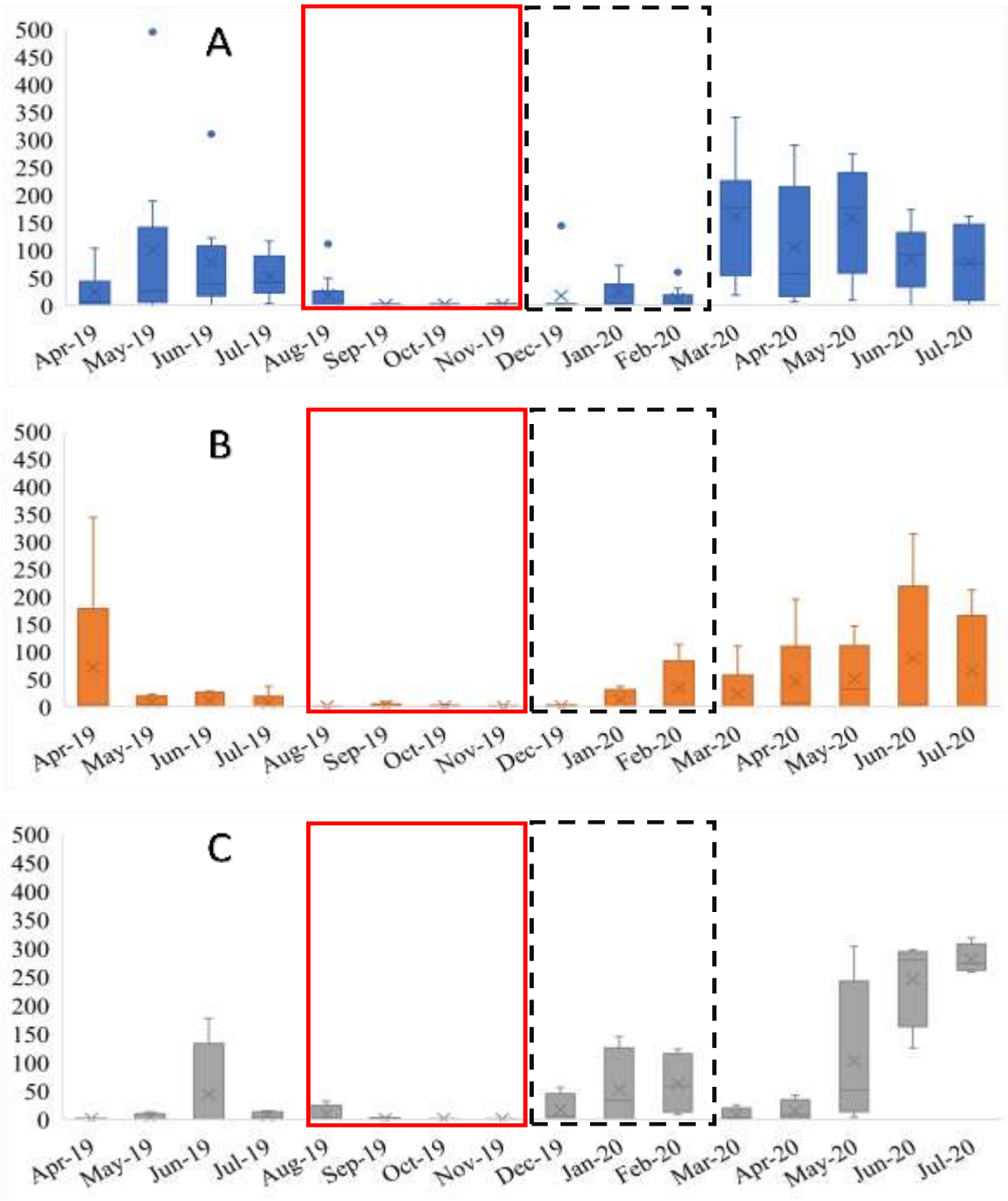


Figure 19. White-tailed deer observations inside feeder enclosures by distance categories on El Sauz Ranch. “A” (near feeders.) “B” (mid feeders.) “C” (far feeders.) Red boxed months (No ivermectin treated corn in feeders/empty/capped) March – July (Ivermectin corn in feeders). Dashed boxed months (feeders were pre-baited/empty/capped.)



Figure 20. Representative photos of bobcats (*Lynx rufus*) inside deer feeder at El Sauz Ranch, 2020.



Figure 21. Representative photos of white-tailed deer inside deer feeder at El Sauz Ranch, 2020.



Figure 22. Representative photos of coyotes inside deer feeder at El Sauz Ranch, 2020.



Figure 23. Representative photos of raccoons inside deer feeder at El Sauz Ranch, 2020.



Figure 24. Representative photos of birds inside deer feeder at El Sauz Ranch, 2020.

DISCUSSION

Feeder Use and Bait Consumption

Although previous research has shown that deer do not spend as much time in open areas compared to areas with natural cover in close proximity in the use of feeding stations (Miller et al. 2003), for my study most of the white-tailed deer visitations were located at feeding stations with high visibility and little to no nearby cover. This could potentially be due to the remoteness of El Sauz Ranch and the limited daily vehicle traffic that occurs at the study site. As a result, deer may be more comfortable in feeding in open areas. In contrast, feeders further inland had more natural cover in close proximity to feeder stations but had less visitations, which contrasts what Miller et al. (2003) reported. Feeder camera photos showed that larger male deer were seen more often feeding than females, which has been shown in other studies (e.g., Pound et al. 1996). Behavioral differences between sex and age classes suggest that older males would likely capitalize on food resources, and I found this was a case in my study. On several occasions, there were images of males sparring over space in the fenced feeder areas (Figure 25). This differential feeder use should be noted as you would expect that the level of treatment between the sexes would differ due to differential access to treated corn.

Feeder Visitation by Species

As previously mentioned, one issue that constantly arose was non-target species observations in the feeder enclosures. Species visitations at feeders on El Sauz Ranch were dominated by raccoons, white-tailed deer, and birds (Figures 14-15). Cooper and Ginnett (2000) and Rattan et al. (2010) confirmed that along with feeders comes the chance of non-targets consuming corn instead of deer. While the fencing around the feeder prevented larger non-target species such as feral hogs and cattle, other species such as raccoons were able to easily bypass

the fence. Several camera photos illustrated that raccoon groups or families would spend many nighttime hours feeding at these stations (Figure 23) while deer mainly visited the feeders individually and did not appear to stay as long as raccoons (Figure 21). It was not unusual to see various species of wildlife feeding together within the enclosure to consume corn (Figure 22). It should also be noted that many of these nontargets were not simply eating corn spillage from the feeder but instead were actively accessing the feeder (e.g., raccoons, coyote, Figures 22-24). On rare occasions bobcats were also sighted within the enclosure but not captured consuming corn (Figure 20). The presence of bobcats could be attributed to the presence of prey base such as rodents, which were also observed anecdotally via several photos (i.e., eye shines, not quantified due to difficulty in knowing numbers) throughout the study.



Figure 25. Male deer sparring inside feeder enclosure, Port Mansfield, 2020.

Efficacy of Pre-baiting

Pre-baiting in the use of deer feeders resulted in an increase of feeder visitation rates. Other studies suggest an increase in both visitations and consumption rates may be attributed to pre-baiting. For example, Kilpatrick and Stober (2002) observed that white-tailed deer did not seek bait sites outside of their traditional home ranges. Study results suggest that providing a time period (i.e., pre-baiting) for deer to locate and actively use deer feeders can improve the efficacy of a wildlife disease preventative program. As previously mentioned, El Sauz Ranch is currently cattle fever tick free; the use of deer feeders on the property are currently being used as a mechanism for preventing ticks from establishing on the property. Due to the nature of having ivermectin treated corn use by species that are hunted and likely could be consumed (e.g., white-tailed deer), the current practice is to close off or empty the feeders of ivermectin corn during the hunting season. Once the hunting season is completed, use of ivermectin treated corn resumes. Because pre-baiting increases visitation rights, maintaining feeders with nontreated corn can serve to resume a preventative strategy for cattle fever tick throughout the year. In other words, results of the study show that pre-baiting feeders with corn in the absence of ivermectin-treated corn increases the consumption of ivermectin treated corn and could be beneficial to mitigating the potentially devastating impacts of cattle fever ticks in the southern United States.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

The goal of this study was to assess feeder usage and ivermectin corn consumption via oral delivery. There are several key recommendations or implications that can be used by the East Foundation and others interested in mitigating the impacts of cattle fever tick. In the case of the East foundation, they are currently cattle fever tick free and can implement some of these recommendations as a mechanism for continuing to be tick free.

1. *Continue Feeder Use* – this study found that use of deer feeders in delivering ivermectin was an effective means in preventing cattle fever tick on El Sauz Ranch. White-tailed deer were one of the primary users of deer feeders and readily accessed ivermectin treated corn throughout the year. Deer feeder types used in this study and the use of enclosure fencing served to improve the efficacy of oral delivery to target species.
2. *Differential Feeder Use* – one finding in this study was the differential use of deer feeders between sex- and age-classes of white-tailed deer. Due to behavioral differences for these various groups, this is to be expected. The differential access to treated corn however could result in differential levels of treatments between these groups. In other words, adult males may have a higher percentage of treatment compared to yearling females. One recommendation in minimizing this differential feeder use is to increase the number of feeders, which would likely reduce competition for what could be a limited resource.
3. *Management of Non-targets* – a number of nontarget species were observed in this study using deer feeders with ivermectin treated corn. Several practices were put in place to minimize the access of nontargets to treated corn to include the feeder type

(i.e., gravity fed) and the use of enclosure fencing. Both of these practices should continue. In addition, the access of feed by raccoons by climbing the feeder legs could be minimized by the placement of “predator will guards” commonly used for example on wood duck boxes. Minimizing feed access by avian species (i.e., they are primarily feeding on spillage) is likely minimal but managers should be aware that game birds such as mourning doves and wild turkey may be treated with ivermectin similar to white-tailed deer. Removal of ivermectin prior to and during the hunting season should mitigate for these impacts.

4. *Use of Pre-baiting* – study results found that pre-baiting increased the use of deer feeder use. Intuitively, this result is not surprising though has not been documented prior to this study. In an effort to maintain feeder use throughout the year, it is recommended that nontreated corn be placed in feeders as a strategy to “restart” access to ivermectin corn once the hunting season is over. This would allow target white-tailed deer to be acclimated and using deer feeders throughout the year.

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