Summer 8-2020

Effects of Management Efforts on Fledging Success of Endangered Interior Least Terns (Sternula antillarum athalassos) on the McClellan-Kerr Arkansas River Navigation System in Arkansas

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EFFECTS OF MANAGEMENT EFFORTS ON FLEDGING SUCCESS OF ENDANGERED INTERIOR LEAST TERNS (*Sternula antillarum athalassos*) ON THE MCCLELLAN-KERR ARKANSAS RIVER NAVIGATION SYSTEM IN ARKANSAS

By

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Submitted to the Faculty of the Graduate College of
Arkansas Tech University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE IN FISHERIES AND WILDLIFE
August 2020

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Acknowledgements

I would like to thank my thesis committee, Drs. Thomas Nupp, Chris Kellner, and Douglas Barron for their help in designing, guiding, analyzing, and writing this study. I would also like to thank my field technicians, Malorie Hudson, Noah Balkman, Jessica Church, Caitlin Goldtrap, Rachael Miller, and fellow graduate students Brandon Grice and Carice Godbey for their assistance with data collection and study design input. I would like to thank the rooftop and site managers Bruce Bailey (Snap-On, Conway, AR), David Clark and David Bonds (Belk, Conway, AR), Dana Hardage (Little Rock Air Force Base, Jacksonville, AR) with the USDOD, and Bryan Day (Little Rock Port Authority, Little Rock, AR) for their support. I would also like to thank Rebecca Peak (USFWS), Cherrie Lee Phillip (USACE), and Jonathan Lee Kirkpatrick (USACE). Lastly, I'd like to thank Cindy Dixon and Valli Wanzer for their logistical support. This project was supported through the U.S. Army Corps of Engineers, Little Rock District and administered through the U.S. Fish and Wildlife Service's CFDA Program 15.640 – Research Grants (Cooperative Agreement Award F18AC00330). Surveys were conducted under USFWS recovery permit TE16616C-1 through Arkansas Tech University.

Abstract

The Interior Least Tern (*Sternula antillarum athalassos*) is an endangered shorebird that primarily nests in colonies on barren riverine sandbars on many major river systems throughout the central United States. Water resource development projects such as damming and channelization have altered the natural flow regimes of these systems leading to a decrease in sandbar quality and quantity, and as a result this species is dependent on management to ensure their recovery. Managers within Arkansas have been applying a variety of management approaches to improve sandbar nesting habitat and success of this population intermittently since 2002, with increased intensity since 2015. My study sought to evaluate the current population status and trends within the McClellan-Kerr Arkansas River Navigation System, and investigate the impact on sandbar nesting habitat these management actions may be having. The population appears to be stable, and on a slight upward trend with an average of 490 adults present over the past six non-flood years, and the success rate of individual colonies within this study area is also trending upwards. Regression analysis failed to attribute any significant effect to management actions regarding fledging success, but found managed sandbars are more likely to be nested upon. I make recommendations for managers to potentially improve the effectiveness of their efforts as they continue to manage for the improvement of Interior Least Tern habitat quality, quantity, and fledging success to meet their legal obligations.

Keywords: Interior Least Tern; Least Tern; Habitat Management; Arkansas River; Hurdle Model

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INTRODUCTION

The Interior Least Tern (*Sternula antillarum athalassos*; hereafter ILT) is a small, federally endangered piscivorous shorebird (U.S. Fish and Wildlife Service 1985; hereafter USFWS) with highly variable yearly reproductive rates. Their populations showed precipitous declines as a result of damming interior rivers during the last century. As part of the recovery effort, their populations are monitored yearly and a variety of management actions have been initiated to ensure their success as a population, as directed by the 2016 biological opinion (USFWS 2016). Consistent surveys allow researchers to track population levels and trends (Farnsworth et al. 2017), and with a median breeding lifespan of 6 years (Lott et al. 2013) it is best to estimate trends of this ILT population as opposed to single-season estimates (Ross 2016).

The ILT is defined as an endangered population that includes all Least Terns (*Sternula antillarum*) nesting >50 miles from the Gulf of Mexico on large interior river systems (U.S. Fish and Wildlife Service (USFWS) 1985, 1990). They nest in colonies on barren sandbars of many major river systems from Texas to North Dakota (Smith and Renken 1991, Lott 2006, Sherfy et al. 2012, Fansworth et al. 2017), and in Arkansas these riverine colonies have had a mean of 26.58 ± 1.84 breeding adults. Adults are monogamous within breeding seasons and typically produce a clutch of 3 eggs (Kirsch 1996), however first-time breeders or renesting attempts later in the season typically produce a clutch size of 1 (Massey and Atwood 1981). Nests are attended by both parents with one parent usually present, but late-stage chicks may be left unattended for periods while both parents forage (Thompson et al. 2020), typically 100-300m from the colony (Hill 1993, Wilson et al. 1993). Eggs and chicks are commonly lost to sandbar flooding, exposure, and predation (Thompson et al. 2020). Disturbances from humans or predators cause adults to flush from the colony leaving eggs and chicks exposed. Adults can renest at least 3 times per season, which takes place 5-30 days after egg loss (Lingle 1993), typically within 70

km of their original nest site. Incubation lasts approximately 18 days (Hays and LeCroy 1971), chicks fledge at approximately 18 days, and fledglings begin to explore beyond their natal colonies after several weeks (Thompson et al. 2020). Postfledging survival is unknown. Approximately one-third of two-year-old birds breed (G. R. Lingle unpubl. Data), and the majority begin breeding in their third year (Massey and Atwood 1981) and attempt to breed every year after. Data is lacking to understand lifetime reproductive success, however California Least Terns (*Sternula antillarum browni*) have an estimated lifetime productivity of 1.49 fledglings per adult with a breeding life of 9.6 years (Massey et al. 1992). Least Terns have been recorded living up to 24 years (Klimkiewicz and Futcher 1989), nesting at 20 years old (JLA). Estimates of survivorship from fledglings to 2-3 years are 0.80-0.82 for California Least Terns (Massey et al. 1992) and annual survivorship of adult ILT's is estimated at 0.85 (Renken and Smith 1995a). Sex ratios within a breeding colony are assumed to be 1:1 with an insignificant number of nonbreeding adults present (Thompson et al. 2020). Data is lacking to accurately estimate natal-site fidelity of chicks, and breeding-site fidelity of ILT's has ranged from 81% to 28% (Boyd 1993, Lingle 1993, Renken and Smith 1995b).

The ILT was listed as federally endangered in 1985 largely due to concerns of habitat loss as a result of water resource development projects, such as the widespread damming and channelization of interior rivers (USFWS 1985). This resulted in a decline of both quality and quantity of suitable sandbar nesting habitat due to decreased sediment transport and deposition, increased erosion, and vegetative establishment (Galat and Lipkin 2000, Nilsson and Berggren 2000, Pegg et al. 2003, Elliott and Jacobson 2006, Parham 2007). On unaltered river systems, seasonal periods of high and low flows maintain sandbars with sparse vegetation (Wohl et al. 2015) that ILT's require for breeding (Ziewitz et al. 1992). Because impacts of river damming to

sandbar nesting habitat are ongoing (Knoll 2006), continual monitoring and management are necessary to maintain the species.

The McClellan-Kerr Arkansas River Navigation System (hereafter MKARNS) was constructed in the 1960's and completed in 1971 for commercial barge navigation and flood prevention. The system spans 445 miles with 18 locks and dams, including nearly 280 miles and 11 locks and dams in Arkansas. The U.S. Army Corps of Engineers (hereafter USACE) is responsible for not only maintaining this navigation system, but for managing it to the benefit of organisms that are threatened and directly impacted by this system, including the ILT (USFWS 2016).

The first objective of this study was to continue yearly surveys and trend evaluations to understand the current status of the ILT population within Arkansas. This study builds on data collected since 2001, with particular emphasis on analyzing the results of the 2018 and 2019 breeding seasons; the former being a highly-productive year, and the latter including an historic flood. Additionally, the USACE has administered various management actions to improve the quality and quantity of ILT sandbar nesting habitat since 2002, with an increase in effort since 2015. The second objective of this study was to be the first to investigate the potential impacts that management actions have had on ILT fledging success on the MKARNS between 2002 and 2018, and to use these findings along with a review of management efforts with other populations to make management recommendations aimed at improving management effectiveness.

CHAPTER 1

INTERIOR LEAST TERN BREEDING ACTIVITY DURING THE 2018 AND 2019 SEASONS ON THE MKARNS AND SURROUNDING AREA IN ARKANSAS

INTRODUCTION

Arkansas Tech University faculty and students have been involved with monitoring ILT's within Arkansas since 2001. Through time these surveys have become more complete, with recent years including infrequent surveys of the lower, unmaintained portion of the Arkansas River downstream from the Wilbur Mills dam (the downriver boundary of the MKARNS; hereafter lower Arkansas River), as well as rooftop surveys on 3-5 rooftop colonies since 2007. I monitored ILT colonies during the 2018 and 2019 breeding seasons at riverine and rooftop locations, as well as two novel gravel lot colonies in 2019, in accordance with the biological opinion (USFWS 2016). Colonies were located by visiting recently used nesting sites and suitable nesting habitat while on the MKARNS. I recorded counts of adults, nests, chicks, and fledglings to assess fledging success of colonies.

The recovery plan for ILT's (USFWS 1990) set a target population of 1,600 breeding birds on the entire Arkansas River, including just 150 birds within the state of Arkansas, and for those numbers to remain stable for 10 years. Due to inadequate survey efforts and lack of information at the time, those targets were likely too low due to the underestimation of population numbers. The first range-wide survey of ILT's took place in 2005 (Lott 2006), and surveys within the state of Arkansas began in 2001. Survey numbers within Arkansas are consistently higher than the target value of 150 and the population appears to be trending slightly upward (Lott 2006, Nupp 2013, Nupp and Jensen 2020). Ongoing monitoring of a species such as the ILT is critical as their observed presence and reproductive rates vary greatly from year to year depending on natural factors, particularly flood levels (Nupp and Jensen 2020). If surveys

are infrequent, population levels and fledging success rates can be perceived as either above or below trend levels, and if the population begins to suffer a decline it must be discovered and remedied immediately to ensure the continued recovery of the species. The USACE maintains the MKARNS and as a result, it is their legal obligation to oversee the continued monitoring of the ILT as an endangered species (USFWS 2016). This helps guide their required management efforts to create and improve sandbar nesting habitat, as the ongoing effects of channel maintenance and flow regulations will continue to directly affect the ILT. The objective of this chapter is to report the results of the 2018 and 2019 breeding season surveys, to compare the non-flood year of 2018 with recent non-flood years, and to analyze the current population status and trends of the ILT within Arkansas.

METHODS

Survey Area

My field assistants and I (hereafter we) conducted ILT colony surveys along the MKARNS within Arkansas spanning from the Wilbur D. Mills Dam (Dam 2) at approximately river mile 19 (hereafter RM) near Pendleton, AR, to approximately RM 285 (Dam 13) near Fort Smith, AR. Our surveys in 2018 also included the unchannelized and unmaintained lower portion of the Arkansas River below the Wilbur D. Mills Dam. Riverine colonies were located by checking previously known nesting locations, as resent reports have indicated ILT's may be likely to reuse suitable sandbars (Nefas 2018) if they remain available. During these surveys, suitable habitat was surveyed for the presence of ILT's. We surveyed rooftops with known ILT colonies in previous years at Belk and Snap-On in Conway, AR, and buildings #450 and #787 at the Little Rock Air Force Base (hereafter LRAFB). Our surveys in 2019 included 2 novel colonies which were discovered in gravel lots near the Arkansas River at the Little Rock Port Authority (hereafter LPRA) (Rebecca Peak [USFWS] pers. comm.).

Field Methods

Surveys were usually conducted biweekly in 2018, and the lower Arkansas River was surveyed twice. During riverine surveys, suitable nesting habitat was surveyed for nesting ILT's or those exhibiting courtship behaviors, with emphasis on checking colony locations used in previous years. Riverine surveys were initiated in late May or when water levels were safe and low enough to expose sandbars; in 2018 surveys began on 25 May, and in 2019 surveys began on 1 Aug. Rooftops that had supported colonies in the past were surveyed along with other gravel-covered rooftops that we identified as potentially suitable. In 2018 rooftop surveys began 5 June, and in 2019 they began on 29 May.

Surveys were conducted under USFWS recovery permit TE16616C-1 through Arkansas Tech University. A 16 ft. Lowe Roughneck aluminum boat powered by a 50 hp Yamaha outboard motor was used in riverine surveys with a crew of 3-4 people. Upon approaching a colony site we used binoculars to counts adults, fledglings, and chicks prior to colony disturbance. We supplemented those counts with walk-through surveys of the colony. Our permit restricted us to 20 minutes at each colony, with wind speed below 25 mph, no precipitation, and a temperature range of 40-90^{o}C within which we were allowed to disturb nesting birds. As a result, surveys were conducted as early in the day as possible. In circumstances when one or more of these conditions was not met, we conducted counts with binoculars to avoid colony disturbance. When surveying a rooftop or riverine colony site on foot, surveyors either partitioned non-overlapping areas of the colony among themselves or walked parallel transect lines throughout the colony until the survey was completed or a restriction of the permit called for a conclusion of the effort.

During surveys we recorded adult counts, chick counts, fledgling counts, nest counts, egg float data for aging (Hays and LeCroy 1971), and environmental conditions. Chicks were aged

and placed into one of four categories: 1) Downy chicks in nest - Chicks believed to be ≤ 2 days old, usually found in nest scrapes; 2) Mobile downy chicks - Chicks believed to be 3-9 days old, usually found under cover or motionless on sand away from nest scrapes; 3) Feathered chicks - chicks believed to be 10-17 days old, with undeveloped primary flight feathers and; 4) Fledglings - chicks ≥18 days old, with developed primary flight feathers. Fledglings observed to be capable of flight were simply counted as "fledglings" (Nupp and Jensen 2020). A Trimble™ GPS (Trimble Navigation, Ltd, Sunnyvale, CA) was used to record colony locations and map site perimeters.

During riverine colony surveys when mobile chick were present, special care was taken to ensure chicks were not inadvertently pushed to a shoreline in their effort to avoid investigators as chicks may abandon the island and attempt to float downstream if sufficiently stressed. In those circumstances, binoculars were used to get estimates of bird counts and ages without closer inspection. Similarly, rooftop colonies with mobile chicks that lacked a surrounding parapet and/or screened water drainages (Belk, Snap-On, and LRAFB #450) were surveyed using binoculars from a static position to avoid incidental chick mortality and the effort was abandoned if adults become disturbed. In some cases, this required one investigator at a time to collect visual counts from the top of an access ladder which resulted in only a fraction of the entire rooftop being visually accessible.

ANALYSIS

Colony initiation dates were calculated by backdating, either from the age of the first observed eggs or from the age of the earliest observed chicks. Eggs were backdated in accordance with egg float analysis (Hays and LeCroy 1971) with a precision of 2 days.

Fledglings produced per breeding pair (hereafter FBR) is a common measure of success for this species (Krogh and Schweitzer 1999). Breeding pairs at a colony was determined by the

nest count if the colony could be completely surveyed; when our transects covered the entire colony and we felt all nests were found. In cases when the colony could not be completely surveyed, the number of breeding pairs was estimated by the number of adults recorded at the date of peak chicks observed, which was also used in replace of incomplete nest counts. This method was determined to be a reasonable surrogate as it is more accurate than incomplete nest counts. With larger colonies this method likely becomes more variable, less precise, and may underestimate the number of nests present at a colony (Figure 1). A simple linear regression of nests and adult counts at completely surveyed colonies in 2018 revealed that nests increase with adult counts less than expected, with an r^2 of 0.5546 ($F_{1,9} = 13.45$, $p = 0.0052$) (Figure 1), where nest counts were found to increase by 0.2734 per adult with a mean nest count of 7.545 ± 1.885. All fledgling counts were restricted to those taken within a limited timeframe to avoid double counting, as flight-capable fledglings may presumably begin intermingling with other colonies towards the end of the nesting season and produce a secondary peak in fledglings present. In 2018 nest counts from the peak of nesting activity, approximately the 2nd week of July, were used to calculate the number of breeding pairs at each ILT colony. However, complete nest counts could not always be obtained within the 20 minute restriction associated with our permit. Counts were especially difficult to make on substrates that camouflaged nests. In these cases, we used the adult counts from the date of peak chicks observed, divided by two, to estimate the number of nests and therefore breeding pairs at the colony. Breeding pairs were estimated with this method for 11 of 22 riverine colonies in 2018. Adult counts recorded are an average from all observers present during a survey. Fledgling counts were peak counts from between 2 and 27 July. Exceptions to this rule were colonies on the lower Arkansas River, surveyed on 5-6 July and 2 August, which had initiation dates approximately one month later than ILT colonies on the MKARNS, where fledglings peaked on 2 August.

In 2019 we faced complications with calculating various estimates during the ILT breeding season (Table 1, Figure 2) as the most severe flooding in decades inundated essential riverine habitat and caused delayed nesting patterns and surveying opportunities. Rooftop colonies and two novel gravel lot colonies at LRPA remained active and accessible as expected, but riverine colonies were not accessible until 1 August which was after the peak in nesting activity. As a result, breeding pairs and nests for these colonies were estimated by using the peak adult count from 5 – 6 August and dividing by two. As for rooftop and gravel lot colonies, breeding pairs within a colony were estimated by averaging the maximum number of adults observed during the peak of nesting, which was approximately 18 June. Only the Snap-On colony produced fledglings which were observed on 25 July. Total adult counts from these surveys possibly includes birds that may have abandoned rooftop colonies and relocated to riverine colonies once water levels decreased. However, I determined this to be the best method for reporting counts despite the potential for inflated adult ILT counts.

Adult counts and FBR rates were used for comparison between the 2018 breeding season and the previous two breeding seasons during non-flood years (2016 and 2017) with Wilcoxon rank sum tests and two-sample *t*-tests. Rate of site reuse, and FBR rates, were compared between rooftop and MKARNS colonies with Wilcoxon rank sum tests and two-sample *t*-tests. Generalized additive models (Hastie and Tibshirani 1990) were used to visualize population trends over time, accessed with the “mgcv” package (Wood 2017) in R (R Core Team 2018), and plotted with the “ggplot2” package (Wickham 2016).

RESULTS

2018 Breeding Season

Colony initiation dates ranged from 22 May through 3 July across all 25 colonies (Table 2, Table 3). While this range is relatively large, most of these colonies (76%) initiated between

22 May and 7 June, a range of just over two weeks. The remaining 6 colonies initiated between 20 June and 3 July, 4 of which were colonies on the lower Arkansas River.

We estimated that 638 ILT adults were present within the state of Arkansas in the summer of 2018 (Table 2); 496 adults in 17 colonies on the MKARNS, 85 adults on the lower Arkansas River in 5 colonies, and 57 adults in 3 rooftop colonies (Table 3). We estimated that 325 nests produced 172 fledglings (FBR = 0.529). Riverine colonies produced 164 fledglings from an estimated 276 nests (FBR = 0.594), and rooftop colonies produced just 8 fledglings from 49 nests (FBR = 0.163; Table 3).

Of 17 colonies recorded on the MKARNS in 2018, only 4 (23.5%) were used in 2017, but all 3 rooftop colonies (100%) were used in in 2017. This was in contrast to 2017 where 66% of MKARNS locations had been used the previous year, and 50% in 2016 (Table 4). There was no difference between 2018 and the previous two breeding seasons combined in terms of colony FBR rates, with a mean of 0.460 ± 0.10 in 2018 and 0.284 ± 0.08 in 2016-2017 ($W = 341$, $p = 0.3185$; Figure 3). There was also no difference when comparing only colonies on the MKARNS, with a mean FBR of 0.470 ± 0.12 in 2018 and 0.334 ± 0.09 in 2016-2017 ($W = 200$, $p = 0.4582$; Figure 4).

Successful colonies (colonies that fledged at least one chick) did not differ between 2018 and the previous two breeding seasons combined in terms of colony FBR rates, with a mean of 0.816 ± 0.11 in 2018 and 0.535 ± 0.11 in 2016-2017 ($t = -1.817$, $df = 29$, $p = 0.0796$; Figure 5). There was also no difference when evaluating only successful colonies on the MKARNS between 2018 and the previous two breeding seasons combined in terms of FBR, with a mean of 0.792 ± 0.13 in 2018 and 0.602 ± 0.11 in 2016-2017 ($t = -1.0865$, $df = 23$, $p = 0.2885$; Figure 6). Evaluating only successful colonies eliminates those that may have failed to fledge a chick due

to external factors such as a severe predation event or localized flooding, and may as a result provide more insight into the productivity of a breeding season.

There was no difference in adult counts per colony between 2018 and the previous two breeding seasons combined, with a mean of 25.5 ± 5.61 in 2018 and 22.8 ± 2.37 in 2016-2017 ($W = 543$, $p = 0.4407$; Figure 7). There was also no difference when comparing only colonies on the MKARNS, with a mean adult count of 29.2 ± 8.09 in 2018 and 23.3 ± 2.60 in 2016-2017 ($W = 291.5$, $p = 0.5458$; Figure 8).

2019 Breeding Season

Due to the extreme flooding in the summer of 2019 (Table 1, Figure 2) we were not able to safely survey any portion of the Arkansas River until 1 August. As a result, our findings are delineated into two parts. The first portion of our surveys (29 May – 8 August) was limited to 4 rooftop colonies and 2 gravel lot colonies. Among these non-riverine colonies, initiation dates ranged from 21 May through 10 June. In the later portion of our surveys we calculated initiation dates of 24 June – 25 July for 4 riverine colonies on the MKARNS (Table 5).

We estimated that 266 ILT adults were present within the state of Arkansas in the summer of 2019 (Table 6); 113 adults in 4 riverine colonies on the MKARNS, 127 adults in 4 rooftop colonies, and 26 adults in 2 gravel lot colonies. We estimated that 187 total nests produced 42 fledglings, which results in an overall FBR of 0.225. Riverine colonies produced 37 fledglings from an estimated 55 nests resulting in an FBR of 0.67. Rooftop colonies produced 5 fledglings from an estimated 121 nests resulting in an FBR of 0.04. Gravel lot colonies produced 0 fledglings from an estimated 11 nests resulting in and FBR of 0.

Rooftop colonies have been reused at an average rate of 76.53% ± 4.64%, and have yielded an average FBR of 0.164 ± 0.025 (Table 9). MKARNS colonies have been reused at an average rate of 49.20% ± 7.95% per year, ranging from as high as 87.50% to as low as 18.18%

(Table 4), and these sites have an average FBR of 0.362 ± 0.028. Rooftop and MKARNS colonies did not differ in FBR rates ($W = 5470$, $p = 0.0816$) (Figure 9), but rooftop colonies are reused significantly more than MKARNS colonies ($t = -3.0315$, $df = 21$, $p = 0.0063$).

A general additive model was used to visualize the trend of adult counts recorded for MKARNS colonies through time. The resulting model accounts for 44.8% of the deviance observed with an r^2 of 0.354 (Figure 10), and reveals a relatively stable, if not slightly increasing, trend. A second general additive model was used to visualize the trend of estimated breeding adults for MKARNS colonies through time. The resulting model accounts for 18.7% of the deviance observed with an r^2 of 0.113 (Figure 11), and reveals a highly variable but increasing trend.

DISCUSSION

Although 2018 was not substantially different from recent non-flood years, it proved to be a highly-successful year with encouraging numbers for this population. In comparison to the previous two years, 2018 had a higher average adults per colony and a higher average FBR per colony, between all colonies and just MKARNS colonies. Comparing breeding success in 2018 with historical records yielded the second highest FBR that we've recorded for this population and the highest number of fledglings that has been recorded (Table 7). Colonies on the MKARNS are most consistently surveyed and among them, since the earliest records in 2001, the 2018 breeding season recorded the highest adult count (496), the second most fledglings (134), and the third highest FBR (0.585) ever recorded (Table 3).

Despite the historic flooding during the 2019 breeding season (Table 1, Figure 2), when compared with the previous flood year of 2015 this ILT population was also highly-successful (Table 7). It is challenging to analyze and compare counts from flood years as ILT's may have nested on sandbars still exposed or newly created by the flood, but that remained inaccessible

and therefore unsurveyed by investigators. For example, when flood levels in 2019 receded and investigators were able to safely survey the MKARNS on 1 August, we found an ILT colony (RM 224, Table 5) on a sandbar presumably created during that flood which already had fledglings, suggesting the colony initiated on or before 24 June when water levels were still unsafe for surveys (Figure 2). During any given flood year it is possible that other colonies like this remained undetected, and for this reason it may be more informative to analyze population trends excluding flood years.

In evaluating population trends, it may be best to evaluate FBR rates over approximately 6 years, the median breeding lifespan of an adult ILT (Lott et al. 2013), as recommended by Ross (2016). It is often cited that an FBR of 0.5 is the minimum sustainable productivity for the ILT (Kirsch 1996, Kirsch and Sidle 1999), and in that respect the breeding season of 2018 was successful with an FBR of 0.529 (Table 7). If we take the recommendations of Ross (2016) and evaluate the previous 6 years, even while excluding the flood years of 2015 and 2019, an FBR of 0.381 (Table 8) is notably lower than Kirsch's estimate (Kirsch 1996, Kirsch and Sidle 1999). However, Kirsch (2016) recommends using extreme caution with this estimate as many demographic assumptions were used in its calculation. An overall investigation of population trends on the MKARNS, excluding flood years, reveals that this population appears relatively stable, if not slightly increasing, regarding counted adults (Figure 10), and the estimated breeding adults is highly variable but also appears to be increasing (Figure 11).

Colony initiation dates in 2018 were in two distinct groupings. Most of the colonies (76%) initiated between 22 May and 7 June, a range of just over two weeks. This is relatively synchronized as expected for the ILT despite being slightly later than the average initiation dates for Least Terns in mid-May (Farnsworth et al. 2017), possibly due to water levels or other factors. The second round of colony initiations, for just 6 colonies, was calculated to be from 20

June to 3 July, and 4 of these colonies were on the lower Arkansas River. This latter group of colony initiations may be due to ILT's who suffered failed nesting attempts earlier in the season and subsequently relocated to a new location to try again (Lingle 1993). Counts were taken from the time of peak nesting activity, approximately the 2nd week of July, so ILT's who may have potentially relocated in this manner would not have been double-counted to bias adult counts or fledging success rates. One exception was the colony at RM 42, which initiated late in the season on 3 July without any nearby colony activity to explain the late arrival and nesting of these birds. This late initiation date may have contributes to the failure of this colony (FBR of 0), as predator activity may increase throughout the nesting season (Kruse et al. 2001) and increasing temperatures later in the summer may increase the mortality rate of eggs and chicks (Purdue 1976, Howell 1959).

The 2018 breeding season was very successful for this population of ILT's; 25 nesting colonies ranged in success with FBR's from 0 - 1.5, 14 colonies (56%) successful in fledging at least one chick, and 13 colonies (52%) with an FBR of 0.5 or greater (Table 2). This compares to the 2017 breeding season where 11 colonies were recorded, 8 of which (72.7%) were successful in fledging at least one chick, 2 of which (18.2%) with an FBR of 0.5 or greater. In 2016, 19 colonies were recorded, 9 of which (47.4%) were successful, 7 of which (36.8%) had an FBR of 0.5 or greater. Across all 25 colonies in 2018, this made for a total FBR of 0.529 with 172 fledglings produced, one of the most productive years on record for ILT's in Arkansas (Table 3). This compares with an overall FBR of 0.18 and 78 fledglings in 2017, and an overall FBR of 0.36 with 64 fledglings in 2016. The adult count of 638 ILT's is amongst the highest adult counts for the breeding population in our study area (Figure 13), compared to 350 adults in 2017 and 540 adults in 2016. This is in part due to surveys on the lower Arkansas River which has not been consistently included in surveys of this population; previously surveyed in 2010, 2011, and

2013. The lower Arkansas River is an unchannelized and unmaintained section of the river with highly-fluctuating water levels making it difficult to survey with any consistency. Two opportunistic surveys on the lower Arkansas River accounted for 5 nesting ILT colonies, 85 adults, and 30 fledglings, which represents a substantial portion of our counts. Without these surveys on the lower Arkansas River, the 2018 breeding season would have yielded 20 colonies with 553 adults, 142 fledglings, and an overall FBR of 0.511 with 11 successful colonies and 10 colonies with an FBR of 0.5 or greater. Given the highly variable water levels on the lower Arkansas River it is therefore surprising that these 5 colonies had an FBR of 0.64, which is higher than the colonies on the MKARNS or rooftops (Table 3). This is strong evidence that the lower Arkansas River should be surveyed during peak riverine breeding activity, in yearly surveys of this population.

In 2018, rooftop colonies suffered from low fledging success exhibiting an FBR of 0.16 (Table 3); Belk was the only successful rooftop colony with an FBR of 0.62 (Table 2). The high parapet (>3m) surrounding this rooftop is beneficial as it can provide shade for chicks, a critical resource on rooftop colonies as they are disproportionately affected by heat stress relative to riverine colonies (Purdue 1976, Watterson 2009). Even so, we recorded evidence of heat induced mortality of eggs and chicks throughout the season at this colony; egg mortality indicated by atypical floating (Hays and LeCroy 1971) with no visible damage, and desiccated chicks with no evidence of injury. The Belk parapet also provides protection from incidental chick mortality as they fall off the roof which can be caused by high winds and adverse weather, as well as human disturbance (Fisk 1978, Krogh and Schweitzer 1999). Another benefit for the Belk colony was that it is in a highly-urbanized location in Conway, Arkansas and as a result did not have a forested area nearby which may make this colony less susceptible to avian depredation. The rooftop colony at LRAFB #787 BX also has a surrounding parapet but the colony suffered a

severe decline between 2 July and 16 July, 2018. This rooftop colony had 26 adults with 10 nests, 16 eggs, and 23 chicks, but two weeks later there were no adults or chicks present. The exact cause of colony failure/abandonment is not known as we lacked any direct evidence of severe weather or depredation, but this event was almost repeated the following year in 2019 and a motion-activated trail camera recorded evidence of a Great Horned Owl (*Bubo virginianus*) walking on the rooftop (Figure 17), and later crows investigating unattended eggs (Figure 18). Given this evidence, and close proximity to wooded areas, is it possible this rooftop colony suffered similar depredation in 2018 leading to its collapse.

Riverine colonies in 2018 were fairly successful with an FBR of 0.59 (Table 3). There were significant signs of disturbance which may explain the lack of success at specific colonies. Nearly every riverine colony had recorded signs or presence of disturbance from species including Canada Geese (*Branta canadensis*), Great Blue Herons (*Ardea herodias*) and Great Egrets (*Ardea alba*). Noteworthy instances of disturbance include the regular occurrence of cattle on RM 153 (FBR of 0.50), and fresh shotgun shells at RM 189.7 (FBR of 0) and RM 275 (FRB of 0.19) which may help explain their relatively low success.

The breeding season of 2019 was marked by an historic flood (Table 1, Figure 2) so I expected surveys to yield similar results to other flood years (Table 10). Early in the summer of 2019 southeast Kansas and northeast Oklahoma experienced heavy rainfall, causing swelling of local lakes and unavoidably high dam releases along the Arkansas River of over 500,000 cfs for flood prevention. By the end of May, local evacuations were being urged for residents in specific areas along the river in OK and AR. The flood eventually breached multiple levees in Arkansas and flooded homes, businesses, highways, and farmland, causing a formal state of emergency, hundreds of evacuations, and assistance by the Red Cross and Arkansas National Guard. In Arkansas, the flood broke records for crest height at multiple locations, the oldest of which was

set in 1927 (Table 1). This inevitably complicated our surveys as water levels prevented riverine surveys until late July. Prior to that, our surveys were focused on 4 rooftop colonies (two in Conway, AR and two at the LRAFB) and 2 novel colonies that were reported in gravel lots at the LRPA (Rebecca Peak [USFWS] pers. comm.). Previous years with flooding events occurred in 2004, 2007, 2008, 2010, and 2015 but none approached the magnitude and severity of the 2019 flood (Table 1).

Colony initiation dates in 2019 were also in two relative groups. This was a likely result of the flooding, where the first group consisted of all 6 non-riverine colonies that initiated between 21 May and 10 June, a range of 3 weeks. The second round of colony initiations consisted of the 4 riverine colonies on the MKARNS that initiated between 24 June and 25 July, once the water levels had subsided (Table 5, Figure 2).

In total, 2019 was not a successful year for this population of ILT's. Individual colonies ranged in success with FBR's of 0 – 0.74, with 7 colonies (70%) resulting in an FBR of 0 (Table 4). Across all 10 colonies this made for a total FBR of 0.225 with 42 fledglings produced (Table 6). The adult count of 266 ILT's is comparable to other flood years (Figure 13). Non-riverine colonies did poorly and exhibited a combined FBR of 0.04, and riverine colonies exhibited an FBR of 0.67 (Table 6), which was almost completely due to one highly-successful colony (RM 224, Table 5).

Rooftop colony surveys in 2019 differed from the previous season as management at Belk revoked our access to that location after 5 June. Prior to that, we observed 53 adults with an encouraging 41 nests and 84 eggs, which was substantially above the numbers observed from 2018 (Table 2, Table 5) at this location. This increase in counts at Belk in 2019 could be expected as ILT's will increase their exploitation of suitable man-made sites as availability of natural sandbars become more limited (Sidle and Kirsch 1993), as was the case with the flood.

After access was revoked at Belk in 2019 we were unable to report an FBR for this colony. However, I made multiple personal trips to this location as I was concerned about the unprotected water drainage ducts that are ground level for the presumed chicks and provide a tunnel from the high parapet-protected rooftop to a large drop onto the access road behind the store. This created a legitimate potential for mobile chicks to fall to their death, as I witnessed chicks taking cover in these ducts in 2018 from investigator disturbance and presumably to seek shade. Whereas no chicks were ever found behind the building in 2018, I found a total of 6 near-fledglings (14-17 days old) capable of erratic flight at best, who had presumably fallen to the ground through these ducts. It seems unlikely that these birds flew off the roof as they seemed incapable of flying more than a few feet off the ground and it would have been difficult for them to get over the high parapet on the rooftop. Of the 6 chicks I observed on the ground, I was able to capture them all including 4 on 15 July and delivered these birds to Belk staff who returned them to the rooftop. On 18 July, I observed one dead fledgling on the pavement behind Belk that had been run over by a vehicle, and Belk staff informed me that they had returned another chick on their own to the rooftop the previous day. Although we cannot report an FBR for the ILT colony at Belk in 2019, it is likely that given its protective parapet, its success the previous year, and the increased number of adults in 2019, that some chicks may have fledged.

Again, with flooding and a reduction of available natural habitat in 2019, ILT's increased their exploitation of man-made habitat by nesting at the infrequently-used building #450 at LRAFB, along with the often-used building #787 BX. Neither colony produced fledglings (Table 5), but the colony on LRAFB #787 BX suffered a between 28 June and 3 July, 2019, similar to the previous year. On 28 June we recorded 34 adults, 22 nests with 43 eggs, and 18 chicks, but the following survey on 3 July we recorded just 5 adults, 21 nests with 38 eggs, and 1 chick. These numbers continued to diminish on subsequent surveys as the colony was apparently

abandoned, and the lone chick was not seen again. A motion-activated trail camera placed on the colony recorded photos of a Great Horned Owl on 30 June (Figure 17), and a crow (*Corvus spp.*) was photographed on 9 July appearing to touch an egg with its beak (Figure 18). As a result we believe it is very likely that a Great Horned Owl depredated this colony's chicks, causing the adult ILT's to largely abandon the colony, leaving the remaining eggs unattended and available to scavenging crows.

The most notable evidence of increased use of man-made habitat by ILT's during the 2019 breeding season were two novel colonies reported on gravel lots at the LRPA (Rebecca Peak [USFWS] pers. comm.). Gravel pits can be successful locations for terns (Sidle and Kirsch 1993, Jenniges and Plettner 2008), but these colonies combined recorded 26 adults and just 1 chick which was never observed to fledge, resulting in an FBR of 0 (Table 5). A notable drop in activity at LRPA Small Lot was seen between surveys on 18 June, which yielded 24 adults and 8 nests with 17 eggs, to a survey on 28 June, which yielded 0 adults, nests, or chicks. A motion-activated camera at this location captured photographs and video of a Striped Skunk (*Mephitis mephitis*) moving methodically among the colony (Figure 14) apparently from nest to nest, as adult ILT's hopelessly tried to harass and deter the predator. The camera also captured a photograph of a Coyote (*Canis latrans*) moving through the colony on 24 July (Figure 15). As a result, we believe it is likely that the skunk depredated most/all ILT nests, followed by a coyote, initiating colony abandonment.

Riverine colony surveys in 2019 began on 1 August when the flood had passed and water levels became safe. Of the four riverine colonies surveyed, two proved successful and two failed (Table 5). A lack of success was to be expected amongst these colonies as a late colony initiation is a disadvantage; predator activity may increase throughout the nesting season (Kruse et al. 2001) and increased temperatures later in the summer may increase the mortality rate of eggs and

chicks (Purdue 1976, Howell 1959). Most of the nesting activity in 2019 along the MKARNS was a colony at RM 224. This location may have been a small sandbar in prior years, but the flooding event appeared to have deposited more sand to create a sizeable sandbar, resulting in a novel ILT colony location. Despite a late initiation time, this colony proved very successful with 95 adults that produced 35 fledglings (83% of all ILT fledglings from 2019) resulting in an FBR of 0.74 (Table 5).

Despite studies suggesting ILT's are prone to reuse colony nesting sites if they remain available and suitable (Burger 1984), this population is reusing sites on the MKARNS at an average rate of 49.20% ± 7.95% per year, ranging from as high as 87.50% to as low as 18.18% (Table 4), and these sites have yielded an average FBR of 0.362 ± 0.028. Rooftop colonies have been surveyed since 2007 and ILT's are reusing rooftop sites at an average rate of 76.53% ± 4.64%, which have yielded an average FBR of 0.164 ± 0.025 (Table 9). In comparison, rooftop colonies are reused more often than MKARNS colonies, and on average tend to have lower FBR rates despite analyses finding no difference. This indicates that rooftop colonies may be an ecological trap for these ILT's, who seem more inclined to return to these specific sites year after year despite a trend of lower FBR rates at these colonies.

Lott (2006) conducted the first range-wide survey of the ILT in 2005, giving evidence to consider the ILT a metapopulation. At the time, he found 319 ILT's on the MKARNS, which accounted for just 1.8% of the total ILT's counted. Lott's (2006) study illustrates that the trends and conclusions drawn from our study only apply to ILT's nesting within the Arkansas River Valley in Arkansas and cannot be considered indicative of ILT trends across their breeding range.

CHAPTER 2

EVALUATING THE EFFECTS OF MANAGEMENT ACTIONS ON FLEDGING SUCCESS OF INTERIOR LEAST TERN COLONIES

INTRODUCTION

The Interior Least Tern (*Sternula antillarum athalassos*, hereafter ILT) is a small shorebird that nests in colonies on barren sandbars of many major river systems from Texas to North Dakota (Smith and Renken 1991, Lott 2006, Sherfy et al. 2012, Fansworth et al. 2017). The ILT was listed as federally endangered 1985 largely due to concerns of habitat loss as a result of water resource development projects, such as the widespread damming and channelization of interior rivers (USFWS 1985). This resulted in a decline of both quality and quantity of suitable sandbar nesting habitat due to decreased sediment deposition, increased erosion, and vegetative establishment (Galat and Lipkin 2000, Nilsson and Berggren 2000, Pegg et al. 2003, Elliott and Jacobson 2006, Parham 2007). On unaltered river systems seasonal periods of high and low flows maintain the presence and characteristics of emergent sandbars with sparse vegetation (Wohl et al. 2015) that ILT's require for breeding (Ziewitz et al. 1992). These multipurpose dams will continue to directly impact sandbar nesting habitat (Knoll 2006) throughout the range of the ILT making habitat management critical to their recovery. In Arkansas, it is the legal duty of the U.S. Army Corps of Engineers who maintains the MKARNS to oversee and manage for the increased success of this endangered shorebird throughout its range pursuant to the biological opinion (USFWS 2016).

Within Arkansas, management for the ILT has been ongoing since 2002 and has included dredge spoil deposition, herbicide treatment, and vegetative mulching (Table 10). Documenting and investigating the effects of these actions is important as resources are limited and these

actions are costly, and as of this writing no direct investigation has been attempted to understand the impacts that management in Arkansas has had on the fledging success of its ILT population.

Background of Least Tern Management History

Water control practices on dammed river systems can be used to manage sandbar nesting habitat by renewing existing sandbars and by discouraging seedling recruitment. Sustained periods of high-output flows can result in vegetation-scouring floods with increased sediment deposition, and these habitat-forming flows have been associated with increases in ILT population size and fledging success (Sidle et al. 1992, Leslie et al. 2000, USACE 2011). Johnson (2000) developed a plan for the Platte River which demonstrated how flow regimes could be managed in order to minimize vegetative establishment on sandbars. Wiley and Lott (2012) state that in theory, dam release can be altered to manage for sandbar nesting habitat by avoiding high flows during peak seed dispersal times, implementing short-term high or low flows to cause seedling mortality through inundation or desiccation, and lastly by manipulating flows to remove young vegetation before the second growing season. These ideal practices are complicated by the water management needs along these river systems, specifically flood control, and therefore will likely not be possible in all regions at all times. The downriver section of the Arkansas River, downstream of the Robert S. Kerr Dam (Lock and Dam 15), has very limited flexibility in controlling their flows (USFWS 2016).

Managing vegetation on sandbar nesting habitat is crucial to ILT success. Kruse et al. (2001) found as vegetation becomes more prevalent, predator abundance increases. Pre-emergent herbicide treatment is most effective for controlling vegetation with mechanical removal as necessary (Jenniges and Plettner 2008), and has proven successful for increasing Least Tern chick survival (Spear et al. 2007). Mechanical removal of vegetation may be necessary, although it is extremely costly and may produce brush piles which need to be removed to maintain the

open expanses of habitat that nesting ILT's prefer (Buckley and Buckley 1980, Wiley and Lott 2012). These brush piles, and any other woody vegetation, may provide perching opportunities for avian predators and immediately render a large area of habitat unsuitable for nesting ILT's. Complete removal of vegetation may not be necessary as nesting colonies will tolerate up to 25% scattered, low-coverage vegetation (Ziewitz et al. 1992), and may even prefer the presence of scattered grasses or small herbaceous vegetation (Burger 1989), likely for the benefit of providing shade for chicks (Wolf 2000, Butcher et al. 2007). Some vegetative communities such as yellow nut-sedge may actually be desirable as they provide erosion resistance and will not encroach onto dry, elevated areas of sandbars that are preferred for nesting (Wiley and Lott 2012). However, even though some coverage of vegetation may be tolerated or even preferred, this could likely indicate the habitat will soon become unsuitable for nesting due to vegetative succession and it should generally be managed as a threat (Wiley and Lott 2012). It is important to conclude vegetative treatments before ILT's arrive at their breeding grounds as Burger (1984) found that Eastern Least Terns (*Sternula antillarum antillarum)* would always return to their previous colony nesting site, but may then chose to abandon it if it has become unsuitable due to increased vegetation, human activity, or other factors.

Habitat creation is an important management tool that can provide additional nesting habitat for ILT's. Man-made sites used by nesting Least Terns include sand pits made from gravel mining or otherwise, not directly adjacent to the river system (Sidle and Kirsch 1993, Jenniges and Plettner 2008, Nupp and Jensen 2020), and sandbars created from dredge spoil deposition (Kirsch 1996, Thompson and Slack 1982, Mallach and Ledberg 1999, Spear et al. 2007, Kotliar and Burger 1986). During the first range-wide survey of the ILT, sand pits accounted for 5.9% of total colonies (Lott 2006). Kirsch (1996) showed that ILT's had no preference between dredge spoil sites and natural sandbars, reproductive productivity did not

differ, and colony-site turnover did not differ provided the physical characteristics on dredge spoil sites adhere to the general preferences for ILT's, such as <25% vegetative cover, gravel or sand substrate, and lacking human disturbance (Ziewitz et al. 1992). Exploitation of suitable man-made sites will likely increase as availability of natural sandbars become more limited (Sidle and Kirsch 1993), making them extremely valuable in flood years.

Least Terns are also known to select gravel-covered rooftops for colony locations (Fisk 1978, Cimbaro 1993, Cooper 1994, Gore and Kinnison 1991, Krogh and Schweitzer 1999, Forys and Borboen-Abrams 2006, Butcher et al. 2007). During the first range-wide survey of the ILT, rooftops accounted for 0.4% of total colonies (Lott 2006). Nesting on rooftops presents a unique set of benefits and challenges. A nearby water source is necessary not only for food, but to aid adults with the brooding and thermoregulation of their eggs and chicks as they collect and store water in their breast feathers (Thompson et al. 2020). As a result, the main factor influencing selection of a rooftop as a colony site appears to be its distance to a body of water (Thompson et al. 2020). There is a different predator regime for these colonies as rooftops can severely decrease or eliminate predation by mammals, leaving avian predators as the main threat (Jackson and Jackson 1985) (Figure 17). The risk of flooding is typically eliminated unless the rooftop is flat (Fisk 1978) however large rainstorms can still wash away eggs and chicks (Krogh and Schweitzer 1999), highlighting the need to screen water drainages (Fish 1978, Nupp and Jensen 2020). Rooftops sites that lack a surrounding parapet may also be vulnerable to high winds which can potentially blow eggs and/or chicks from the roof. Rooftop colony sites can have significantly higher temperatures relative to natural or man-made riverine locations (Krogh and Schweitzer 1999, Watterson 2009) and as temperatures increase, chicks spend more time being brooded by an adult or in the shade (Cimbaro 1993, Butcher et al. 2007). Howell (1959) found that under severe heat stress of >45^{o}C, young Least Tern chicks can thermoregulate

independently for up to 38 minutes. Although Least Tern chicks are particularly well adapted to regulate their body temperature against high external temperatures, availability of shade can still be crucial for chick survival and it can be hard to find on a rooftop. In an effort to provide additional shade for rooftop colonies, structures such as wooden teepees and artificial plants have been introduced and Butcher et al. (2007) found that ILT chicks would use artificial plants for shade. Even with the addition of shade however, periods of extreme heat will disproportionately affect rooftop colonies relative to riverine colonies, especially considering that exposure to ground temperatures of >41°C can prove lethal to the eggs of Charadriiform birds (Purdue 1976). As a result, rooftop colonies vary in fledging success but can be at least as productive as riverine colonies (Fisk 1975, Gore and Kinnison 1991, Savereno and Murphy 1995) (Table 2, Table 5). Anthropogenic disturbances at rooftop colonies are also a cause for concern as it can cause chicks to run and fall off of roofs (Fisk 1978, Krogh and Schweitzer 1999) if there is no parapet present, or fall from/into water drainages if accessible to chicks. To increase the fledging success of rooftop colonies it is recommended to add shade structures if necessary, preferably artificial plants (Butcher et al. 2007), add a temporary barrier during the breeding season if no parapet is present, and to screen water drainage openings (Fisk 1978). Although not ideal, these rooftop locations may become essential during flood years when natural riverine sandbars are less available and terns increase their exploitation of man-made locations (Sidle and Kirsch 1993).

Predation is a primary factor affecting the fledging success of ILT's and can cause total failure of entire colonies (Burger 1984). Predation of eggs and chicks has been documented by mammals (Burger and Gochfeld 1990, Rimmer and Deblinger 1992, Jenniges and Plettner 2008) (Figure 14, Figure 15), birds (Jenks-Jay 1982, O'Connell and Beck 2002, Rimmer and Deblinger 1992, Jenniges and Plettner 2008) (Figure 16, Figure 17, Figure 18), reptiles (Jenniges and Plettner 2008), and even southern fire ants (*Solenopsis xyloni*) (Hooper-Bui et al. 2004). The

colonial nesting strategy of ILT's does result in increased vigilance for predators (Hamilton 1971) but these colonies have no defense against nocturnal predators aside from nest desertion, particularly against avian predators such as owls (Burger 1989) (Figure 16, Figure 17). Successful efforts to reduce predation rates on Least Terns and other colonies of beach- or sandbar-nesting shorebirds have included electric and non-electric fencing (Jenniges and Plettner 2008, Minsky 1980, Burger 1989, Rimmer and Deblinger 1992, Thompson et al. 2020, Spear et al. 2007), predator removal (Burger 1989, Jenniges and Plettner 2008, Thompson et al. 2020), and protective structures (Thompson et al. 2020, Jenks-Jay 1982). Wooden teepee-like structures have been introduced to Least Tern colonies and although Jenks-Jay (1982) concluded they were effective at reducing the rate of predation from avian predators, it is likely that high temperatures drove chicks to seek shelter for shade where they also experienced less predation, as seeking shelter is not a typical behavior of Least Tern chicks in the presence of a potential predator (Butcher et al. 2007). On a rooftop colony of ILT's, similar teepee-like structures were introduced along with artificial plants and when adults flushed to mob a potential predator the typical response of chicks was to lie motionless on the ground and rely on camouflage, rather than move to shelter (Butcher et al. 2007). Kruse et al. (2001) found that predators such as raccoons, mink, and crows account for the vast majority of ILT egg depredation, and raptors such as kestrels and owls accounted for the vast majority of chick mortality.

Disturbance from human activity can cause declines in hatching and fledging success (Burger 1984, Burger 1989, Burger and Gochfeld 1990) and over time can cause site abandonment (Erwin 1980). Disturbances can range from interspecific to anthropogenic interactions, including recreational visitation on natural sandbars and commercial operations at or near man-made sites (Bent 1921, Crow 1974, Neck and Riskind 1981, Dryer and Dryer 1985, Burger 1989, Burger et al. 1995). The indirect consequences of disturbance likely outweigh the

direct consequences as it can potentially interfere with parental care throughout an entire colony (Burger 1982). Adult Least Terns respond to disturbances by flushing from their nests either to intimidate the threat or flee to safety, leaving the nest deserted and exposed to predators and the elements (Lemmetyinen 1971, Anderson and Keith 1980, Burger 1982). Successful efforts to reduce human disturbances have included string or wire perimeters (Burger 1989), fencing (Burger 1989, Jenniges and Plettner 2008), and signs (Burger 1989, Jenniges and Plettner 2008, Figure 19). Burger (1989) notes that the most effective method of colony protection from human disturbance was the employment of a warden, on duty for five or more days per week, ideally present during weekends and adhering to simple behavioral guidelines to allow quick habituation of terns to the warden's presence. She notes that the presence of a warden generally resulted in an increase of a colony's success. Researchers can also be a cause of colony disturbance, and investigator disturbance can even lower the fledging success of terns (Anderson and Keith 1980, Brubeck et al. 1981, Gochfeld 1981, Nisbet 1981), highlighting that survey methods must be designed to minimize the frequency and intensity of disturbance as much as possible. Erwin (1989) recommends a buffer zone of 100-meters to minimize disturbance for Least Terns that could be applied to protective boundaries from the public and to investigators when possible. To maintain a cooperative relationship with the public, it is recommended that exclusionary elements be removed outside of the breeding season but educational signs be maintained (Burger 1989) (Figure 19).

The ILT nests in shallow depressions, or scrapes, on open gravel or sand where eggs and chicks are vulnerable to exposure and heat stress (Thompson et al. 2020). Howell (1959) considered 45ºC the threshold to cause severe heat stress in non-mobile Least Tern chicks, which showed signs of severe stress after 38 minutes. Butcher et al. (2007) found that temperatures above 35ºC and below 30ºC caused mobile chicks to seek shelter in the shade or from brooding

by an adult. Shade can provide significant relief from the heat (Wolf 2000) and brooding adults contribute to the effort of thermoregulating their chicks by transporting water in their breast feathers (Thompson et al. 2020). There have been various efforts to provide shade structures within nesting Least Tern colonies to improve chick survival (Thompson et al. 2020). Butcher et al. (2007) found that chicks significantly utilized artificial plants for shade in a rooftop colony. This likely helps explain why although nesting ILT sandbars may appear barren, they will tolerate up to 25% scattered, low-coverage vegetation (Ziewitz et al. 1992), may prefer the presence of scattered grasses or small herbaceous vegetation (Burger 1989), and may also prefer to nest near small pieces of driftwood (Marcus et al. 2007). It can therefore be concluded that the addition of small shade structures such as scattered low-coverage vegetation, artificial plants, and small pieces of driftwood to a completely barren site may increase its suitability for nesting ILT's.

Least Terns may re-establish colonies at abandoned sites or establish new colonies without human assistance, but relatively simple methods can influence nest site selection within suitable habitat. Decoys have been used in tandem with other methods (predator control, playback of vocalizations) to attract Arctic Terns (*Sterna paradisaea*) and Common Terns (*Sterna hirundo*) to return to abandoned colony sites (Kress 1983), used alone to attract Eastern Least Terns to return to abandoned colony sites (Kotliar and Burger 1984), and to attract California Least Terns (*Sternula antillarum browni*) to new sites (Massey 1981, Fancher 1983). Various types of Least Tern decoys have been utilized including papier-mâché (Massey 1981), decoys cut from flat wooden boards, carved from wood, and shaped from Styrofoam (Burger 1989), with rounded decoys painted as adult terns being the most successful. Kotliar and Burger (1984) found that decoys were effective at attracting Eastern Least Terns to nest within close proximity amongst equally suitable habitat. Furthermore, Burger (1988) found that the colony

size of decoys, their spatial arrangement, and ratio of paired/unpaired decoys influenced how effective the method was at attracting Eastern Least Terns. As a result, decoys could likely be a useful management tool to aid in the re-establishment of nesting colonies on abandoned sites, the establishment of colonies on newly-created sites, and potentially for relocating nesting colonies within a larger suitable habitat in order to minimize disturbance, predation, or flood risk (Kotlair and Burger 1984).

Marcus et al. (2007) found that it is possible to shift ILT nest site selection within ecologically similar plots by using a combination of deterrents and attractants. He found that spreading gravel and driftwood (10 pieces per 1,000m^2) on top of sand acted as an attractant in combination with the use of Mylar reflective streamers as a deterrent in an adjacent area, along with a control area. It also appeared ILT's preferred to nest near driftwood in attractant plots. Given the study design it is difficult to infer the relative effectiveness of each treatment independently, however there is precedent for added gravel to be an attractant (Kirsch 1996) and for Bird-Scaring Reflecting Tape® (Bruggers et al. 1986) or similar Mylar streamers (Marcus et al. 2007) to be a deterrent.

The first objective of this chapter is to determine if any specific type of management effort implemented by the USACE on the MKARNS, or management in general, has had a measureable immediate effect on ILT fledging success, occupation and adult count, and if there is an effect of cumulative management on a sandbar. Given the potential of vegetation control to improve ILT chick survival (Kruse et al. 2001, Spear et al. 2007) and for dredge spoil deposition to not only create new habitat but to potentially improve existing sandbar nesting habitat by smothering vegetation (Wiley and Lott 2012), I expect that comparing management actions through time with fledging success will reveal a positive correlation with all 3 specific management actions (dredge spoil deposition, herbicide treatment, and mulching) and with

management in general, as well as increasing the likelihood of occupation by ILT's. I do not expect to find an effect from cumulative management due to the emergent and dynamic nature of these sandbars, making it unlikely that any positive effect of a management effort extends beyond approximately two breeding seasons. Furthermore, I analyzed the fledging success rates of individual colonies on the MKARNS through time to determine if colony fledging success trends have been stable.

The second objective of this chapter is to understand how the USACE has been allocating management efforts since 2002 on the MKARNS relative to ILT colony occupation, to determine if management is being used in the right places at the right times to be most effective.

The third objective of this chapter is to review management actions that have been implemented to improve the habitat and fledging success of Least Tern colonies from other populations. This is to provide insight into the effects that other studied management actions have had on Least Tern colonies and populations, which may prove useful in recommending additional modes of management to increase the effectiveness of ILT management in Arkansas.

METHODS

Survey Area

Investigators conducted ILT colony surveys along the MKARNS within Arkansas spanning from the Wilbur D. Mills Dam (Dam 2) at approximately river mile 19 (hereafter RM) near Pendleton, AR, to approximately RM 285 (Dam 13) near Fort Smith, AR. Surveys have also opportunistically included the unchannelized and unmaintained lower portion of the Arkansas River below the Wilbur D. Mills Dam in 2010, 2011, 2013, and 2018. Riverine colonies were located by checking previously known nesting locations, as reports have indicated ILT's may be likely to reuse a suitable and available sandbar (Burger 1984). During riverine surveys, any suitable habitat observed was surveyed for the presence of ILT's. Rooftops were surveyed with

known ILT colonies in previous years and have included Maybelline in Clarksville, AR, Belk and Snap-On in Conway, AR, and buildings #450 and #787 at the Little Rock Air Force Base (hereafter LRAFB). Potentially suitable rooftops have also been identified using satellite imagery and investigated to search for adult ILT's flying overhead.

Field Methods

Surveys ranged in frequency from attempted colony visits at least 3 times per breeding season (roughly correlating with the timing of colony establishment, peak chicks present, and fledging) to approximately biweekly colony visits depending on the ongoing projects at the time. Some areas were not surveyed every year, and 2007-2008 recorded no surveys. During riverine surveys, all suitable nesting habitat was surveyed for the presence of nesting ILT's or those exhibiting courtship behaviors, with emphasis on checking colony locations used in previous years. Riverine surveys were initiated as early as late May or when water levels were safe and low enough to expose sandbars during flood years (2004, 2007, 2008, 2010, 2015, and 2018), which can be as late as August (Figure 2). Rooftop colonies were surveyed based on previously identified rooftops, and other potentially suitable rooftops were investigated within each season for adult ILT's overhead.

Yearly surveys were conducted under the appropriate permits. Surveys in 2018 were conducted under USFWS recovery permit TE16616C-1 through Arkansas Tech University. Riverine surveys are conducted with a small outboard boat and a typical crew of 3-4 people. Upon approaching a colony site, all possible counts (adults, fledglings, and chicks) were taken using binoculars before the initial disturbance of the colony and were supplemented at the end of the effort if necessary. Included in the governing permits are restrictions on allowable colony disturbance; restriction in 2018 included allowable disturbance time (20 minutes), wind speed (<25 mph), precipitation (none), and temperature range (40-90^{o}C). As a result, surveys have

typically been conducted as early in the day as possible. In circumstances when one or more of these conditions was not met, all possible counts (adults, chicks, and fledglings) were taken from the boat using binoculars to avoid colony disturbance. When surveying a rooftop or riverine colony site on foot, surveyors either partitioned non-overlapping areas of the colony amongst themselves or walked parallel transect lines throughout the colony until the survey is completed or a restriction of the permit called for a conclusion of the effort.

During riverine colony surveys when mobile chick were present, special care was taken to ensure chicks were not inadvertently pushed to a shoreline in their effort to avoid investigators as chicks may abandon the island and attempt to float downstream if sufficiently stressed. In those circumstances, binoculars were used to get estimates of bird counts and ages without closer inspection. Similarly, rooftop colonies with mobile chicks that lacked a surrounding parapet and/or screened water drainages (Belk, Snap-On, and LRAFB #450) were surveyed using binoculars from a static position to avoid incidental chick mortality, and the effort was abandoned if adults become disturbed. In some cases, that required one investigator at a time to collect visual counts from the top of an access ladder which resulted in only a fraction of the entire rooftop being visually accessible.

Survey efforts recorded all relevant information: adult counts, chick counts, fledgling counts, nest counts, egg float data for aging (Hays and LeCroy 1971), and various environmental conditions. Adult counts were only reported for colonies where nesting occurred. Chicks were aged and placed into one of four categories: 1) Downy chicks in nest - Chicks believed to be ≤ 2 days old, usually found in nest scrapes; 2) Mobile downy chicks - Chicks believed to be 3-9 days old, usually found under cover or motionless on sand away from nest scrapes; 3) Feathered chicks - chicks believed to be 10-17 days old, with undeveloped primary flight feathers and; 4) Fledglings - chicks ≥18 days old, with developed primary flight feathers. Fledglings observed to

be capable of flight were simply counted as "fledglings" (Nupp and Jensen 2020). A GPS device such as a Trimble™ GPS (Trimble Navigation, Ltd, Sunnyvale, CA) was typically used to record colony location and map the colony site perimeter, as well as to map individual nest locations depending on secondary research interests at the time.

ANALYSIS

Raw numbers were used for comparison of management actions relative to ILT occupation and fledging success. This allowed for a direct comparisons between years, and to investigate if management has been applied in the right places at the right time to be as effective as possible.

My intent in the following models was to parse out the effect of management actions performed by the USACE on ILT nesting sandbars may have had on the fledging success of ILT's, using data from 2001 through 2018. Small sample sizes and inconsistently applied management rendered complex models that handle repeated and random effects to be inappropriate, and less complex models that handle zero-inflated data to be more suitable. Hurdle models (Mullahy 1986) are two part regression models, accessed from the "pscl" package (Zeileis et al. 2008) in R (R Core Team 2018). Hurdle models consist of two parts; one involves a binary analysis that compares zero and non-zero responses, and a second part models all non-zero count data that has crossed that hurdle in a truncated negative binomial regression. Hurdle models require a discrete response variable, so fledgling counts were used to indicate colony success. However, fledgling counts alone are biased by colony size so the number of nests recorded at the peak of nesting season were included in the models to be an indicator of colony size. The relationship between fledgling counts and FBR was investigated by using a generalized additive model (Hastie and Tibshirani 1990) accessed with the "mgcv" package (Wood 2017) in R (R Core Team 2018), and visualized with the "ggplot2" package (Wickham 2016). The

purpose of this analysis was to understand and visualize the general nature of the relationship between factors identified in the hurdle models and FBR.

The first hurdle model was built to investigate the immediate effects of specific management actions; combined year-of and year-after effects of dredge spoil deposition, herbicide treatment, and mulch treatment, compared to unmanaged years. The second hurdle model focused on the same immediate effects of any management action in general, by combining all three recorded management types. The third hurdle model investigated the effects of the cumulative management history of a sandbar, where sandbars received an additional cumulative management score each time management was applied to that specific location. The final hurdle model will use estimated breeding pairs as the response variable and investigate if there is an effect of general management on ILT occupation, indicated by adult presence, and an effect on the number of adults present. All models used an alpha level of 0.05 and included variables indicating the proximity to a flood (flood year, post-flood year, or non-flood year), whether the site was used previously by ILT's, and the number of nests to be an indicator of colony size (not included in the final hurdle with adult counts). All variable levels were ordered to make normal factor states the base level (non-flood year, unmanaged, site unoccupied the previous year).

Hurdle models are particularly appropriate for this analysis due to the nature of the response variable in the first models, fledglings. Not only can hurdle models appropriately handle zero-inflated count data, but a portion of zero-fledgling counts is likely due to extrinsic and unmeasured factors such as local flooding events, severe weather, and even singular instances of severe predation events leading to colony failure (failure to fledge at least one chick). The binary analysis allows for an investigation between colonies that failed and those that were successful, and the subsequent negative binomial regression on positive fledgling count

observations allows us to exclude colonies that may have failed due to one of these extrinsic factors and identify factors that influence the magnitude of fledging success. In the final hurdle model using adult counts as the response variable, the binary analysis will investigate if factors such as management have an impact on ILT occupation of a site indicated by the presence or absence of adults, and the subsequent negative binomial regression will investigate a potential effect on the number of adults present.

Generalized additive models (Hastie and Tibshirani 1990) were used to investigate the trends of FBR rates from individual colonies through time, accessed with the "mgcv" package (Wood 2017) and visualized with the "ggplot2" package (Wickham 2016) in R (R Core Team 2018). This analysis was to understand the trend and stability of individual colony fledging success rates through time on the MKARNS.

RESULTS

The earliest records of sandbar management on the MKARNS start in 2002 with dredge spoil deposition, which remained the sole type of management through 2010 (Table 10). No management actions were recorded in 2006 or from 2011-2014. From 2015-2018 herbicide and mechanical mulch treatments were conducted along with dredge spoil deposition. In total, between 2002 and 2018, 82 management actions are recorded on 33 different locations. During that time, 37 actions (45.1%) were conducted on 17 locations (51.5%) that have never been occupied by ILT's at any time before or after. During the period of more varied management since 2015, 21 of 52 actions (40.4%) have been recorded on 15 locations which have never been occupied by ILT's. Furthermore, 19 locations that have had ILT colonies within 2014-2017 received no management from 2015-2018, and 13 of those colonies successfully fledged a chick at least once. Thus, only 20 (24.4%) of the 82 management actions occurred on locations which hosted an ILT colony either in that year or in the previous breeding year (Table 10), with a

yearly mean of 13.41% ± 5.14%. There is clearly room for improvement in this management strategy.

The hurdle model I used to investigate immediate effects of specific management actions on reproductive productivity found no significant effects of any individual type of management action in the zero hurdle binomial model (spoil: $p = 0.1471$; herbicide: $p = 0.3396$; mulch: $p = 0.4968$), or in the truncated negative binomial model (spoil: $p = 0.6500$, Figure 20; herbicide: $p = 0.1857$, Figure 21; mulch: $p = 0.8835$, Figure 22) (Table 11). In summary, this model found no effect of specific management actions on whether or not a colony was successful, or on the level of success among successful colonies.

The hurdle model I used to investigate the immediate effects of non-specific management on reproductive productivity found no significant effects in the zero hurdle binomial model ($p = 0.1516$), or in the truncated negative binomial model ($p = 0.1763$, Figure 23) (Table 12). In summary, this model found no effect of management in general on whether or not a colony was successful, or on the level of success among successful colonies that fledged at least one chick.

The hurdle model I used to investigate the relationship between cumulative number of management activates for each colony site and reproductive productivity found no significant relationship in the zero hurdle binomial model ($p = 0.2931$), however this relationship was significant in the truncated negative binomial model ($p = 0.0328$, Figure 24) (Table 13). In summary, this model found no effect of a sandbar's cumulative number of management activities on whether or not a colony was successful in fledgling a chick, but did find an effect on the level of success among successful colonies. This effect increased the baseline average of 1.9906 fledglings by 1.2101 times with each progressive level of cumulative management score, amongst those observations of positive fledgling counts.

The final hurdle model I used to investigate the effects of non-specific management on the breeding adults present found a significant effect of management in the zero hurdle binomial model ($p < 0.0001$), but no effect in the truncated negative binomial model ($p = 4847$) (Table 14). The significant effect of management in the zero hurdle model increased the baseline odds of having a positive count, 0.0953, by 3.1533 times. In summary, management made it significantly more likely that breeding adults were present, therefore whether a colony was established at that specific location or not. This hurdle model was unique from the previous models in that all observations were included, regardless of whether or not an ILT colony was present. The main limitation of this model is that I assumed all locations were available in any given year although this is likely not the case, as I lacked the data to make this distinction. However, despite the dynamic nature of these sandbars their actual presence/absence is decidedly more stable, and therefore the general findings of this model are reliable.

A general additive model was used to illustrate the relationship between the number of fledglings, the response variable from the hurdle models, to FBR rates. The resulting model accounts for 65.8% of the deviance observed with an r^2 of 0.648 (Figure 25). Smoothing parameters were chosen to easily visualize any apparent trend, and a general positive correlation is revealed between fledgling counts and FBR rates. It is therefore appropriate to view fledglings, used as the response variable in the previous hurdle models, as an adequate proxy for fledging success.

A generalized additive model was used to investigate the trend of individual colony FBR rates through time. This trend does not appear to be stable but does appear to be slightly increasing through time, and the resulting model accounts for 3.9% of the deviance observed with an r^2 of 0.0334 (Figure 26). A repeated analysis including only successful colonies which

fledged at least one chick, reveals a similarly unstable but increasing trend. This model accounted for 9.79% of the deviance observed with an r^2 of 0.0821 (Figure 27).

DISCUSSION

Interior Least Terns are selective in regards to sandbar nesting habitat, generally requiring <25% scattered vegetative cover and a gravel or sand substrate (Ziewitz et al. 1992). The USACE in Arkansas started applying management for ILT's along the MKARNS with dredge spoil deposition in 2002, and since 2015 has also been using herbicide and mulching treatments. It appears that sandbars which have historically had more management efforts applied to them host more successful ILT colonies when occupied. This would seem to suggest that the effects of management actions may be cumulative in their effect on ILT fledging success. However, given the emergent and dynamic nature of riverine sandbars from year to year it is unlikely that the effects of any management action extends beyond a year or two. Furthermore, the distance between colonies with high cumulative management scores and recent management actions can be vast and contain gaps of up to 7 unmanaged years. This relationship may result from small sample sizes, allowing one or two highly successful colonies to bias the model results. For example, only 3 successful colonies occurred on sandbars with a cumulative management score of 4, and this included the highly-successful colony at RM 146.8 in 2018 with an FBR of 1.33 (Table 2).

Because my analysis found no immediate effects of increased fledging success associated with any specific type of management or with management in general, we must question the efficacy of management in general along the MKARNS. The truncated negative binomial regression of the hurdle models used only observations of positive fledgling counts and excluded colonies that failed for any reason, which should have given the effects of management the best chance of being detected.

A body of evidence suggests that sandbar management actions such as dredge spoil deposition, herbicidal treatments, and mulching treatments improve sandbar quality for nesting ILT's and fledging success. However, my analysis suggests this was not evident on the MKARNS. This could be due to a variety of reasons. First, the manner in which management actions have been applied may not be consistently optimal. Dredge spoil may not always produce suitable substrate for nesting ILT's if the material is too fine-grained (silt), or too large (small rocks). This could potentially decrease sandbar quality for ILT's if deposited on a sandbar which already had the preferred gravel or sand substrate, even if it could clear some detrimental vegetation in the process. The vegetation control measures of herbicide and mulching must also be done appropriately. If herbicide treatments were performed on established woody vegetation, the plants may die but remain standing as an aspect of detrimental vegetative cover and provide perching for avian predators if not manually removed. Furthermore, when mulching is applied to a sandbar, the resulting material must be removed from the site and not left as brush piles which can also provide perching spots for predators and be perceived as detrimental vegetative coverage by nesting ILT's. Both of these examples of nonoptimal vegetative management applications were observed during my surveys in 2018 on a single sandbar, causing a relatively small ILT colony to nest on an extreme end of an otherwise large and suitable sandbar. Repeated instances such as this may have obscured the positive effect management would otherwise have had. Second, few colony sites on the MKARNS are utilized in successive years by ILT's so my ability to evaluate management on colonies that were occupied both before and after management were minimal.

Despite studies suggesting ILT's are prone to reuse colony nesting sites if they remain available and suitable (Burger 1984), this population is reusing sites on the MKARNS at an average rate of 49.20% ± 7.95% per year, ranging from as high as 87.50% to as low as 18.18%

(Table 4). Only 20 (24.4%) of the 82 total management actions occurred on locations which hosted an ILT colony either in that year or in the previous breeding year (Table 10), with a yearly mean of 13.41% ± 5.14%. In total, 29.87% of managed sites host an ILT colony in the year of or the year after management, and this rate improves to 32.86% (mean 23.13% ± 7.4%) if we remove cases where both the year of and year after management are flood years, when managed sites may not have been available for nesting. This suggests if managers increased the rate that recently occupied sites receive management (currently 24.4%, mean 13.41% ± 5.14%), the rate at which ILT colonies establish on recently managed sites may increase from the current 32.86% (mean 23.13% ± 7.4%) to approach the rate of site reuse by ILT's at 49.20 % ± 7.95%. In summary, if management is applied to recently occupied sites more often, management efforts may get to have an immediate effect on ILT colonies more frequently. This it further supported by my data which found management has a positive effect on whether or not an ILT colony establishes at a given location, indicating that management on recently occupied sites would in fact increase the rate that ILT's occupy the location the following year. This would cause the rate of site reuse to increase and/or stabilize, and aid in future analyses of management effectiveness on the MKARNS.

Despite my analysis not finding significant effects of ILT management on fledging success, the fledging success of colonies in this population is on an unstable but slight upward trend (Figure 26, Figure 27). My analysis does not point to a specific factor, but I also cannot eliminate management as a cause of the slightly increasing trend as managed sites showed a pattern of higher average FBR rates. My analysis does suggest that there is further room for improvement with more effective management strategies. Due to the nature of my data it may be that management on the MKARNS does in fact have a positive effect on not only ILT colony establishment, but also on fledging success, that was undetected. Given these factors and the

literature suggesting management on the MKARNS should be having a positive impact on ILT fledging success, it should be considered essential that management efforts continue for this population.

CONCLUSION: MANAGEMENT RECOMMENDATIONS

To increase the effectiveness of management, management on previously used sites should be prioritized. Even if managers focus management on sandbars with active ILT colonies they may only find roughly half of those sites hosting ILT colonies in the following year, but that rate should increase and assist in the future analyses of management effectiveness. Second, I recommend prioritization of actions on sandbars that have the largest potential for increasing ILT colony size and that were occupied in the previous non-flood year. Third, management should focus on colonies that have been most successful in recent breeding seasons. For example, a large sandbar with a relatively small ILT nesting colony may be an indicator that management could extend the area of suitable nesting habitat and allow for a larger colony to exist. If that colony has also recently had a relatively high FBR rate, it may further indicate a suitable location in terms of low predation rates, harassment pressures, or other detrimental factors to fledging success. It is also important to identify nonoptimal dredge spoil material so it is not inadvertently used to decrease the suitability of an existing ILT nesting site.

These recommendations build on the findings of Ross (2016) who recommended that new sandbar nesting habitat should be created using spoil from ongoing dredging operations to benefit the ILT population within this study area, and also used to supplement low-elevation habitat when necessary. He added an emphasis on prioritizing or creating new locations that are not connected to the shore, are in an early successional state, on wide river bends more than 7 miles downstream from a dam, and as far away from trees, the shoreline, and man-made structures as possible to decrease predation risk.

If necessary in the fledging success rate of ILT colonies in this study area could be increased by using attractants and deterrents. For example, decoys may encourage new colonies to establish on newly-created habitat (Massey 1981, Fancher 1983, Kotliar and Burger 1984),

and reflective streamers may be useful to deter nesting at habitat sinks (Bruggers et al. 1986, Marcus et al. 2007). The addition of suitably-sized gravel may also attract nesting ILT's, however logistically challenging (Marcus et al. 2007). The addition of small, scattered pieces of driftwood will likely encourage nesting (Marcus et al. 2007) on an otherwise barren sandbar and may be a possible action with the extra effort of investigators. Furthermore, the addition of small shade structures could help increase chick survival rates at both riverine and rooftop colonies (Butcher et at. 2007) and prove particularly useful during flood years when nesting habitat is limited. Rooftop colonies are reused by these ILT's more frequently than MKARNS locations, even though they tend to have lower FBR rates on average. Therefore it is recommended to either improve rooftop locations with features such as shade structures, parapets, and screened drainages, or deter ILT's from nesting on these sites by using streamers.

Existing efforts to lessen human disturbance rates of ILT colonies by means of placing signage on boat ramps and colony sites must be continued with the cooperative work of the USACE and USFWS, and enforced by the Arkansas Game and Fish Commission (AGFC). Whereas an on-site warden at ILT colonies would be ideal (Burger 1989), the resources for such an effort may be out of reach. However, communication between investigators and the AGFC could help identify colonies most at risk to human disturbance throughout the summer, such as well-known popular sandbars during the 4th of July, and increase surveillance of those colonies and present signage during that time.

Rooftop colonies tend to be less successful than riverine colonies, and although their availability may be necessary during flood years it is potentially to the benefit of ILT's to be deterred from these sites to encourage nesting at riverine locations. The rooftop at the Belk department store in Conway, AR has proven to have a high potential for success, and the simple measure of fencing water drainages could make this location close to ideal. The addition of shade

structures at other rooftops may help improve the success of those colonies, however it may be best to add deterrents given their recent low success rates.

Due to the dynamic nature of their human-influenced nesting habitat, highly variable reproductive rates from year to year, and pursuant to the biological opinion (USFWS 2016), it is imperative that the Interior Least Tern continue to be managed, and monitored yearly, to ensure their ongoing and increases success within Arkansas. Managers do not have complete freedom when it comes to distributing management efforts along the entire MKARNS and resource availability is variable. However, I believe that if my recommendations are used in conjunction with those of Ross (2016), within the existing logistical framework of the managers, management can prove to be more effective at increasing the fledging success of nesting ILT's on the MKARNS.

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TABLES

Table 1. New records set by the flood of 2019 on the Arkansas River in Arkansas and year of the previous record that was broken (courtesy of National Weather Service Little Rock; https://www.weather.gov/lzk/flood2019.htm accessed 16 April 2020).

Location	Flood Stage	Crest/Date	Versus Highest Crest on Record	Rank	Record Crest/Year Prior to Event
Van Buren	22.0 ft	40.8 ft/June 1	+2.7 ft	1st	38.1 ft/1945
Ozark	357.0 ft	375.0 ft/May 30	-0.5 ft	2nd	375.5 ft/1943
Dardanelle	32.0 ft	45.0 ft/May 30	+1.8 ft	1st	44.1 ft/1943
Morrilton	30.0 ft	43.0 ft/June 4	+1.0 ft	1st	42.0 ft/1927
Toad Suck	275.0 ft	285.4 ft/June 4	+2.5 ft	1st	282.9 ft/1990
Little Rock	23.0 ft	29.7 ft/June 5	-4.9 ft	7th	34.6 ft/1833
Pine Bluff	42.0 ft	50.8 ft/June 6	-1.3 ft	2nd	52.1 ft/1943
Pendleton	31.0 ft	37.6 ft/June 6	+3.5 ft	1st	34.1 ft/1973

Table 2. Interior Least Tern colonies, peak adult and nest counts, total chick and fledgling counts, and colony FBR rates for the Arkansas River Valley, Arkansas, during the 2018 nesting season.

Colony Location	**Initiation Date**	**Adults**	**Nests**†	**Chicks**	**Fledglings**	**Fledgling Rate (FBR)**
283[H]	31-May	6	5	2	5	1.00
275	23-May	18	16	16	3	0.19
240.4	22-May	65	21	12	16	0.76
189.7[H]	4-Jun	2	0 (3)	2	0	0
189	31-May	4	0 (2)	2	3	1.50
184	4-Jun	60	7 (30)	19	20	0.67
175.5	23-May	2	2	0	0	0
170.5[T]	23-May	87	8 (43)	28	41	0.95
153	24-May	12	6	2	3	0.50
152	20-Jun	9	4	1	0	0
146.8[H]	1-Jun	17	2 (9)	2	12	1.33
142[H]	24-May	17	3	0	0	0
101[T]	27-May	117	32 (58)	20	30	0.52
58.3	2-Jun	28	6	5	0	0
55	2-Jun	5	0 (2)	1	1	0.50
42	3-Jul	30	7	0	0	0
34.5	7-Jun	17	12	0	0	0
Bend 9	24-Jun	25	12 (19)	1	13	0.68
Bend 7.5	2-Jul	5	1	0	0	0
Bend 7	24-Jun	14	0 (7)	1	5	0.71
Bend 5	24-Jun	16	3 (8)	0	12	1.50
Bend 3	1-Jun	25	1 (12)	2	0	0
LRAFB #787 BX	22-May	26	25	23	0	0
Snap-On[X]	25-May	20	11	16	0	0
Belk[X]	24-May	11	13	12	8	0.62
Total		**638**	**197 (325)**	**167**	**172**	**Overall 0.529**

(†) We calculated adjusted nest counts for sites when on-site nest counts were obviously low. We were unable to provide accurate nest counts when (1) coarse substrate increased nest camouflage; (2) vegetation decreased nest visibility; or (3) survey time constraints precluded extensive nest searching. When this occurred, we calculated an adjusted nest count as the adult count from the peak season day (usually when the most chicks were present) divided by two. We used nest counts and adjusted nest counts as a representation of breeding adult pairs.

(T) Time restrictions imposed by our recovery permit prevented us from surveying the entire site at least once during peak season, resulting in incomplete nest and/or chick counts.

(H) High temperatures prevented surveying the site on foot at least once during peak season, resulting in no nest counts and an incomplete/absent chick and fledgling count. All nests, chicks, or fledglings visually observed were recorded.

(X) Surveys at these rooftops were sometimes incomplete because they lacked a surrounding parapet or screened water drainages, and the chicks were susceptible to running off the edge of the rooftops. We used binoculars and surveyed from a static position.

Table 3. Summary of Interior Least Tern counts for the Arkansas River Valley, Arkansas, during the 2018 nesting season.

	Colonies	Initiation Dates	Adults	Nests†	Chicks	Fledglings	Fledgling Rate (FBR)
MKARNS TotalTH	17	22-May - 3-Jul	496	131 (229)	112	134	0.585
Lower Total	5	1-Jun - 2-Jul	85	17 (47)	4	30	0.638
Riverine TotalTH	22	22-May - 3-Jul	581	148 (276)	116	164	0.594
Rooftop Total^{X}	3	22-May - 25-May	57	49	51	8	0.163
Grand Total	**25**	**22-May - 3-Jul**	**638**	**197 (325)**	**167**	**172**	**Overall 0.529**

(†) We calculated adjusted nest counts for sites when on-site nest counts were obviously low. We were unable to provide accurate nest counts when (1) coarse substrate increased nest camouflage; (2) vegetation decreased nest visibility; or (3) survey time constraints precluded extensive nest searching. When this occurred, we calculated an adjusted nest count as the adult count from the peak season day (usually when the most chicks were present) divided by two. We used nest counts and adjusted nest counts as a representation of breeding adult pairs.

(T) Time restrictions imposed by our recovery permit prevented us from surveying the entire site at least once during peak season, resulting in incomplete nest and/or chick counts. This applies to RM 170.5 and 101.

(H) High temperatures prevented surveying a site on foot at least once during peak season, resulting in no nest counts and an incomplete/absent chick and fledgling count. All nests, chicks, or fledglings visually observed were recorded. This applies to RM 283, 189.7, 146.8, and 142.

(X) Surveys at some rooftops were sometimes incomplete because they lacked a surrounding parapet or screened water drainages, and the chicks were susceptible to running off the edge of the rooftops. We used binoculars and surveyed from a static position. This applies to Snap-On and Belk.

Table 4. Yearly rates of sandbar reoccupation for Interior Least Tern colonies (MKARNS only) during non-flood years, in the Arkansas River Valley, Arkansas.

	2003	2005	2006	2009	2011	2012	2013	2014	2016	2017	2018	Average
Total Colonies	4	11	14	23	14	17	14	16	16	9	17	**14.09**
Reused Colony Sites*	1	2	4	7	11	8	12	14	8	6	4	**7**
% Sites Reused	25.00%	18.18%	28.57%	30.43%	78.57%	47.06%	85.71%	87.50%	50.00%	66.67%	23.53%	**49.20%**

(*) A sandbar location was considered reused if it hosted a colony of Interior Least Terns either in the previous year, or in the previous non-flood year.

Table 5. Interior Least Tern colonies, peak adult and nest counts, total chick and fledgling counts, and colony FBR rates for the Arkansas River Valley, Arkansas, during the 2019 nesting season.

Colony Location	Initiation Date	Adults	Nests†	Chicks	Fledglings	Fledgling Rate (FBR)
224[T]	24-Jun	95	6 (47)	42	35	0.74
179.7	25-Jul	2	1	0	0	0
179.5	28-Jun	8	2 (4)	4	2	0.50
179	15-Jul	8	3	3	0	0
Subtotal 8/1-9/7		113	12 (55)	49	37	0.673
LRPA Small Lot	5-Jun	24	8	0	0	0
LRPA Big Lot	10-Jun	2	3	1	0	0
LRAFB #450[X]	22-May	5	4	7	0	0
LRAFB #787 BX[T]	25-May	34	38	18	0	0
Snap-On[X]	23-May	35	38	15	5	0.13
Belk*	21-May	53	41	5	0	
Subtotal 5/29-8/8		153	132	46	5	0.038
Grand Total		**266**	**144 (187)**	**95**	**42**	**Overall 0.225**

(†) We calculated adjusted nest counts for sites when on-site nest counts were obviously low. Specifically, sometimes we may have been unable to accurately count nests when (1) coarse substrate increased nest camouflage; (2) vegetation decreased nest visibility; or (3) survey time constraints precluded extensive nest searching. When this occurred, we calculated an adjusted nest count as the adult count from the peak season day (usually when the most chicks were present) divided by two. We used nest counts and adjusted nest counts as a representation of breeding adult pairs.

(T) Time restrictions imposed by our recovery permit prevented us from surveying the entire site at least once during peak season, resulting in incomplete nest and/or chick counts.

(X) Surveys at these rooftops were sometimes incomplete because they lacked a surrounding parapet or screened water drainages, and the chicks were susceptible to running off the edge of the rooftops. We used binoculars and surveyed from a static position.

(*) Access to the Belk rooftop was restricted by Belk management after 6/5/2019 and this prevented us from performing counts after this date. It is possible that this colony successfully fledged chicks as 4 near-fledging birds were found alive in the parking lot and returned to the roof and at least one fledgling was observed dead in the parking lot after it apparently had been struck and killed by a vehicle.

Table 6. Summary of Interior Least Tern counts for the Arkansas River Valley, Arkansas, during the 2019 nesting season.

	Colonies	Initiation Dates	Adults	Nests[†]	Chicks	Fledglings	Fledgling Rate (FBR)
MKARNS Total[T]	4	24-Jun - 25-Jul	113	12 (55)	49	37	0.673
Rooftop Total[TX*]	4	21-May - 25-May	127	121	45	5	0.041
Gravel Lot Total	2	5-Jun - 10-Jun	26	11	1	0	0
Grand Total	**10**	**21-May - 25-Jul**	**266**	**144 (187)**	**95**	**42**	**Overall 0.225**

([†]) We calculated adjusted nest counts for sites when on-site nest counts were obviously low. Specifically, sometimes we may have been unable to accurately count nests when (1) coarse substrate increased nest camouflage; (2) vegetation decreased nest visibility; or (3) survey time constraints precluded extensive nest searching. When this occurred, we calculated an adjusted nest count as the adult count from the peak season day (usually when the most chicks were present) divided by two. We used nest counts and adjusted nest counts as a representation of breeding adult pairs.

([T]) Time restrictions imposed by our recovery permit prevented us from surveying an entire site at least once during peak season, resulting in incomplete nest and/or chick counts. This applies to RM 224 and LRAFB #787 BX.

([X]) Surveys at some rooftops were sometimes incomplete because they lacked a surrounding parapet or screened water drainages, and the chicks were susceptible to running off the edge of the rooftops. We used binoculars and surveyed from a static position. This applies to LRAFB #450 and Snap-On.

(*) Access to the Belk rooftop was restricted by Belk management after 6/5/2019 and this prevented us from performing counts after this date. It is possible that this colony successfully fledged chicks as 4 near-fledging birds were found alive in the parking lot and returned to the roof and at least one fledgling was observed dead in the parking lot after it apparently had been struck and killed by a vehicle.

Table 7. Yearly adults, nests, and fledgling counts, with fledglings per breeding pair (FBR) for Interior Least Tern colonies at riverine and rooftop nesting locations in the Arkansas River Valley, Arkansas, 2012 - 2019.

	Adults			**Nests†**			**Fledglings**			**Fledging Rate (FBR)**		
Year	**River**	**Rooftop**	**Total**	**River**	**Rooftop**	**Total**	**River**	**Rooftop**	**Total**	**River**	**Rooftop**	**Overall**
2012	422	48	470	210	43	253	136	3	139	0.65	0.07	0.549
2013	434	78	512	242	46	288	66	12	78	0.27	0.26	0.271
2014	387	47	434	246	32	278	68	16	84	0.28	0.5	0.302
2015[F]	27	162	189	0	128	128	1	9	10	0	0.07	0.078
2016	477	63	540	168	43	211	64	0	64	0.36	0	0.303
2017	246	104	350	127	104	231	72	6	78	0.57	0.06	0.338
2018	581	57	638	148 (276)	49	325	164	8	172	0.59	0.16	0.529
2019*[F]	113	153	266	12 (55)	132	187	37	5	42	0.67	0.4	0.225
Average	**336**	**89**	**425**	**166**	**72**	**238**	**76**	**7**	**83**	**0.426**	**0.145**	**0.324**

(†) We calculated adjusted nest counts for sites when on-site nest counts were obviously low. Specifically, sometimes we may have been unable to accurately count nests when (1) coarse substrate increased nest camouflage; (2) vegetation decreased nest visibility; or (3) survey time constraints precluded extensive nest searching. When this occurred, we calculated an adjusted nest count as the adult count from the peak season day (usually when the most chicks were present) divided by two. We used nest counts and adjusted nest counts as a representation of breeding adult pairs.

(*) Includes two gravel lot colonies at Little Rock Port Authority, considered "Rooftop" colonies in this table.

(F) Flood year

Table 8. Analysis of Interior Least Tern counts in the Arkansas River Valley, Arkansas over the previous 6 years, the median breeding lifespan of an adult Interior Least Tern (Lott et al. 2013) as recommended by Ross (2016) to evaluate population trends.

Years		Average Adults			Average Nests†			Average Fledglings			FBR		
		River	**Rooftop**	**Overall**	**River**	**Rooftop**	**Overall**	**River**	**Rooftop**	**Overall**	**River**	**Rooftop**	**Overall**
All Years	2014-2019*	305.2	97.7	402.8	145.3	81.3	226.7	67.7	7.3	75.0	0.466	0.090	0.331
Non-Flood Years	2014, 2016, 2017, 2018	422.8	67.8	490.5	204.3	57.0	261.3	92.0	7.5	99.5	0.450	0.132	0.381

(†) We calculated adjusted nest counts for sites when on-site nest counts were obviously low. Specifically, sometimes we may have been unable to accurately count nests when (1) coarse substrate increased nest camouflage; (2) vegetation decreased nest visibility; or (3) survey time constraints precluded extensive nest searching. When this occurred, we calculated an adjusted nest count as the adult count from the peak season day (usually when the most chicks were present) divided by two. We used nest counts and adjusted nest counts as a representation of breeding adult pairs.

(*) Includes two gravel lot colonies at Little Rock Port Authority (2019), considered "Rooftop" colonies in this table.

Table 9. Interior Least Tern rooftop colony FBR rates from 2001-2019.

	2007^{F}	2008^{F}	2009	2010^{F}	2011	2012	2013	2014	2015^{F}	2016	2017	2018	2019^{F}
LRAFB #787 BX						0.17	0.33	0.2	0	0		0	0
LRAFB #450	0.36	0.27	0.12							0	0.1		0
LRAFB #430		0.33											
Belk		0.33		0.2	0.17	0.1	0.14	0.68	0.11	0	0.05	0.62	-
Snap-On	0.43			0.17	0.16	0		0	0	0	0	0	0.13
Maybelline	0.18	0.33	0.4	0.07	0.06	0	0.44						
Hanesbrand	0.28	0.2	0	0.18					0.25		0		
Care Link	0.5												
Priority Wire	0												

(^{F}) Flood year

Table 10. Yearly observed nesting colonies, adults, nests, fledglings, and fledglings per breeding pair (FBR) for Interior Least Tern colonies on MKARNS nesting locations, with management summaries, for the Arkansas River Valley, Arkansas, 2001 - 2018.

Year	Colonies	Adults	Nests[†]	Fledglings	Fledging Rate (FBR)	Management Actions: Dredge Spoil	Herbicide	Mulch	Total	On Recently Occupied Sites*
2001	6	196	125	75	0.600	0	0	0	0	0
2002	8	264	219	88	0.402	2	0	0	2	0
2003	4	256	65	0	0.000	1	0	0	1	0
2004[F]	7	220	111	4	0.036	1	0	0	1	0
2005	11	332	194	34	0.175	1	0	0	1	0
2006	14	491	64	29	0.453	0	0	0	0	0
2007[F]						4	0	0	4	0
2008[F]						7	0	0	7	1
2009	23	391	165	42	0.255	11	0	0	11	1
2010[F]	15	443	177	35	0.198	3	0	0	3	0
2011	14	321	179	97	0.542	0	0	0	0	0
2012	17	422	210	136	0.648	0	0	0	0	0
2013	14	434	242	66	0.273	0	0	0	0	0
2014	16	387	246	68	0.276	0	0	0	0	0
2015[F]	1	27	0	1		1	7	3	11	6
2016	16	477	168	64	0.381	0	3	2	5	1
2017	9	246	127	72	0.567	2	6	1	9	3
2018	17	496	131 (229)	134	0.585	0	22	5	27	8
	13	**362.54**	**158**	**69.62**	**0.397**	**33**	**38**	**11**	**82**	**20**
Average (No Floods)						**Total**				

([†]) We calculated adjusted nest counts for sites when on-site nest counts were obviously low. Specifically, sometimes we may have been unable to accurately count nests when (1) coarse substrate increased nest camouflage; (2) vegetation decreased nest visibility; or (3) survey time constraints precluded extensive nest searching. When this occurred, we calculated an adjusted nest count as the adult count from the peak season day (usually when the most chicks were present) divided by two. We used nest counts and adjusted nest counts as a representation of breeding adult pairs.

([F]) Flood year

(*) Recently occupied sites are unique riverine locations that hosted a nesting colony in the year of management, or in the previous non-flood year.

Table 11. Hurdle model results investigating effects of specific management actions on fledglings produced from ILT colonies on the MKARNS, in the Arkansas River Valley, Arkansas, 2001 – 2018.

	Zero Hurdle Model					Truncated Negative Binomial				
Variable (level)	**Estimate**	**Exp. Coef.[X]**	**SE**	**p-value**		**Estimate**	**Exp. Coef.[X]**	**SE**	**p-value**	
(Intercept)	0.0322	1.0327	0.3156	0.9188		0.7403	2.0966	0.2242	0.0010	*
Spoil Prox. (managed[M])	1.6049	4.9773	1.1069	0.1471		0.2193	1.2452	0.4834	0.6500	
Herb Prox. (managed[M])	0.7094	2.0327	0.7429	0.3396		0.4318	1.5400	0.3263	0.1857	
Mulch Prox. (managed[M])	-0.7499	0.4724	1.1036	0.4968		0.1014	1.1067	0.6920	0.8835	
Flood Prox. (post-flood year)	-0.2490	0.7796	0.3608	0.4901		-0.0252	0.9751	0.2038	0.9014	
Flood Prox. (flood year)	-0.7925	0.4527	0.5036	0.1156		-0.9893	0.3719	0.4006	0.0135	*
Site Used Previously (yes)	0.1989	1.2201	0.3701	0.5909		0.2218	1.2484	0.1892	0.2409	
Nests	0.0387	1.0395	0.0164	0.0181	*	0.0601	1.0619	0.0092	5.42E-11	*

([M]) An observation was considered managed if the management action was administered in the year of, or the year prior to the observation.
([X]) Exponentiated coefficients are read as their effect on the baseline. For example in the zero hurdle model, the baseline odds of having a positive count versus a zero count is 1.0327, which is increased/decreased X times relative to a factor. In the truncated negative binomial model, among observations with positive fledgling counts the average count is 2.0966 and it is increased/decreased X times relative to a factor.

Table 12. Hurdle model results investigating effects of management actions on fledglings produced from ILT colonies on the MKARNS, in the Arkansas River Valley, Arkansas, 2001 – 2018.

	Zero Hurdle Model					Truncated Negative Binomial				
Variable (level)	**Estimate**	**Exp. Coef.** [X]	**SE**	**p-value**		**Estimate**	**Exp. Coef.** [X]	**SE**	**p-value**	
(Intercept)	-0.0005	0.9995	0.3147	0.9988		0.7392	2.0943	0.2245	0.0010	*
Management Prox. (managed[M])	0.7866	2.1958	0.5485	0.1516		0.3499	1.4189	0.2588	0.1763	
Flood Prox. (post-flood year)	-0.2265	0.7973	0.3587	0.5277		-0.0289	0.9716	0.2019	0.8863	
Flood Prox. (flood year)	-0.7105	0.4914	0.4919	0.1486		-1.0517	0.3493	0.3573	0.0032	*
Site Used Previously (yes)	0.2444	1.2768	0.3668	0.5053		0.2226	1.2493	0.1880	0.2365	
Nests	0.0380	1.0387	0.0162	0.0187	*	0.0605	1.0623	0.0092	5.43E-11	*

([M]) An observation was considered managed if the management action was administered in the year of, or the year prior to the observation.
([X]) Exponentiated coefficients are read as their effect on the baseline. For example in the zero hurdle model, the baseline odds of having a positive count versus a zero count is 0.9995, which is increased/decreased X times relative to a factor. In the truncated negative binomial model, among observations with positive fledgling counts the average count is 2.0943 and it is increased/decreased X times relative to a factor.

Table 13. Hurdle model results investigating effects of the cumulative management score of a sandbar on fledglings produced from ILT colonies on the MKARNS, in the Arkansas River Valley, Arkansas, 2001 – 2018.

	Zero Hurdle Model					Truncated Negative Binomial				
Variable (level)	**Estimate**	**Exp. Coef.** [X]	**SE**	**p-value**		**Estimate**	**Exp. Coef.** [X]	**SE**	**p-value**	
(Intercept)	0.0047	1.0047	0.3180	0.9881		0.6885	1.9907	0.2255	0.0023	*
Cumulative Management Score	0.2004	1.2219	0.1906	0.2931		0.1907	1.2101	0.0893	0.0328	*
Flood Prox. (post-flood year)	-0.1804	0.8349	0.3605	0.6167		0.0091	1.0091	0.2009	0.9640	
Flood Prox. (flood year)	-0.6686	0.5124	0.4916	0.1738		-0.9432	0.3894	0.3428	0.0059	*
Site Used Previously (yes)	0.1797	1.1969	0.3654	0.6229		0.1926	1.2124	0.1858	0.3000	
Nests	0.0380	1.0388	0.0161	0.0184	*	0.0599	1.0617	0.0089	2.00E-11	*

([X]) Exponentiated coefficients are read as their effect on the baseline. For example in the zero hurdle model, the baseline odds of having a positive count versus a zero count is 1.0047, which is increased/decreased X times relative to a factor. In the truncated negative binomial model, among observations with positive fledgling counts the average count is 1.9907 and it is increased/decreased X times relative to a factor.

Table 14. Hurdle model results investigating effects of management actions on breeding adults present in ILT colonies on the MKARNS, in the Arkansas River Valley, Arkansas, 2001 – 2018.

	Zero Hurdle Model					Truncated Negative Binomial				
Variable (level)	**Estimate**	**Exp. Coef. [X]**	**SE**	**p-value**		**Estimate**	**Exp. Coef. [X]**	**SE**	**p-value**	
(Intercept)	-2.3508	0.0953	0.1325	2.00E-16	*	3.0791	21.7387	0.1125	2.00E-16	*
Management Prox. (managed[M])	1.1484	3.1533	0.2943	9.51E-05	*	0.1407	1.1511	0.2013	0.4847	
Flood Prox. (post-flood year)	0.5375	1.7117	0.1884	0.0043	*	-0.1200	0.8870	0.1447	0.4072	
Flood Prox. (flood year)	-1.2025	0.3004	0.2528	1.98E-06	*	0.0343	1.0349	0.2044	0.8668	
Site Used Previously (yes)	1.9969	7.3662	0.1979	2.00E-16	*	0.4570	1.5793	0.1205	0.0010	*

([M]) An observation was considered managed if the management action was administered in the year of, or the year prior to the observation.
([X]) Exponentiated coefficients are read as their effect on the baseline. For example in the zero hurdle model, the baseline odds of having a positive count versus a zero count is 0.0953, which is increased/decreased X times relative to a factor. In the truncated negative binomial model, among observations with positive fledgling counts the average count is 21.7387 and it is increased/decreased X times relative to a factor.

FIGURES

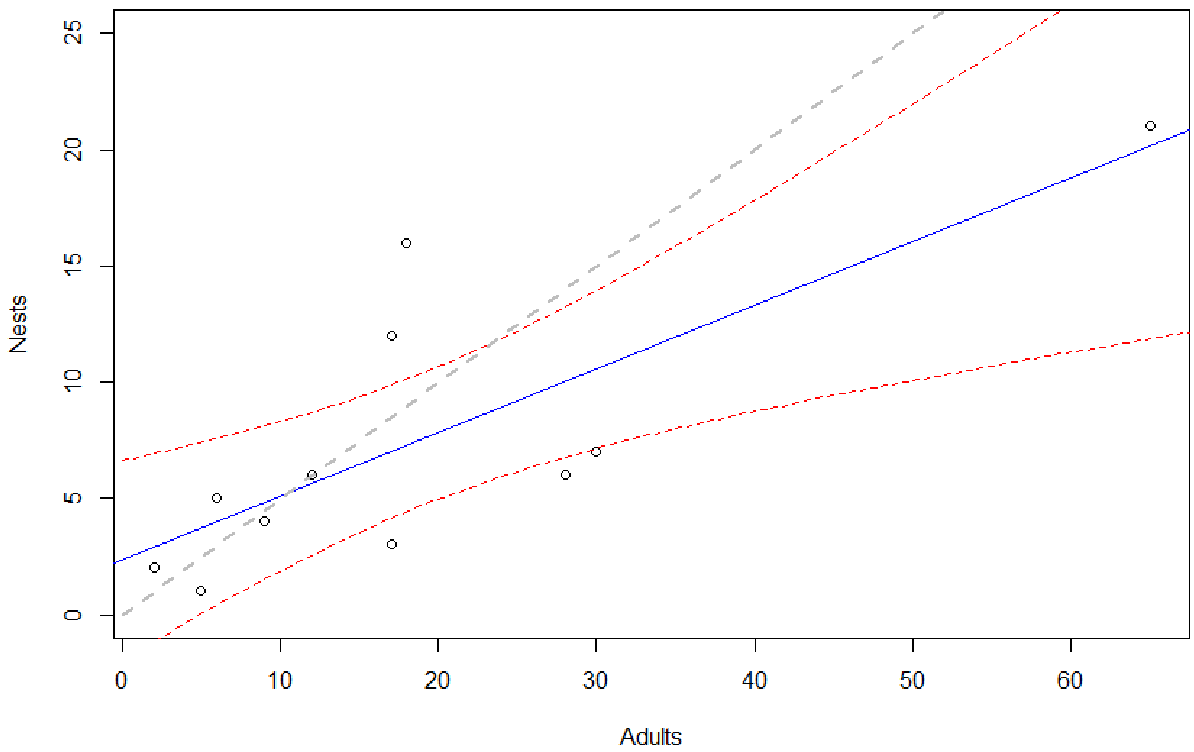

Figure 1. Graph of a linear model result investigating the relationship of adult and nest counts from completely surveyed riverine colonies in 2018 with 95% confidence intervals, including an overlaid line (dotted gray) expressing the expected nest counts (and therefore breeding pairs present) relative to a given colony's adult count at the date of peak chicks observed.

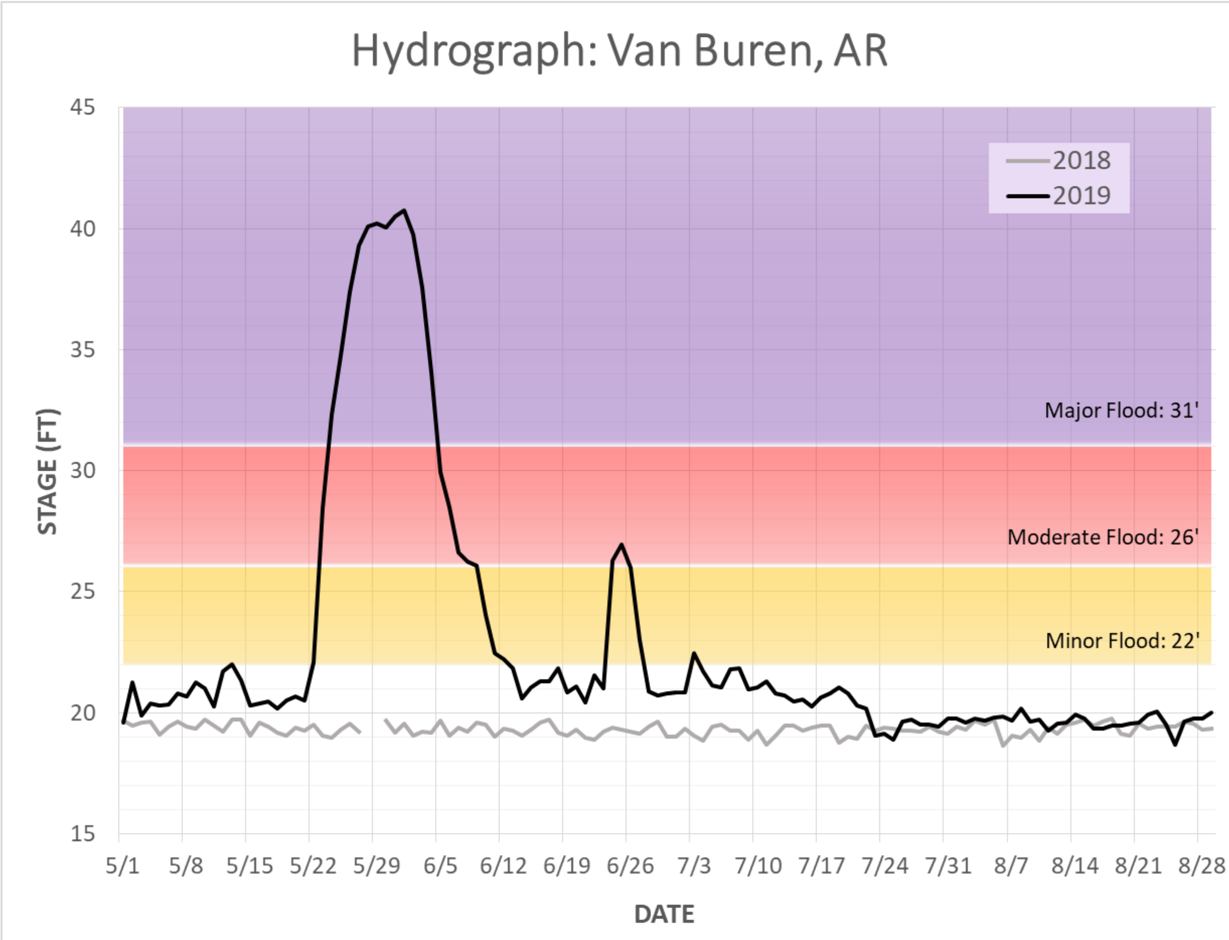

Figure 2. Hydrograph from Van Buren, Arkansas showing the extent of the 2019 flooding compared to the previous non-flood year of 2018.

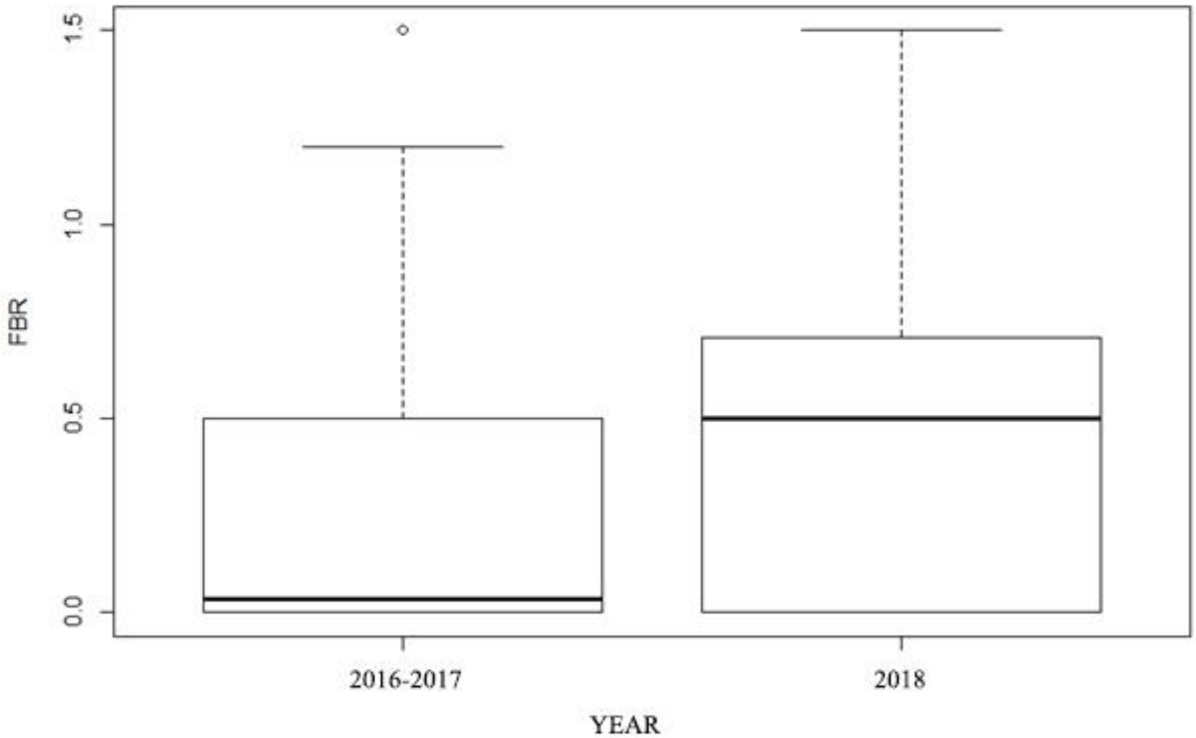

Figure 3. Boxplots comparing overall FBR rates from 2016 and 2017 combined against 2018, with the interquartile range and median displayed and FBR on the y-axis.

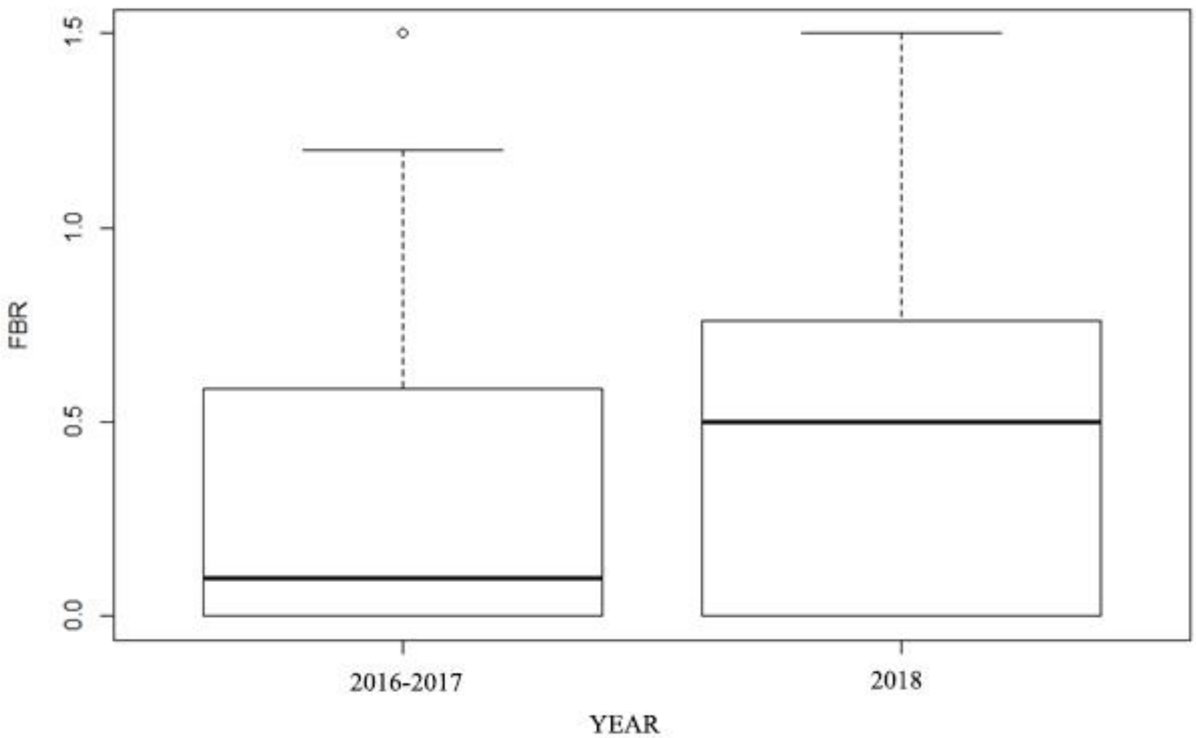

Figure 4. Boxplots comparing FBR rates from colonies on the MKARNS from 2016 and 2017 combined against 2018, with the interquartile range and median displayed and FBR on the y-axis.

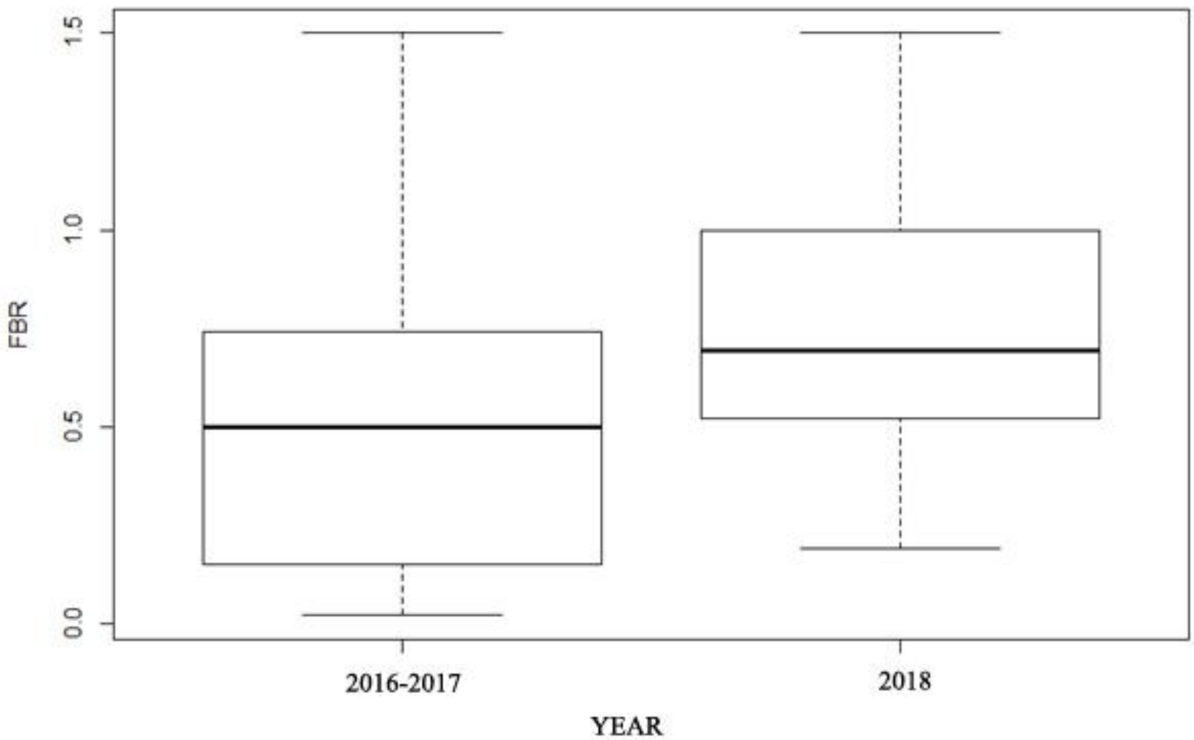

Figure 5. Boxplots comparing overall FBR rates of only successful colonies from 2016 and 2017 combined against 2018, with the interquartile range and median displayed and FBR on the y-axis.

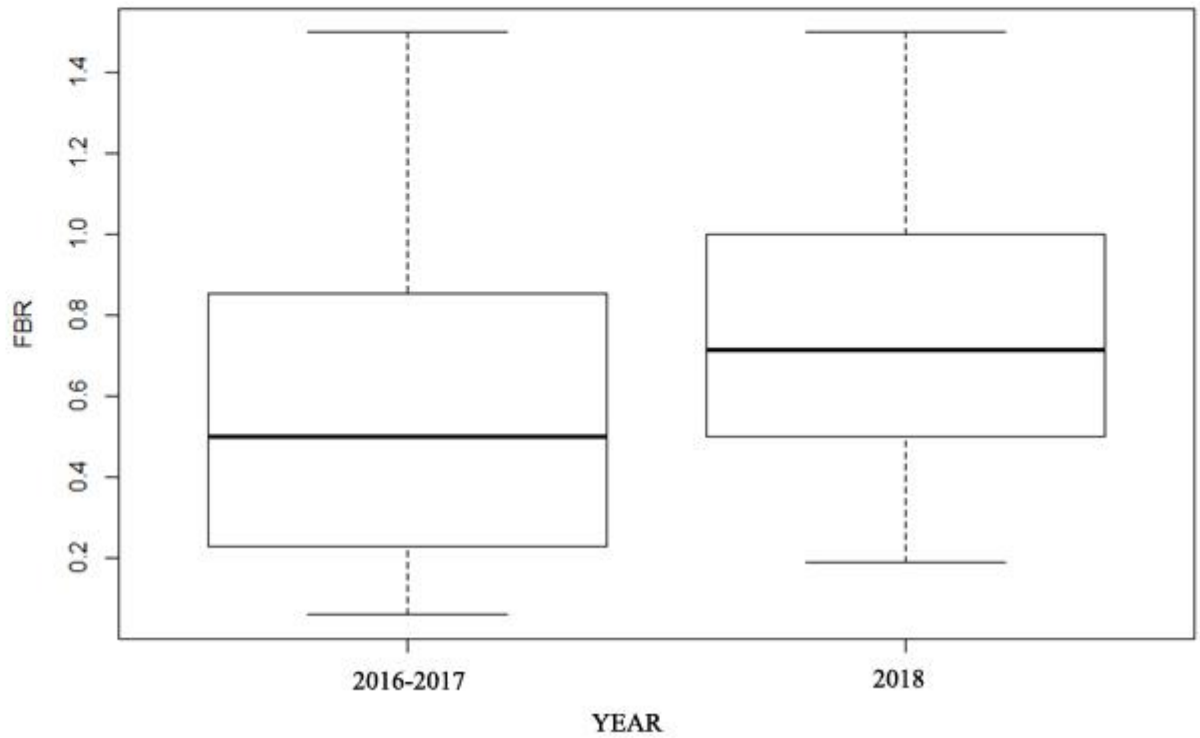

Figure 6. Boxplots comparing FBR rates from only successful colonies on the MKARNS from 2016 and 2017 combined against 2018, with the interquartile range and median displayed and FBR on the y-axis.

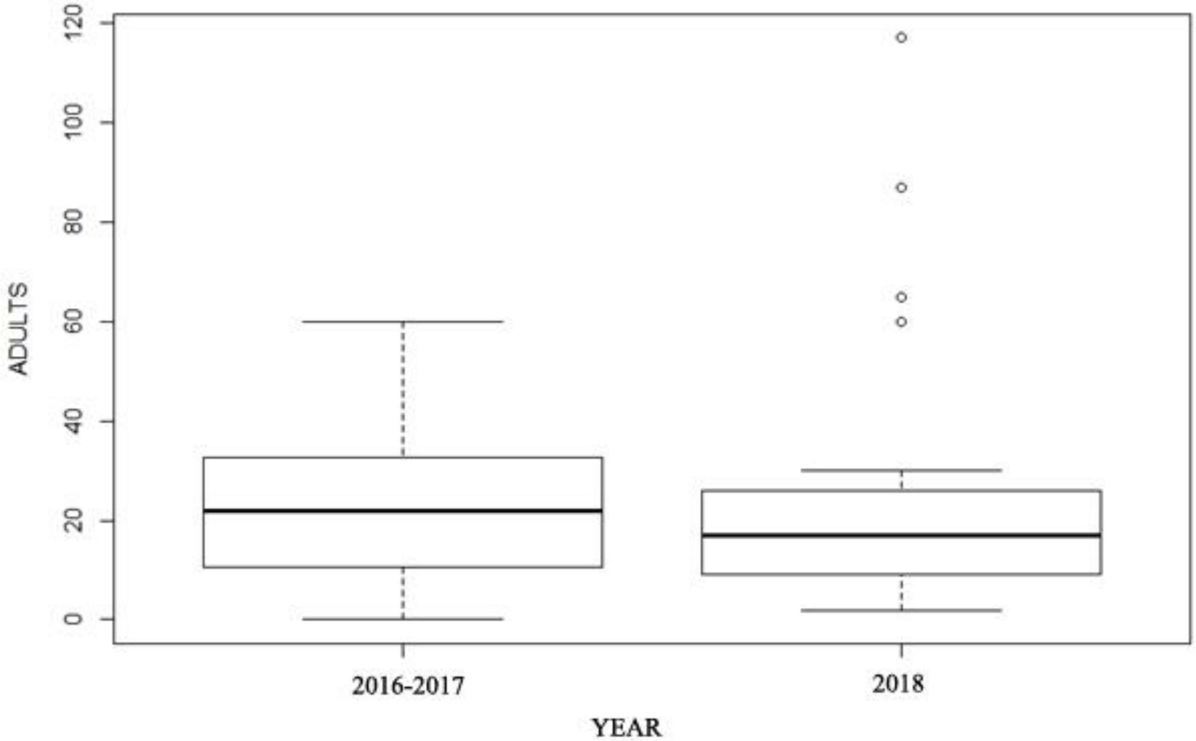

Figure 7. Boxplots comparing overall adult counts from 2016 and 2017 combined against 2018, with the interquartile range and median displayed and adults on the y-axis.

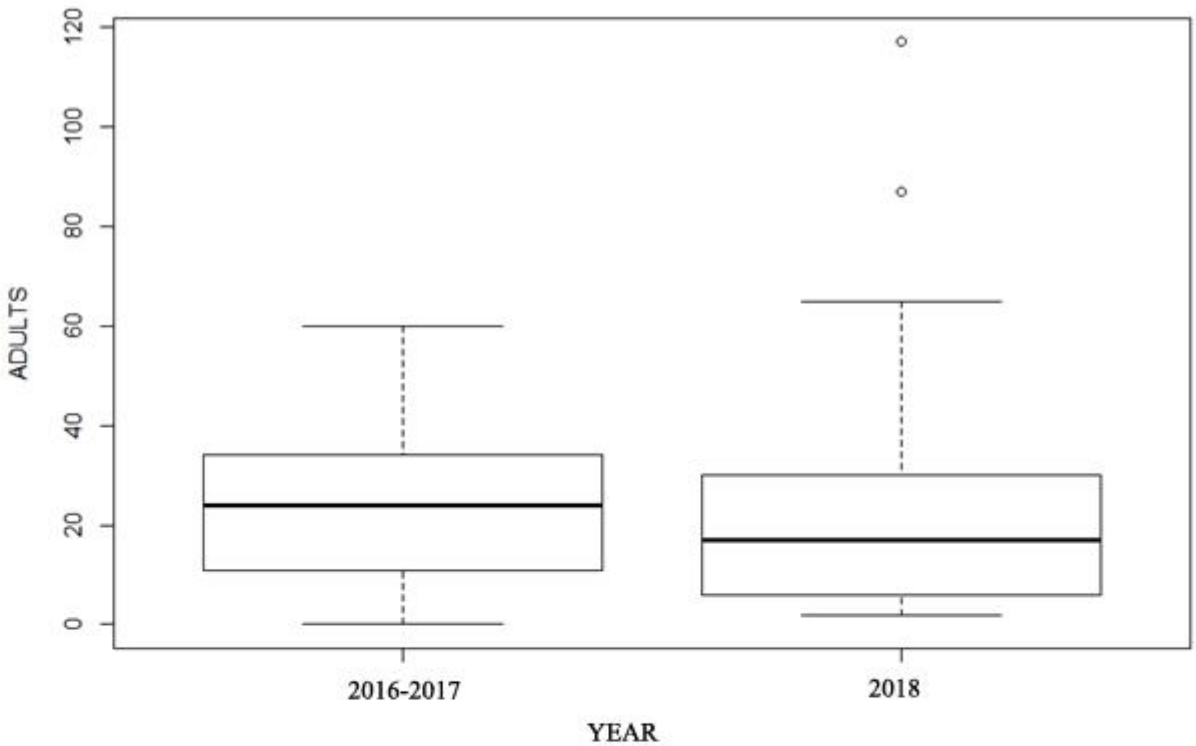

Figure 8. Boxplots comparing adult counts from colonies on the MKARNS from 2016 and 2017 combined against 2018, with the interquartile range and median displayed and adults on the y-axis.

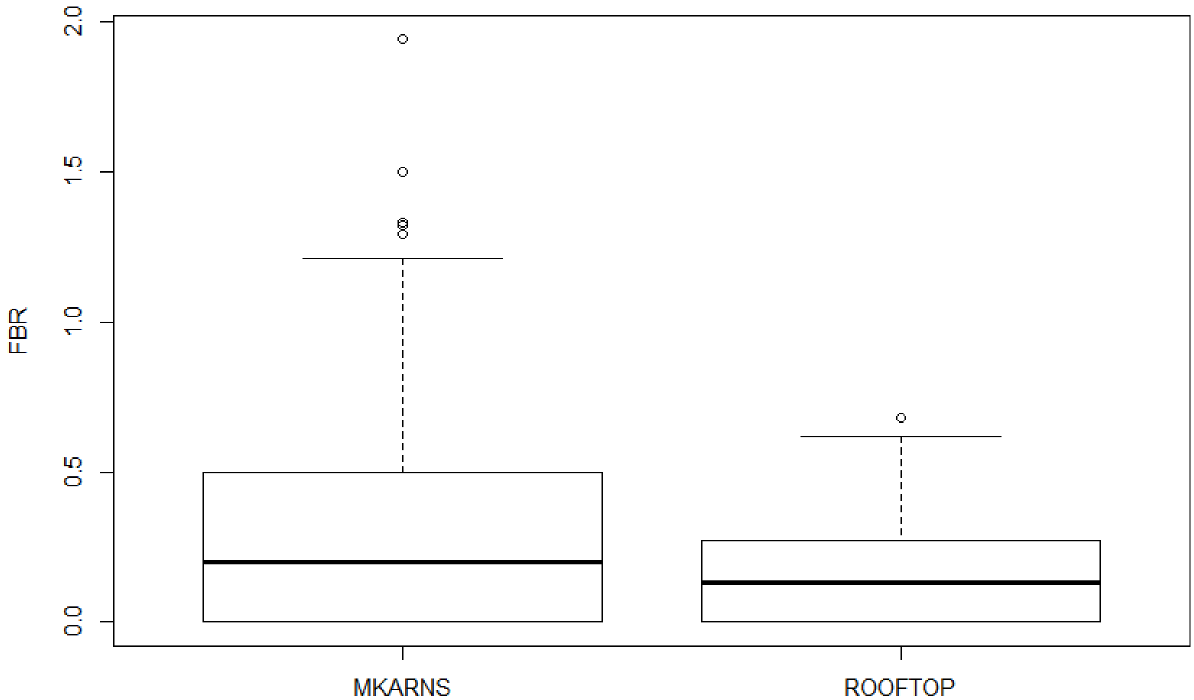

Figure 9. Boxplots comparing FBR rates between Interior Least Tern colonies within the MKARNS and at rooftop locations, with the interquartile range and median displayed and FBR on the y-axis.

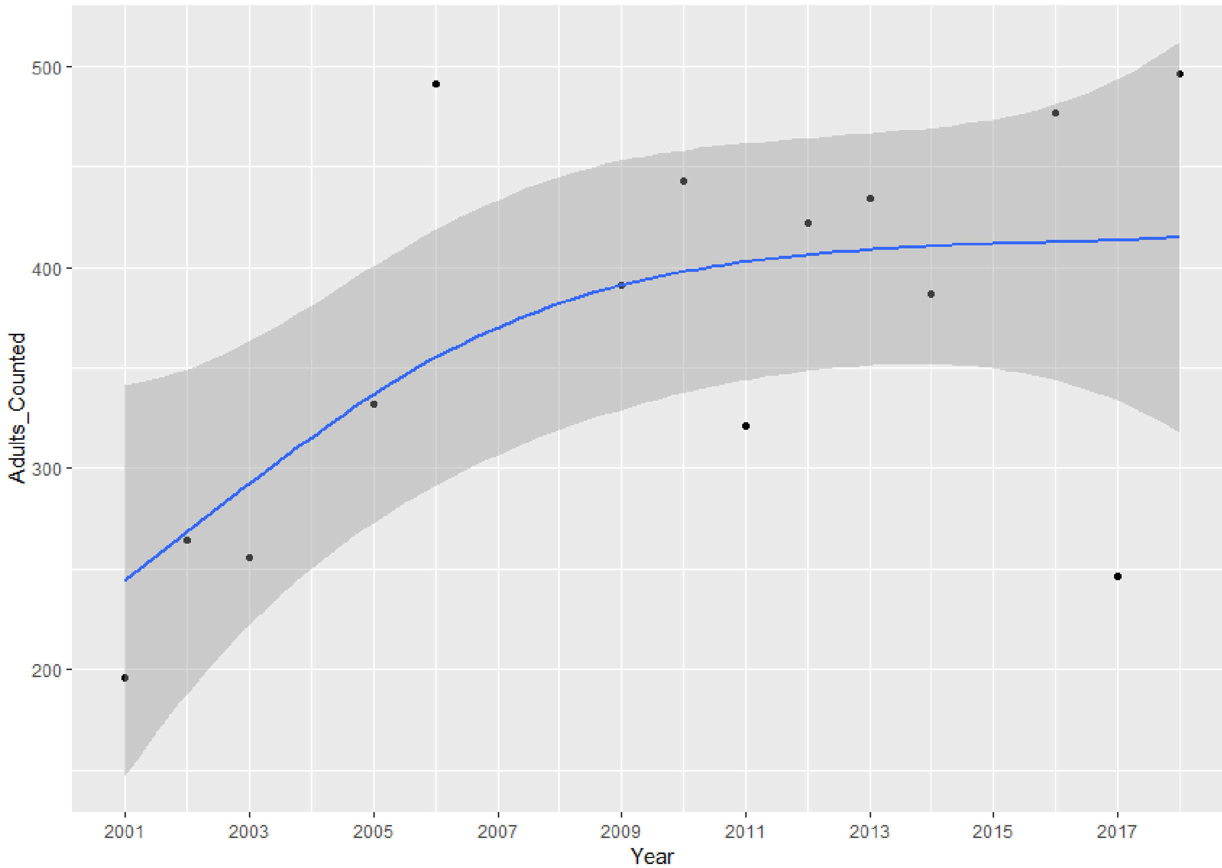

Figure 10. Graph of a generalized additive model's results to visualize the trend of adult ILT's through time on the MKARNS, excluding flood years, with 95% confidence intervals and adults on the y-axis.

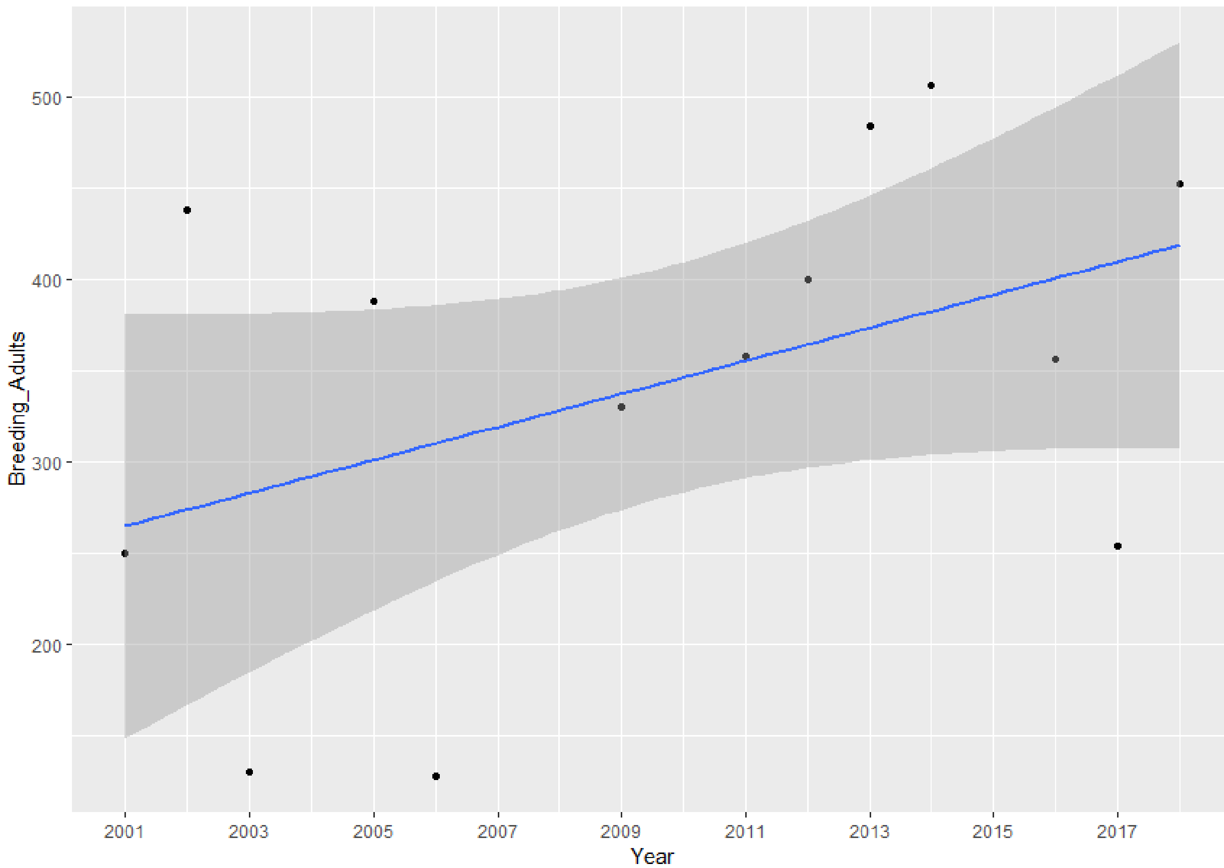

Figure 11. Graph of a generalized additive model's results to visualize the trend of estimate breeding adult ILT's through time on the MKARNS, excluding flood years, with 95% confidence intervals and adults on the y-axis.

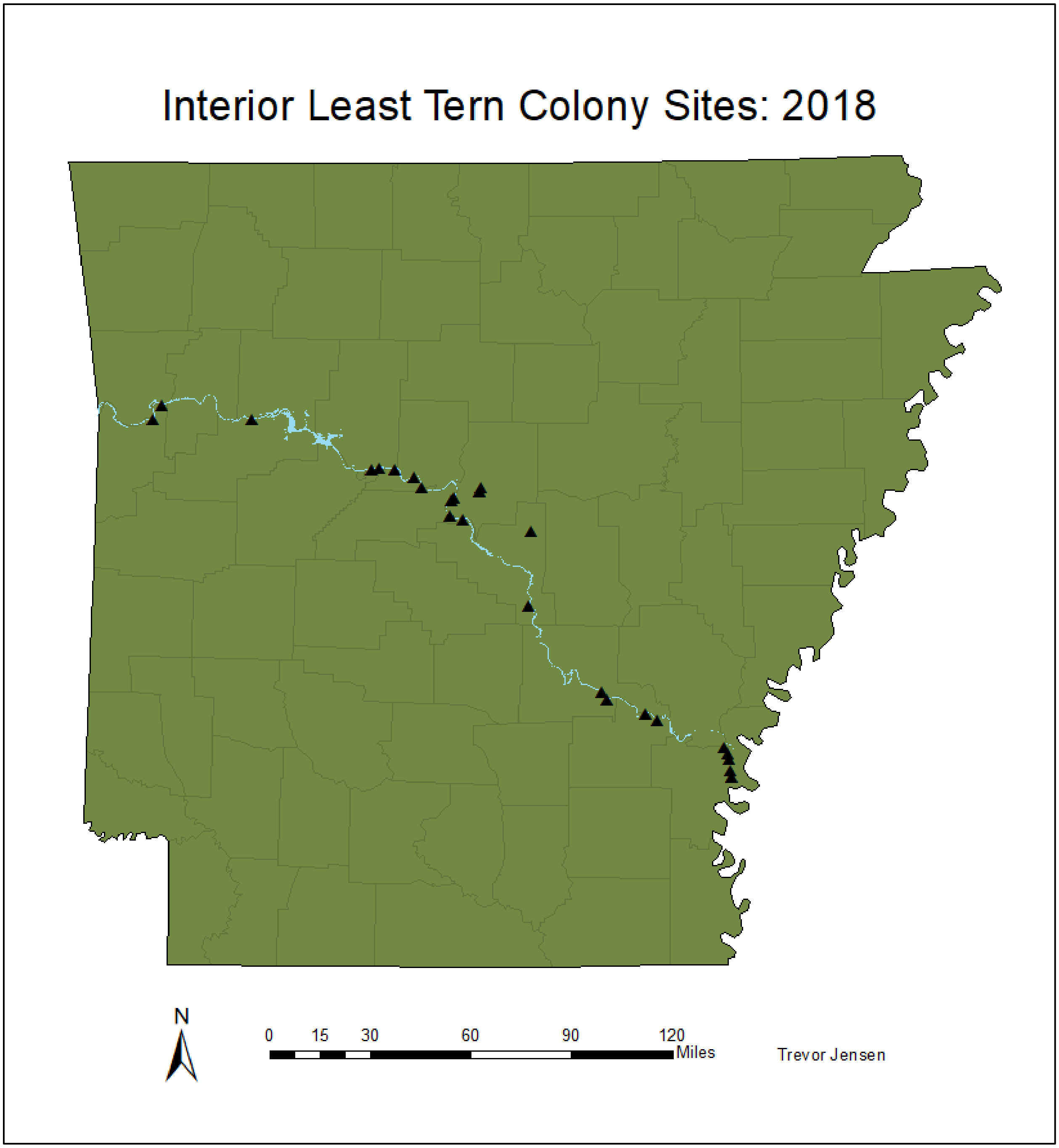

Figure 12. Map of all Interior Least Colonies during the 2018 breeding season.

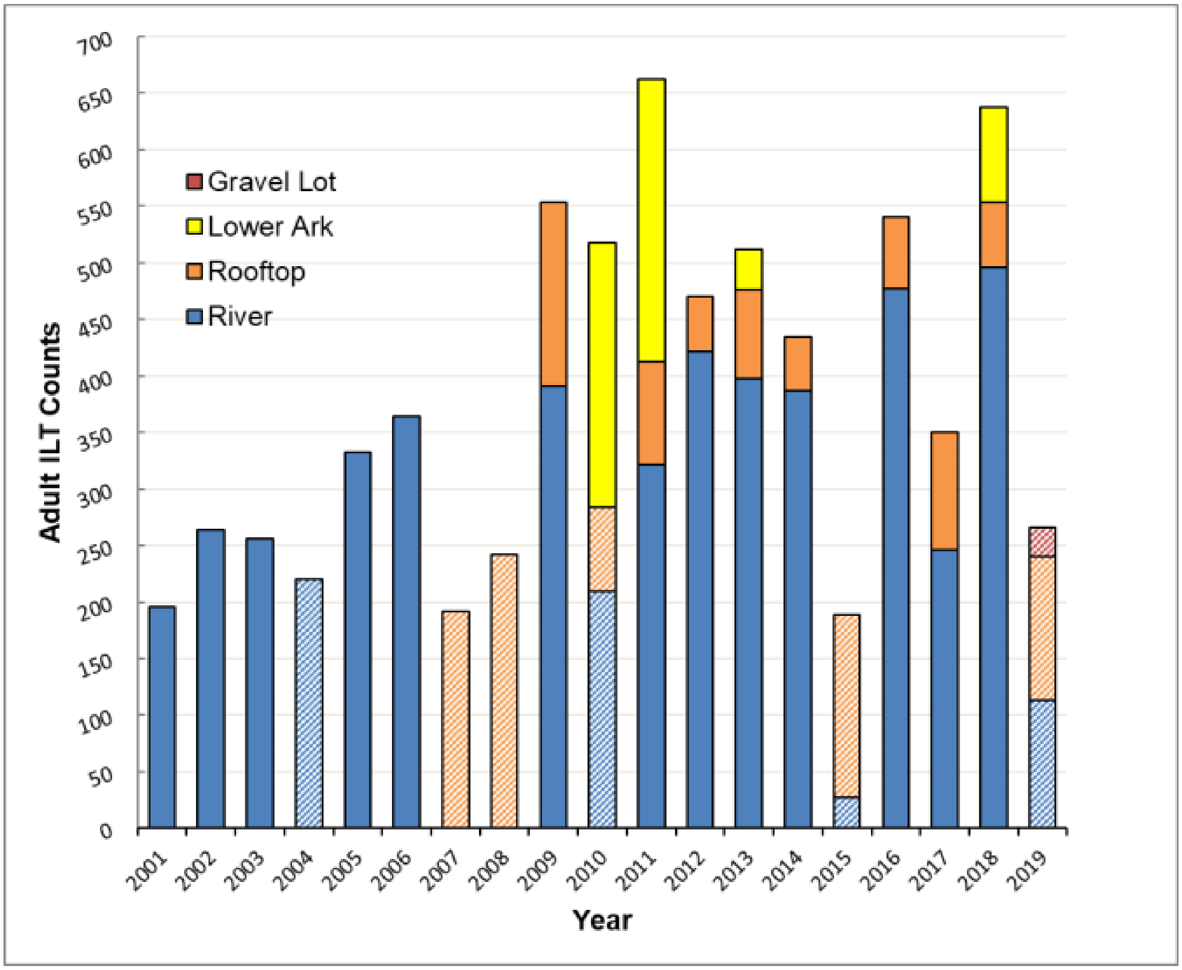

Figure 13. Adult Interior Least Tern counts from the Arkansas River Valley, Arkansas, 2001-2019. Complete surveys of the McClellan-Kerr Arkansas River Navigation System began in 2004, and opportunistic surveys of the lower, unmaintained stretch of the Arkansas River (below the Wilbur. D. Mills dam) were done in 2010, 2011, 2013, and 2018. Non-solid bard indicate flood years (2004, 2007, 2008, 2010, 2015, and 2019).

Figure 14. Motion-activated camera photograph from 20 June, 2019 at the ILT colony at Little Rock Port Authority (LRPA) Small Lot, showing a Striped Kkunk (*Mephitis mephitis*). Video shows the skunk moving methodically from nest to nest, presumably eating ILT eggs, as adult ILT's hopelessly try to harass the skunk by mobbing. The previous survey on 18 June recorded 24 adult ILT's, and 8 nests with 17 eggs, but the following survey on 28 June recorded 0 adults, 0 nests and 0 eggs.

Figure 15. Motion-activated camera photograph from 24 June, 2019 at the ILT colony at Little Rock Port Authority (LRPA) Small Lot, showing a Coyote (*Canis latrans*). This disturbance follows a predation event by a Striped Skunk (*Mephitis mephitis*) (Figure 14) where the previous survey on 18 June recorded 24 adult ILT's, and 8 nests with 17 eggs, but the following survey on 28 June recorded 0 adults, 0 nests and 0 eggs.

Figure 16. Motion-activated camera photograph from 22 July, 2019 at the ILT colony at Little Rock Port Authority (LRPA) Big Lot, likely showing a Great Horned Owl (*Bubo virginianus*). No chicks were observed on the prior, or subsequent, survey at this colony.

Figure 17. Motion-activated camera photograph from 30 June, 2019 at the ILT colony at Little Rock Air Force Base (LRAFB) building #787 BX of a Great Horned Owl (*Bubo virginianus*). The previous survey on 28 June recorded 34 adult ILT's, 22 nests with 43 eggs, and 18 chicks, but the following survey on 3 July recorded just 5 adults, 21 nests with 38 eggs, and 1 chick.

Figure 18. Motion-activated camera photograph from 9 July, 2019 at the ILT colony at Little Rock Air Force Base (LRAFB) building #787 BX of a crow (*Corvus spp.*) with its beak above an unattended ILT egg. A previous survey on 28 June recorded 34 adult ILT's, 22 nests with 43 eggs, and 18 chicks, but then a great horned owl was photographed at the colony (*Bubo virginianus*) (Figure 17). The subsequent survey on 3 July recorded just 5 adults, 21 nests with 38 eggs, and 1 chick. Presumably adult ILT's abandoned the colony after the great horned owl depredated chicks, leaving the remaining eggs unattended and available to crows, as seen here.

Figure 19. Example of a sign placed at active ILT colonies to discourage human disturbance during the nesting season of 2018.

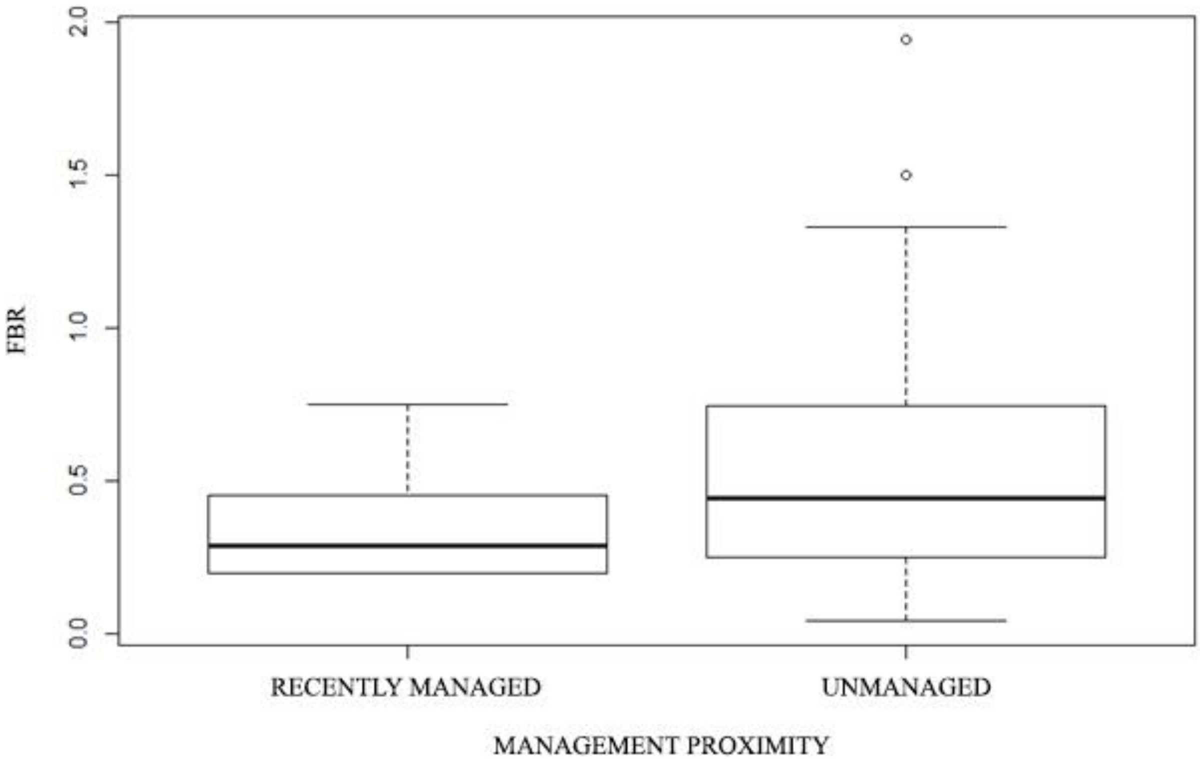

Figure 20. Boxplots comparing FBR rates for colonies on the MKARNS with spoil management, combining year-of and year-after FBR's, using only positive count data from colonies that fledged at least one chick, with the interquartile range and median displayed and FBR on the y-axis.

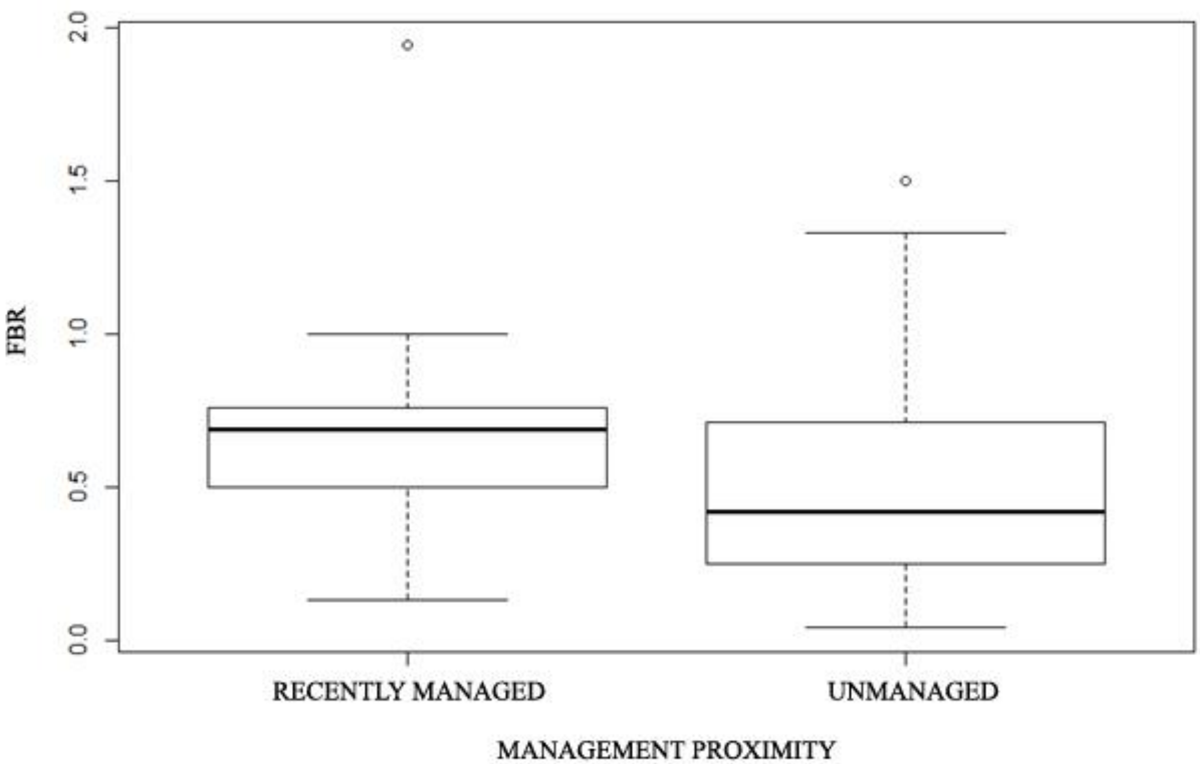

Figure 21. Boxplots comparing FBR rates for colonies on the MKARNS with herbicide treatment, combining year-of and year-after FBR’s, using only positive count data from colonies that fledged at least one chick, with the interquartile range and median displayed and FBR on the y-axis.

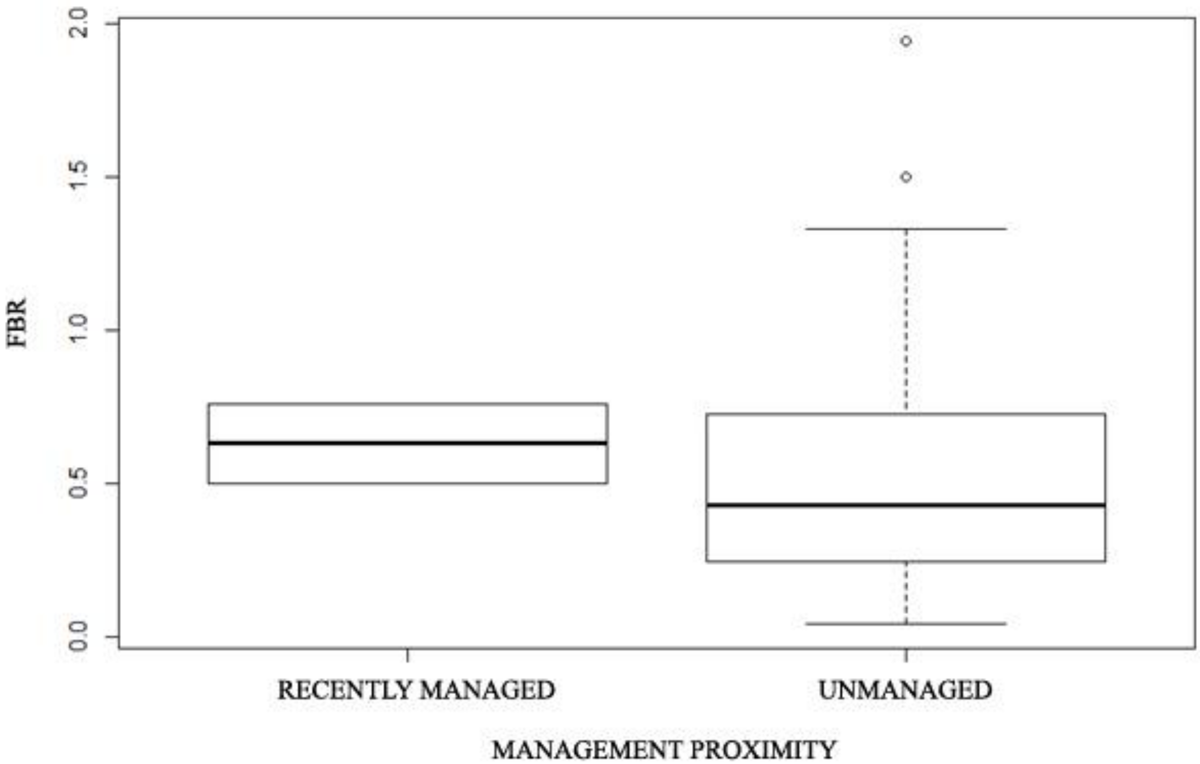

Figure 22. Boxplots comparing FBR rates for colonies on the MKARNS with mulch treatment, combining year-of and year-after FBR's, using only positive count data from colonies that fledged at least one chick, with the interquartile range and median displayed and FBR on the y-axis.

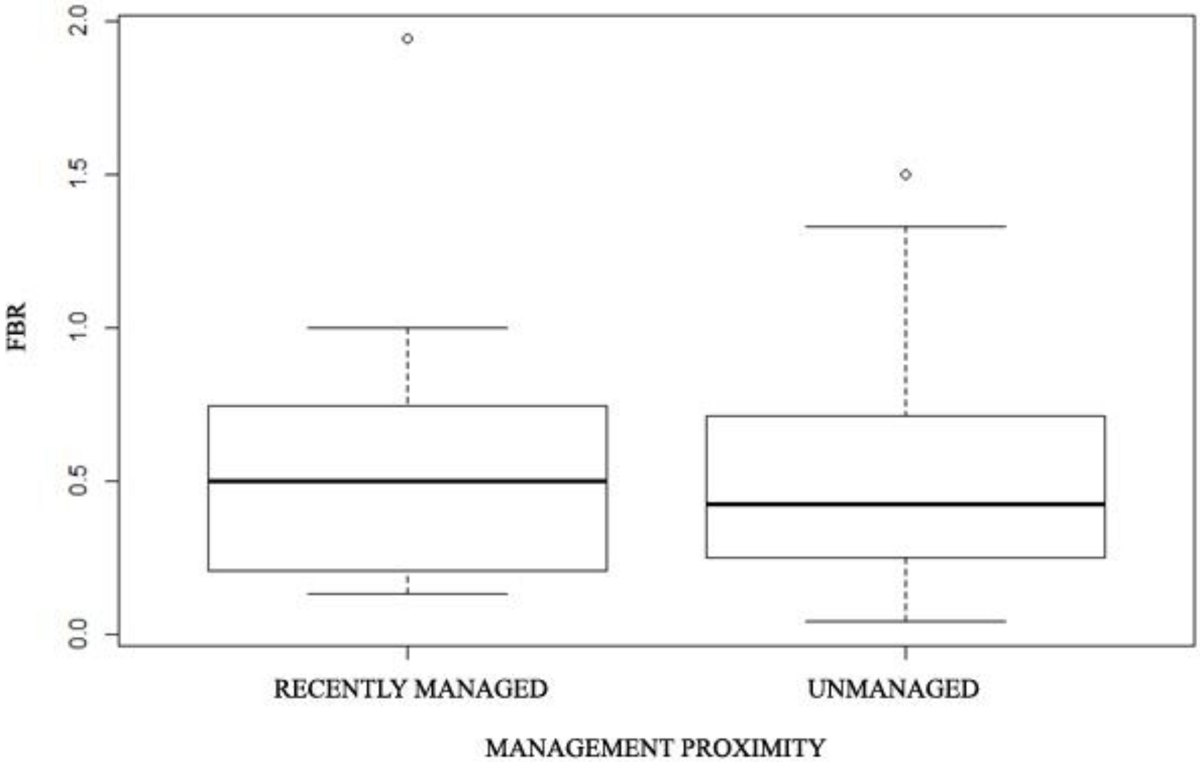

Figure 23. Boxplots comparing FBR rates for colonies on the MKARNS with management in general, combining year-of and year-after FBR's, using only positive count data from colonies that fledged at least one chick, with the interquartile range and median displayed and FBR on the y-axis.

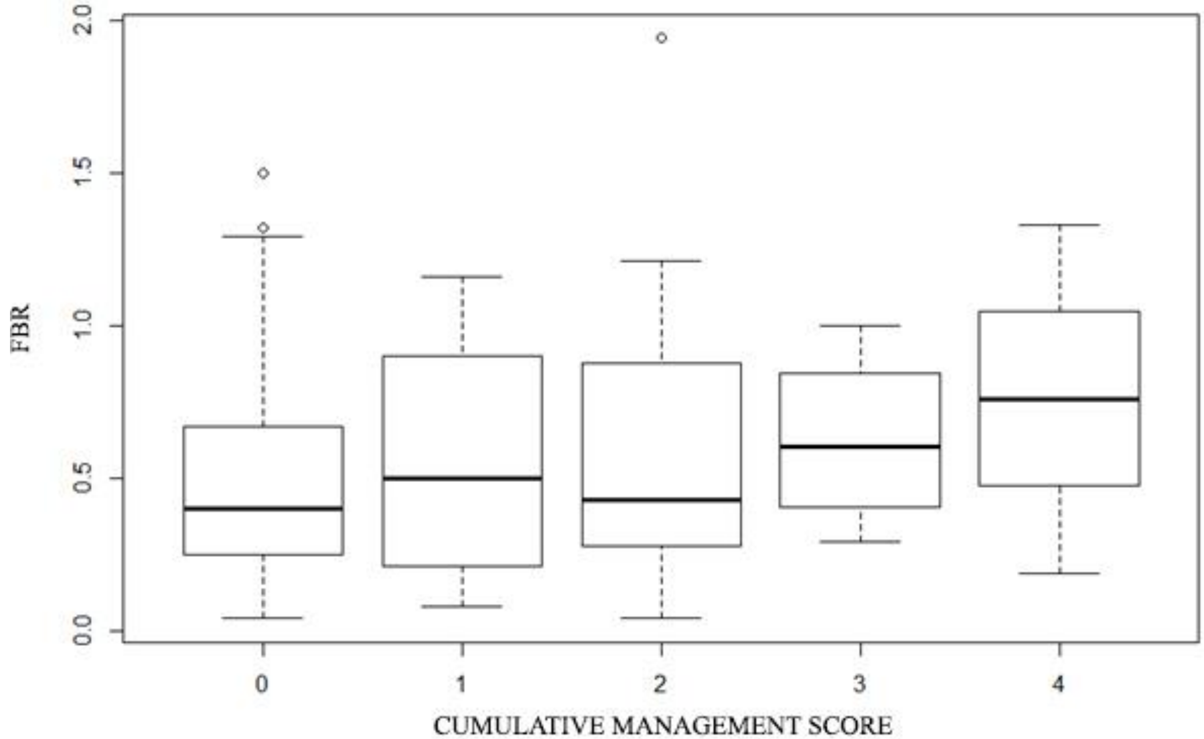

Figure 24. Boxplots comparing FBR rates for colonies on the MKARNS with the cumulative management score of the sandbar, using only positive count data from colonies that fledged at least one chick, with the interquartile range and median displayed and FBR on the y-axis.

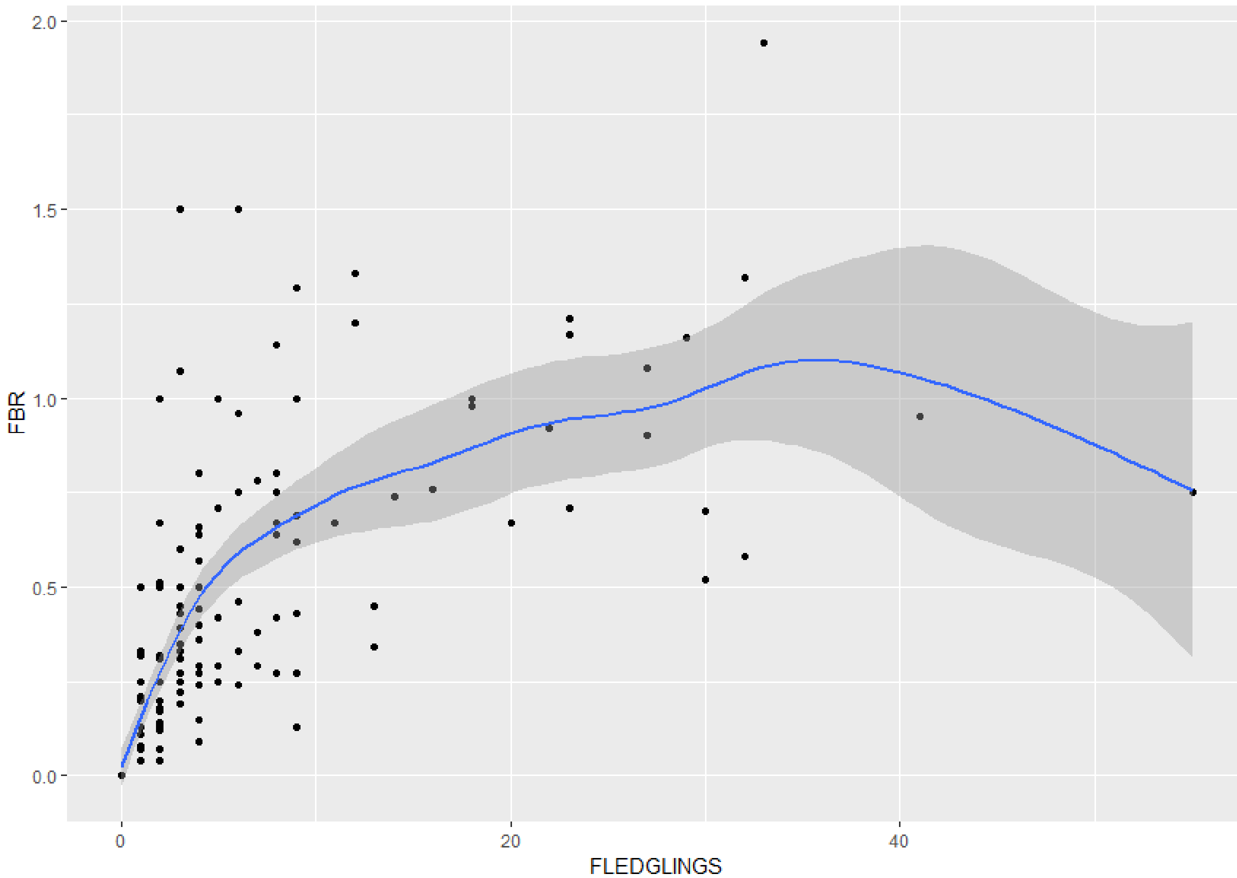

Figure 25. Graph of a generalized additive model's results directly comparing fledgling counts and FBR rates with 95% confidence intervals, using data from 2001-2018.

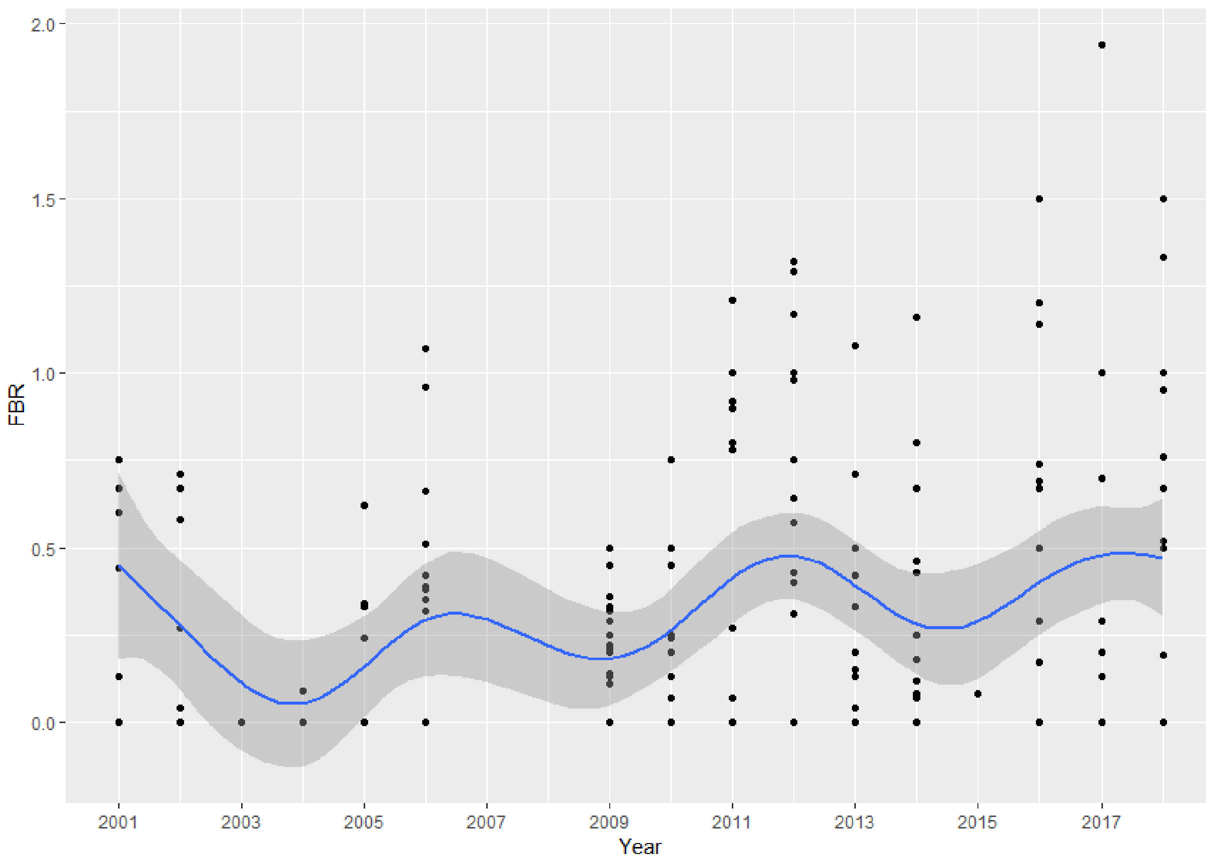

Figure 26. Graph of a generalized additive model's results investigating the trend of individual colony FBR rates through time on the MKARNS, with 95% confidence intervals

Figure 27. Graph of a generalized additive model's results investigating the trend of individual colony FBR rates through time on the MKARNS, using only successful colonies, with 95% confidence intervals.


Adult Interior Least Tern (*Sternula antillarum athalassos)* feeding a fledgling next to an egg, on a rooftop colony in Conway, AR. © Trevor Jensen Photography