Platte River Recovery Implementation Program

Piping Plover and Interior Least Tern Monitoring and Research on the Central Platte River, Nebraska in 2023

DRAFT REPORT


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Governance Committee

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22 December 2023

Suggested Citation:

PRRIP. 2024. Platte River Recovery Implementation Program: Piping plover and interior least tern monitoring and research on the central Platte River, Nebraska in 2023. 2023 Annual Report.

PREFACE

This report summarizes the Platte River Recovery Implementation Program's (Program or PRRIP) monitoring and research efforts for piping plovers and interior least terns during 2023. We prepared this report to inform Program partners, licensing agencies, and the public of our activities and to provide a summary of results to fulfill the requirements of the Program's state (Nebraska Master Permit #1208) and federal (TE183430-3) monitoring permits.

Annual monitoring reports produced by West Incorporated (2001–2007) and Program EDO staff (2008–2023) include previous data and analyses and are available on the Program's online Public Library (https://platteriverprogram.org/program-library). PRRIP's published data are also available for use by other programs to provide information on plover and tern productivity on the central Platte River that may be helpful for broader scale interpretation of species productivity and management decisions.

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TABLE OF ABBREVIATIONS

Abbreviation	Definition
ac	Acres
AHR	Associated Habitat Reach
cfs	Cubic feet per second
CI	Confidence interval
CNPPID	Central Nebraska Public Power and Irrigation District
CPNRD	Central Platte Natural Resources District
EA	Environmental Account
EBQ	Extension Big Question
EDO	Executive Director's Office
ft	Feet or foot
GC	Governance Committee
ISAC	Independent Scientific Advisory Committee
J-2	Johnson Hydropower Return
LETE	Interior least tern, *Sternula antillarum*
MCA	Moving complex approach
mi	Miles
NPPD	Nebraska Public Power District
OCSW	Off-channel sand and water
PIPL	Piping plover, *Charadrius melodus*
PRRIP or Program	Platte River Recovery Implementation Program
TAC	Technical Advisory Committee
USDA-APHIS-WS	United States Department of Agriculture and Animal and Plant Health Inspections Service Wildlife Services
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WS	Wildlife Services

EXECUTIVE SUMMARY

Improving productivity of piping plovers (*Charadrius melodus*; hereafter plovers) and interior least terns (*Sternula antillarum*; hereafter terns) on the central Platte River is a primary management objective of Platte River Recovery Implementation Program ("Program" or "PRRIP"). Long-term monitoring of plovers and terns by the Program has been key to understanding the status of both species along the central Platte River. During 2023, the Executive Director's Office (EDO) and Program partners surveyed the river and 18 adjacent off-channel sand and water (OCSW) sites for plovers and terns along PRRIP's Associated Habitat Reach (AHR) on the central Platte River between Lexington and Chapman, Nebraska. Biologists conducted surveys twice per month between 1 May and 1 August to enumerate the number of adults and nests. Once ≥1 nest was found, biologists monitored the site twice per week to determine nest fate and if the nest was successful, enumerate number of chicks, monitor chick fates, and enumerate number of fledglings. In addition to these monitoring efforts, the EDO implemented additional remote camera monitoring, predator track surveys, and predator management actions at six Program-managed OCSW sites for the third straight year to better understand the role of predation on plover productivity and the efficacy of predator deterrents on nest and chick depredations. Below, we summarize results from our 2023 plover and tern monitoring, and predator management and monitoring efforts.

Plover Monitoring

Plovers nested at 10 of 18 OCSW sites that provided a total of 256 ac of potential nesting habitat during 2023. Additionally, we observed the first plover nest on an island in the Platte River channel since 2016. We have observed a significant, positive relationship between the estimated number of plover breeding pairs and area of potential nesting habitat at OCSW sites since 2001. We estimated a peak of 41 plover breeding pairs (BPE) at our monitored sites across the AHR during 2023, which was the highest BPE since 2019. Forty of 48 plover nests were successful, which were the most successful nests since 2016, resulting in the highest apparent nest success (0.83) observed during the contemporary 2010–2023 monitoring period. Plover nests produced 143 chicks (<15 days old) and 58 fledglings (≥28 days old), which were the most fledglings enumerated on our sites since 2012. We observed higher fledge ratios in 2023 than 2022 with increases from 1.37 chicks/BPE (0.95 chicks/nest) to 1.41 chicks/BPE (1.21 chicks/nest).

We observed a high amount of variability in plover reproductive effort and success among sites. Dyer, Blue Hole, Newark East, and Kearney Broadfoot South were the most productive OCSW nesting sites for plovers in 2023 with fledge ratios ≥1. These four sites were also the most productive during 2022. High apparent nest success and fledge ratios at each of these sites was largely due to limited predation of nests and chicks. The other six OCSW sites at which we observed plover nesting had between one and three successful nests with fledge ratios ranging between 0.0 chicks/BPE (0.0 chicks/nest) and 2.0 chicks/BPE (2.0 chicks/nest). The nest on an island in the river channel at the Dippel property was depredated after five days.

We successfully assigned nest fates to 37 of the 48 plover nests observed during 2023. Twenty-nine nests successfully fledged (0.604 of nests), two nests failed due to abandonment (0.042), and five nests and one brood failed due to predation (0.125). Nine broods failed due to unknown causes

(0.188) and the fates of one nest and one brood were unknown (0.042). Since initiating remote camera monitoring in 2020, the proportion of nests and broods that failed due to unknown causes has decreased from a maximum of 0.566 of nest fates in 2019 to 0.188 in 2023.

Results from our 2023 plover monitoring efforts indicate continued increases in plover nest productivity metrics on monitored sites across the central Platte River from recent lows observed during 2018 and 2019. The number of plover fledglings and fledge ratios observed during 2023 were the highest since 2012 and 2014, respectively, which was shortly after the Program began constructing and adding more potential nesting habitat at OCSW sites. These increases in nest success and productivity were likely attributable to fewer severe weather events during summer 2023 and a decrease in predation of nests and chicks relative to previous years.

Tern Monitoring

Terns breeding on OCSW sites along the central Platte River continued to nest in high numbers during 2023 with above-average productivity relative to 2010–2022 averages. Terns nested at eight of 18 OCSW sites during 2023 and there has been a positive relationship between the estimated number of tern breeding pairs and area of potential nesting habitat at OCSW sites since 2001. We estimated a peak of 90 tern breeding pairs at our monitored sites, which was the highest tern BPE since 2019. Of 124 tern nests, 83 were successful for an apparent nest success of 0.67, which was comparable to 2022. Tern nests produced 207 chicks (<15 days old) resulting in a hatch ratio of 2.30 chicks/BPE (1.67 chicks/nest). The 124 tern fledglings (≥21 days old) observed resulted in a fledge ratio of 1.38 chicks/BPE (1.00 chicks/nest) and represented the most tern fledglings enumerated at our sites since 2015. These fledge ratios represented a slight decrease from the high of 1.68 chicks/BPE (1.12 chicks/nest) observed in 2022. However, the ratios of 1.00 chicks/nest and 1.38 chicks/BPE observed in 2023 were still above the average (1.18 chicks/BPE; 0.86 chicks/nest) during 2010–2022.

Of the eight OCSW sites with tern nesting during 2023, we observed a greater number of nests established at the Newark East, Blue Hole, Kearney Broadfoot South, Dyer, and OSG Lexington sites. Three of these five sites had fledge ratios >1 based on BPE. At the Newark East site, which has become one of the Program's most consistent sites for higher tern productivity, we observed 34 of 41 tern nests to be successful that produced 45 fledglings for a fledge ratio of 1.32 chicks/BPE (1.10 chicks/nest). In contrast, at OSG Lexington, only two of 11 nests were successful and produced two fledglings. We also observed tern fledge ratios >1 at Cottonwood Ranch (2.83 chicks/BPE; 17 fledglings; six successful nests) and Newark West (2.00 chicks/BPE; eight fledglings; five successful nests).

We successfully assigned nest fates to 84 of the 124 tern nests observed during 2023. Sixty-four nests successfully fledged (0.516 of nests); two nests and one brood failed due to abandonment (0.024); one nest failed due to flooding (0.008); one nest failed due to weather (0.008); and 15 nests failed due to predation (0.121). A total of 20 nests and 18 broods failed due to unknown causes (0.306) and the fate of two nests was unknown. The proportion of tern nests that failed due to unknown causes was higher in 2023 than 2022, but still lower than the 2017–2019 period prior to implementation of camera monitoring. Severe weather events led to the failure of 13% of tern nests in 2022; however, <1% of nests failed due to weather during 2023.

Predator Management and Monitoring

The Program employed basic predator management efforts at three OCSW sites (Cottonwood Ranch; Dyer; Newark East), which included trapping and removal of mammalian predators; removal of trees within a ≥492 ft radius of the nesting area; installation of avian spikes on all potential non-removable perches; maintaining a ≥100 ft water moat surrounding nesting peninsulas; and installation of electrified predator exclusion fences across the entrances to each peninsula. At three other OCSW sites (Kearney Broadfoot South; Leaman; Newark West), the Program used additional predator management efforts in the form of predator exclusion fencing with electrified wires surrounding nesting peninsulas and predator deterrent lights.

EDO biologists and technicians conducted a total of 92 shoreline track surveys across the six OCSW sites during 2023, ranging from 12 weekly surveys at Leaman to 18 weekly surveys at Newark East, and recorded 222 total unique track registers (2.41 track registers/survey). Biologists deployed 29 shoreline cameras for a total of 3,347 camera days across the six sites. Shoreline cameras recorded 802 unique predator registers resulting in 0.240 unique registers/camera day across all six sites. We observed 0.185 registers/camera day at the three sites with basic predator management compared to 0.305 registers/camera day at sites with additional predator management. We documented avian species most frequently on shoreline cameras across all six sites.

Biologists deployed 25 site-level cameras for a total of 3,084 camera days across the six sites and recorded 223 unique predator registers resulting in 0.072 unique registers/camera day. We observed 0.067 site-level registers/camera day at the three sites with basic predator management compared to 0.080 site-level registers/camera day at sites with additional predator management. We documented avian species most frequently on site-level cameras across all six sites.

Biologists deployed 36 nest-level cameras to monitor 71 nests (34 plover; 37 tern) for a total of 1,107 camera days across the six sites. Additionally, biologists placed one nest-level camera at the plover nest located on an island in the river channel at the Dippel property that added five camera days. Nest-level cameras documented 12 unique registers of predator species (e.g., within view of camera but did not depredate the nest) resulting in 0.011 nest-level registers/camera day. Nest-level cameras documented seven predation events resulting in 0.006 predation event registers/camera day across all six sites and the in-channel site. Of the seven predation events, one was at a site with additional predator management (Kearney Broadfoot South), five were at sites with basic predator management (Cottonwood Ranch; Dyer; Newark East), and one was at the Dippel in-channel site with no predator management. We observed predation events more frequently at sites with basic predator management (0.007 predation events/total camera days at basic sites) than at those with additional predator management (0.003 predation events/total camera days at additional sites).

We documented three predation events that were not captured on a nest-level cameras through use of a combination of predator monitoring techniques. Overall, nine plover and tern nests failed due to predation and the final egg from one plover nest was depredated after chicks had hatched and were away from the nest during the predation event. Plover nests were depredated by great horned owls (*Bubo virginianus*; two nests), a bull snake (*Pituophis catenifer sayi*), a coyote (*Canis latrans*), and a raccoon (*Procyon lotor*). Tern nests were depredated by great horned owls (three nests), a bull snake, and a Canada goose (*Branta canadensis*) that stepped on eggs.

Biologists placed nest cameras at 72 of 120 (60%) plover and tern nests at the six OCSW sites and one on-channel site in 2023. Fifty-nine of the 72 nests with cameras and 36 of 48 nests without cameras were successful. For both plover and tern nests combined, we found no significant difference in daily survival rates (DSR) for nests with (DSR = 0.991; 95% confidence interval [CI]: 0.984, 0.996) or without cameras (DSR = 0.986; 95% CI: 0.979, 0.993). Biologists deployed cameras at 35 of 36 plover nests at the six OCSW sites and one on-channel site with 29 of the 35 nests successful. One plover nest at Kearney Broadfoot South did not have a camera and was successful. Biologists deployed cameras at 37 of 84 tern nests at the six sites and we found no significant difference in DSR for tern nests with (DSR = 0.989; 95% CI: 0.976, 0.997) or without cameras (DSR = 0.987; 95% CI: 0.974, 0.997). Combined average DSR for plover and tern nests during 2010–2016 across all six sites prior to camera deployment was 0.968 (95% CI: 0.932, 1.00), which was lower than our DSR estimates for nests with and without cameras during 2023. The 95% CIs of average DSR during 2010–2016 overlapped the 95% CIs of DSR estimates for 2023.

We used a combination of predator monitoring techniques to help reduce uncertainty of plover and tern nest fates, better understand predator communities at nesting sites, and evaluate the effectiveness of additional predator management efforts during 2023. We observed reduced predation of both plover and tern nests in 2023 compared to 2022 despite recording more registers/camera day of potential predators at shoreline at site-level cameras in 2023. We documented more registers of potential predator species at shoreline cameras than at site-level cameras, and more registers at site-level cameras than nest-level cameras during 2023, which would be expected for an effective predator deterrent management strategy. We have documented increasing fledge ratios for plovers since 2021 at the six OCSW sites with predator management and monitoring. However, this increase was concurrent with increasing plover fledge ratios at sites across the AHR and we have observed a high amount of variability in fledge ratios at individual sites across years. We have documented more interannual and site-by-site variability in tern fledge ratios at the six OCSW sites since the beginning of our predator management in 2021 due, in part, to nest failures from severe weather in 2022.

In this report, we summarize results from the Program's management and monitoring efforts for plovers and terns during 2023 on the central Platte River and at OCSW nesting sites adjacent to the river. We also detail findings from our predator management, monitoring, and research efforts at six OCSW sites during 2023. Overall, the Program is using long-term plover and tern monitoring data and research on predator impacts on nest and brood success to evaluate progress toward management objectives and support adaptive management decision-making related to plovers and terns.

INTRODUCTION

The northern Great Plains population of piping plovers (*Charadrius melodus*; hereafter plovers) was listed as threatened on 10 January 1986 (50 Federal Register 50726) by the United States Fish and Wildlife Service (USFWS) under the Endangered Species Act (ESA). The northern Great Plains plover remains listed as threatened due to concerns over the species' viability given impacts of predation and habitat loss on survival and productivity (USFWS 2020). The interior least tern (*Sternula antillarum*; hereafter tern) was listed as endangered under the ESA on 27 June 1985 (50 Federal Register 21784). The USFWS removed the tern from ESA protective status on 12 February 2021 (86 Federal Register 2564); however, the tern remains protected under the Migratory Bird Treaty Act and the Nebraska Non-Game and Endangered Species Conservation Act (Nebraska Rev. Statute §37-801-811).

The Platte River provides key habitat for plovers and terns with both species nesting on manufactured sand and gravel pits adjacent to the active river channel and on unvegetated sandbars in the river channel (Sidle and Kirsch 1993, Kirsch 1996, Farnsworth et al. 2017, Farrell et al. 2018, Jorgensen et al. 2021). The Platte River Recovery Implementation Program (PRRIP or Program) is responsible for implementing certain aspects of plover and tern recovery plans along the central Platte River (PRRIP 2021b) and manages land and water to attain specific management objectives. The management objective for plovers and terns as defined in the Program's First Increment Adaptive Management Plan (AMP; PRRIP 2021b) is to improve their productivity along the central Platte River through: (1) increasing the number of fledged chicks; and (2) reducing adult mortality. Increasing the number of fledged chicks may be done through increasing the number of breeding pairs and/or increasing fledge ratios, the latter of which is related to nest loss and chick mortality due to predation, weather, flooding, and inadequate forage. Reducing adult morality may primarily be accomplished by reducing predation, although severe weather may affect adult survival. The Program uses the number of nesting pairs and number of chicks fledged per nest or breeding pair (i.e., fledge ratio) as indicators for monitoring the status of plovers and terns. Though not required for ESA compliance, in 2021 the Program's Governance Committee (GC) directed Executive Director's Office (EDO) staff to continue monitoring terns following the same protocol as it did prior to federal delisting (PRRIP 2021a).

The Program's monitoring efforts for plovers and terns (PRRIP 2017) include: (1) observing use and nest productivity on riverine in-channel sandbars and created or rehabilitated off-channel sand and water (OCSW) nesting sites along the central Platte River between Lexington and Chapman, Nebraska; (2) identifying and documenting factors that influence nest site selection and nest and brood success; and (3) monitoring potential predators to gather information on the predator community present on and around nesting sites. The Program's First Increment Extension Science Plan, written in 2022, identified two Extension "Big Questions" related specifically to plover productivity and the role of predation (PRRIP 2022a). The first, "how much of an effect does predation have on plover productivity," is being addressed using data on nest and brood predation to quantify the impact of predation, by identifying predator species, and by determining whether losses are incurred during incubation or brood rearing (PRRIP 2022a). The second, "how effective is Program management at mitigating losses of plover productivity due to predation," is being addressed through data collection on the efficacy of trapping, fencing, and/or predator deterrent lighting at reducing nest and brood failure due to predation (PRRIP 2022a).

In this report, we summarize results from the Program's management and monitoring efforts for plovers and terns during 2023 on the central Platte River and at OCSW nesting sites adjacent to the river. We also detail findings from our predator management, monitoring, and research efforts at six OCSW sites during 2023. The monitoring conducted during 2023 was a collaborative effort between Program EDO staff and the Nebraska Public Power District (NPPD). Overall, long-term plover and tern monitoring data and research on predator impacts on plovers are being used to evaluate progress toward management objectives and to support adaptive management decision-making related to plovers and terns.

STUDY AREA

Our study area encompassed the Program's Associated Habitat Reach (AHR) segment of the central Platte River between Lexington and Chapman, Nebraska (~90 river mi, Figure 1) and OCSW sites within 3.5 mi of the river in this reach (Figure 2). River or on-channel habitat includes naturally formed or constructed midstream sandbars used for nesting and the open river channel used for foraging. The number of low-elevation sandbars present within the PRRIP AHR of the central Platte River has been variable and dependent on seasonal and daily fluctuations in river flow. The size and distribution of non-vegetated, high-elevation sandbars characteristic of plover and tern nesting sites within the region has been dependent upon construction and vegetation management efforts.

OCSW habitat includes spoil piles of sparsely- or non-vegetated sand at sand and gravel mines and constructed nesting sites. Migratory plovers typically arrive in early May and nest on OCSW habitat or constructed on-channel islands. Adults forage on low elevation river sandbars or along the waterline of OCSW habitat, though they are more reliant on OCSW shorelines while nesting (Sherfy et al. 2012). Chicks forage along OCSW waterlines until fledging when they are often observed foraging on the river channel. Migratory terns typically arrive later in May and nest on OCSW habitat or constructed on-channel islands. Terns forage at both the sand and water site and on the river channel, though they rely more on the river channel for foraging (Sherfy et al. 2012). Fledged terns at OCSW habitat along the AHR have been observed beginning to learn to forage in the water surrounding the nesting area, then are later often observed on the river channel.

2023 RIVER CONDITIONS

Daily river discharge at the Kearney gage (USGS gage 06770200, USGS 2023) between 1 May and 4 September 2023 was generally higher than the median daily river discharge between 2001 and 2022 over the same period (Figure 3[1]). Other than lower flow conditions that occurred 1–11 May, 21–28 May, 26 July through 4 August, and 19 August through September 4, daily river discharge was higher than the median (Figure 3). The Environmental Account (EA) flow release to suppress germination of in-channel woody vegetation was started by the Program in late May

[1] River discharge data was provisional and will be updated once approved by the USGS.

with EA flows reaching the Kearney gage on 29 May (Figure 3). Flow increased during the first week of June and peaked at 2,240 cubic feet per second (cfs) on 6 June (Figure 3). The EA flow release was halted on 14 June with the last of EA water reaching the Kearney gage on 19 June (Figure 3). The pictures below provide examples of river conditions on 15 May, 15 June, and 15 July that demonstrate river flow before, during, and after the June flow release in relation to sandbar habitat and vegetation growth from west to east across the AHR.

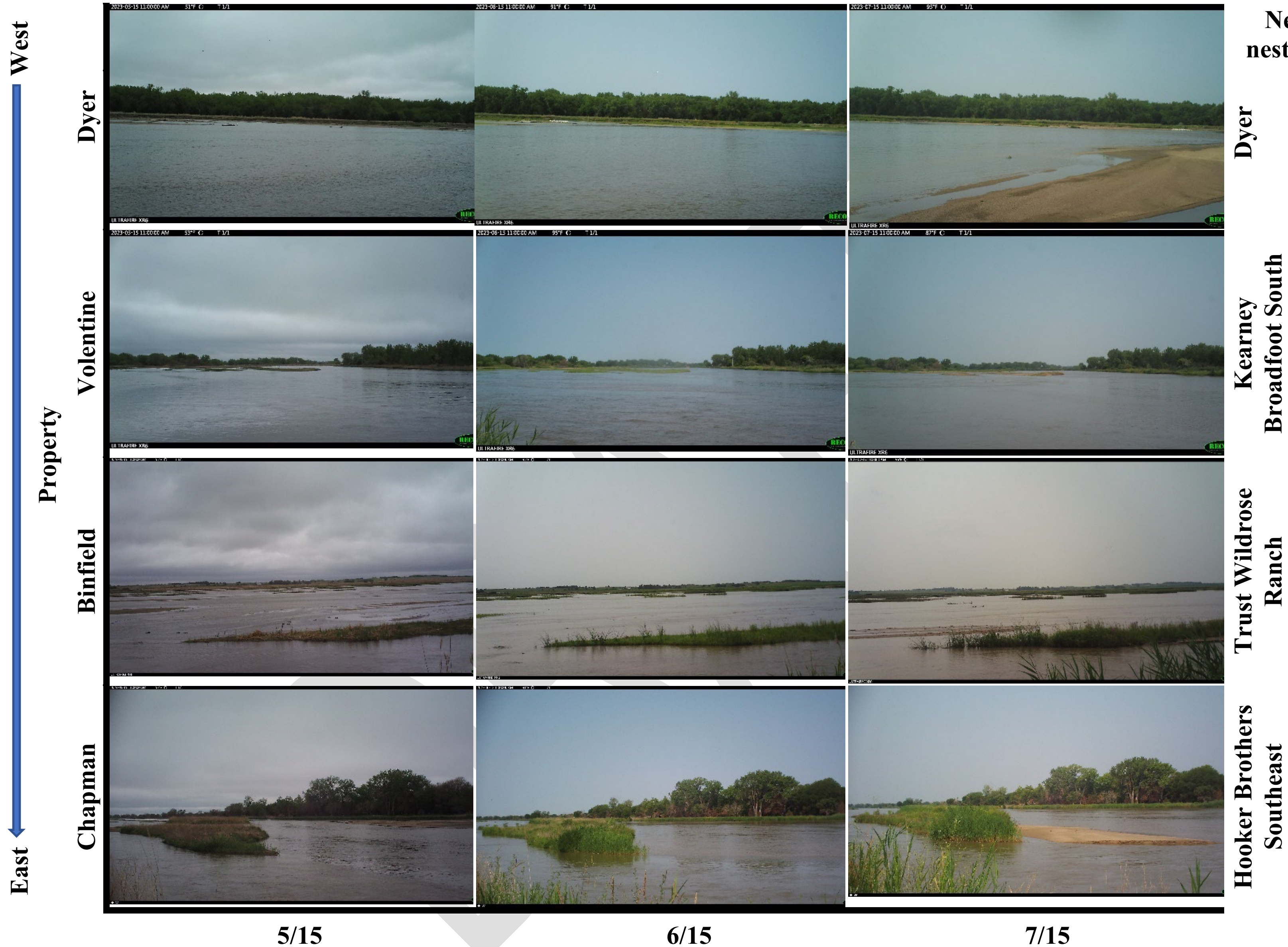
A combination of abnormally wet conditions in Colorado in June and above-average snowpack in Wyoming during winter 2022–2023 resulted in high flows in the South Platte River and North Platte River, respectively. In turn, discharge on the central Platte River was well above average during June and July with discharge peaking at 6,490 cfs on 2 July (Figure 3). The lowest flow recorded at the Kearney gage during the nesting season (1 May–1 August) was 47.8 cfs on 3 May at the beginning of plover nesting (Figure 3). Flow decreased below 100 cfs at the end of August as fledging came to an end and birds left the reach (Figure 3).

MANAGEMENT

The Program undertook management actions designed to increase the amount of nesting habitat (bare sand), improve foraging habitat, and increase productivity of plovers and terns at on- and off-channel sites during fall 2022 and spring 2023. Management activities were site specific and included: mechanical actions to improve nesting conditions and remove vegetative cover (reducing washouts along shorelines, disking, tree removal); chemical application to kill or prevent emergence of vegetation (fall and/or spring herbicide application); and predator control (trapping, fencing, and/or predator deterrent lights).

OFF-CHANNEL MECHANICAL HABITAT CREATION AND MAINTENANCE (2007–2023)

Approximately 48 ac of managed off-channel nesting habitat were present in the AHR at the beginning of the Program's First Increment in 2009 (Figure 4). The Program began acquiring and restoring off- channel sites in 2009 and monitoring at these sites began in 2010. Total monitored off-channel habitat in the AHR increased to ~250 ac by 2021 as the Program constructed and restored potential nesting habitat (Figure 4). Area of potential nesting habitat across the AHR has remained mostly unchanged since 2021 and peaked at 256 ac in 2023 (Figure 4). Across nine Program managed sites, bare sand habitat decreased by a total of 1.3 ac between 2022 and 2023 (see site specific details below). The largest loss in potential nesting habitat at Program sites between 2022 and 2023 occurred at the OSG Lexington site where 1.5 ac of habitat was lost due to shoreline erosion. The Follmer site experienced the largest gain in potential nesting habitat between 2022 and 2023 with an increase of 0.8 ac of bare sand. Across nine sites not owned or managed by the Program, bare sand habitat increased by a total of 7.4 ac with the largest increase occurring at the Hooker Brothers Southeast site (6.5 ac; see site specific details below). The DeWeese site lost the greatest amount of potential nesting habitat with a loss of 1.5 ac between 2022 and 2023.



Vegetation monitoring pictures demonstrating changes in on-channel habitat availability through time across the AHR from west (top) to east (bottom) before (left column), during (middle column), and following (right column) June flow release. The Program property and nearest OCSW nesting site corresponding with the location of each photo series are provided on the left and right y-axis, respectively.

Off-Channel Sand and Water Sites

The Program actively managed 13 of the 18 off-channel sites that were monitored during 2023 with the goal of increasing plover and tern productivity (Figure 2). Management efforts at each of the 18 sites are summarized below. Site numbers correspond to map locations on Figure 2. Provided in parentheses after each site name are letters denoting management efforts and history of each site. Program owned or leased sites are denoted with a "P;" managed sites are identified with an "M;" sites constructed specifically for plover and tern nesting are denoted by a "C;" and sand and gravel mines (formerly and currently active) that were rehabilitated into or designated as possible nesting habitat are identified with a "G".

1. OSG Lexington (PMG)–Program contractors applied a contact herbicide to kill existing vegetation along the waterline during fall 2022 and pre-emergent herbicide to the nesting area during spring 2023. Predator trapping occurred during the 2023 nesting season. We installed a permanent 4-ft-high woven wire predator exclusion fence in spring 2021 across the north entrance to the nesting area. The fence had offset electric wires to prevent terrestrial predators from climbing and an electrified top wire to prevent avian predators from perching. Additionally, we installed a temporary 4-ft-high electrified predator exclusion fence across the east entrance to the nesting area separating the nesting site from ongoing sand and gravel mining occurring to the east of the habitat. We installed a permanent 4-ft high woven wire fence in spring 2023 around the western and southwestern outer perimeter of the site as a predator deterrent and to limit human disturbance to the site. Potential nesting habitat decreased by 1.5 ac between 2022 and 2023 due to shoreline erosion.

2. NPPD Lexington (MG)–Program contractors applied a pre-emergent herbicide to the nesting area during spring 2023. Predator trapping occurred during the 2023 nesting season. Woven-wire predator exclusion fences with offset electric wires along the west side of the nesting areas were maintained during 2023. No sand and gravel mining occurred during 2023.

3. Dyer (PMG)–Program contractors applied a contact herbicide to kill existing vegetation along the waterline during fall 2022 and pre-emergent herbicide to the nesting area during spring 2023. Predator trapping occurred during the 2023 nesting season. We maintained permanent 4-ft-high woven wire predator exclusion fences with offset electric wires and an electrified top wire across the south ends of each peninsula. No sand and gravel mining occurred during 2023.

4. Cottonwood Ranch (PMC)–Program contractors applied a contact herbicide to kill existing vegetation along the waterline during fall 2022 and pre-emergent herbicide to the nesting area during spring 2023. Predator trapping occurred during the 2023 nesting season. We maintained a permanent 4-ft-high woven wire predator exclusion fence with offset electric wires and top wire at the entrance to the nesting peninsula during 2023. No sand and gravel mining occurred during 2023.

5. T&F Lakeside (G)–Not managed. Sand and gravel mining occurred during 2023. Potential nesting habitat increased by 3.1 ac between 2022 and 2023.

6. Blue Hole (MG)–Program contractors applied a pre-emergent herbicide to the nesting area during spring 2023. Predator trapping occurred during the 2023 nesting season. There was no predator exclusion fence at the site. Sand and gravel mining did not occur during 2023; however, the area west of this OCSW site is a high traffic area for loading and unloading equipment. This site lost 0.4 ac between 2022 and 2023 due to bank erosion into the river that occurred on the south side of the site.

7. Johnson (MG)–Program contractors applied a pre-emergent herbicide to the nesting area during spring 2023. No predator trapping occurred during 2023. NPPD maintained a non-electrified woven-wire predator exclusion fence along the west side of the nesting area. Sand and gravel mining occurred during 2023.

8. Ed Broadfoot and Sons (G)–Not managed. Sand and gravel mining occurred during 2023 and the site lost 1 ac of potential nesting habitat between 2022 and 2023.

9. Kearney Broadfoot South (PMG)–Program contractors applied a contact herbicide to kill existing vegetation along the waterline during fall 2022 and pre-emergent herbicide to the nesting area during spring 2023. Predator trapping along the exterior shorelines of the site occurred during 2023. We maintained a permanent 4-ft-high woven wire fence with an electrified top wire (to prevent avian perching) along the interior shoreline of the entire nesting peninsula. The fence also spanned the east end of the peninsula, thereby limiting access from its only land entrance. Predator deterrent lights were again installed on the site for the 2023 nesting season as a part of our additional predator management study. Sand and gravel mining during 2023 took place north of the main peninsula where nesting occurred.

10. Non-Access Islands Kearney Broadfoot South (PMG)–Predator trapping occurred during 2023. Due to active mining, the area of this site varies from year to year. There were 5.6 ac of unmanaged, suboptimal habitat available on these islands for plover or tern nesting and foraging during 2023. Available habitat consists of the interior, unvegetated portions of islands to the west and the unvegetated sandy tailing that remains as the eastern peninsula is mined. The shorelines of most of these islands are partially or heavily vegetated, thus do not contribute to the acres counted as habitat for this site. The far eastern portion of the actively mined peninsula is unvegetated; however, it is not suitable for nesting due to the activity in the area and changing terrain and is not counted toward total acreage either.

11. Newark West (PMG)–Program contractors applied a contact herbicide to kill existing vegetation along the waterline during fall 2022 and pre-emergent herbicide to the nesting area during spring 2023. We maintained permanent 4-ft-high woven wire predator exclusion fences with offset electric wires and a top wire across the ends of each peninsula. In addition, the entire perimeter of the exterior of this site, outside of the surrounding water barrier, was enclosed with a permanent 4-ft-high woven wire fence with an offset electric wire. Predator trapping inside the perimeter fence, but outside the nesting peninsula occurred during 2023. We installed predator deterrent lights on the nesting site during spring 2023 as part of our additional predator management. No sand and gravel mining occurred during 2023.

12. Newark East (PMG)–Program contractors applied a contact herbicide to kill existing vegetation along the waterline during fall 2022 and pre-emergent herbicide to the nesting area during spring 2023. Predator trapping occurred during 2023. We maintained a permanent 4-ft-high woven wire predator fence with offset electric wires and electrified top wire across the west peninsula and a temporary 4-ft-high electrified predator fence across the east peninsula. Limited sand and gravel mining occurred east of the nesting areas.

13. Leaman (PMC)–Program contractors applied a contact herbicide to kill existing vegetation along the waterline during fall 2022 and pre-emergent herbicide to the nesting area during spring 2023. Predator trapping occurred during 2023. The nesting peninsula was closed from its only land connection by a permanent 4-ft-high woven wire predator exclusion fence with an electrified top wire and offset electric wires. Additionally, there was a 4-ft-high woven wire fence that was not electrified separating the northern boundary of the site from the property to the north, but this fence did not completely enclose the site. We installed predator deterrent lights on the nesting site during spring 2023 as part of our additional predator management efforts. No sand and gravel mining occurred, but the site lost 0.4 ac of nesting habitat due to shoreline erosion.

14. Trust Wildrose East (MG)–Program contractors last disked the nesting area in the fall of 2021. No herbicide was applied in the fall of 2022 or in the spring of 2023. No sand and gravel mining occurred.

15. Follmer (PMG)–Program contractors applied a contact herbicide to kill existing vegetation along the waterline during fall 2022 and pre-emergent herbicide to the nesting area during spring 2023. Predator trapping occurred during 2023. No fence has been built at this site given no documented use by plovers or terns to date. Sand and gravel mining occurred between the two existing managed peninsulas in 2023 and area of potential nesting habitat increased by 0.8 ac.

16. DeWeese (G)–Not managed. Sand and gravel mining occurred during 2023 and potential nesting habitat decreased by 1.5 ac. None of the 3.6 ac of potential nesting habitat at the site was located adjacent to a shoreline or water, and no birds have nested at this site.

17. Hooker Brothers Southeast (G)–Not managed. Sand and gravel mining occurred during 2023 and area of potential nesting habitat increased by 6.5 ac.

18. Hooker Brothers East (G)–Not managed. Sand and gravel mining occurred during 2023.

ON-CHANNEL MECHANICAL HABITAT CREATION AND MAINTENANCE (2007–2023)

Constructed on-channel habitat availability was variable and somewhat limited during the First Increment of the Program and no additional on-channel habitat has been added during the First Increment Extension (Figure 5). Approximately 24 ac of constructed on-channel habitat were present in the AHR in 2007 as the result of efforts by other conservation organizations (Figure 5). That habitat was subsequently lost over the course of several years due to erosion during high flow events. On-channel habitat construction by other conservation organizations has been very limited since 2007. The Program began large-scale on-channel habitat construction efforts at the Elm Creek complex in fall 2012 and created on-channel habitat at the Cottonwood Ranch and Plum Creek complexes as part of sediment augmentation activities to add 55 ac of habitat during the 2013 nesting season (Figure 5). Much of that habitat was lost during a high flow event in fall 2013. On-channel island construction began at the Shoemaker Island complex following the fall 2013 event. A high flow event in June 2014 eroded a portion of the habitat constructed in fall 2013, but the Program was able to construct a total of 28 ac of on-channel habitat during the fall 2014 at the Elm Creek and Shoemaker Island complexes to increase on-channel habitat availability for the 2015 nesting season (Figure 5). However, most of it was lost due to erosion during 2015 and 2016 high flow events. The Program did not construct on-channel habitat after 2014 and there has been limited suitable on-channel habitat available for plover and tern nesting during 2017–2023.

On-channel maintenance on Program managed properties was mainly in the form or herbicide application at targeted sites prior to the 2023 nesting season. Program contractors applied contact herbicide to vegetation in fall 2022 and pre-emergent herbicide in spring 2023 to in-channel islands at the Cottonwood Ranch Complex, and to the moving complex approach (MCA) island in the Chapman Complex. Program contractors disked the MCA island in the Chapman Complex during spring 2023 to increase foraging habitat along the river, but no nesting habitat that met Program requirements was created or maintained.

PLOVER AND TERN MONITORING

METHODS

MONITORING PROTOCOL REVISIONS OVER TIME

In 1997, the Department of the Interior and the States of Nebraska, Colorado, and Wyoming adopted the "Cooperative Agreement for Platte River Research and Other Efforts Relating to Endangered Species Habitats" (Cooperative Agreement). In 2001, the Cooperative Agreement coordinated a standardized protocol for monitoring reproductive success and reproductive habitat parameters of plovers and terns on the central Platte River from Lexington to Chapman, Nebraska. The standardized protocol was implemented by CNPPID, CPNRD, NPPD, and USFWS during 2001–2006 (https://platteriverprogram.org/program-library; Target Species: piping plover, interior least tern; Keywords: protocol implementation, [Year of Study]). In 2007, the Program assumed this responsibility and Program staff, contracted personnel, and cooperators have since implemented the monitoring protocol. The protocol was revised prior to the 2010 nesting season (PRRIP 2010) and again prior to the 2017 nesting season (PRRIP 2017). Data for 2023 were collected following the 2017 monitoring protocol.

Changes in monitoring protocols that affect the comparability of results over time have been noted where appropriate in tables and figures. Most changes occurred in 2010 and included:

- The definition of fledging age changed from 15 days for both species to fledging ages of 21 days for terns and 28 days for plovers.
- River surveys increased from three to seven surveys between May and August.
- Both inside and outside monitoring was implemented at all off-channel sites during 2010–2016.

- The Program began building and restoring OCSW sites to increase the amount of stable available habitat.
- The Program gained bi-weekly access to sites that had been previously restricted, and therefore were not included in reproductive calculations prior to 2010.

These changes, along with a gradual refinement of fating decisions to make them more consistent, have allowed us to improve our monitoring accuracy.

SEMI-MONTHLY OCSW AND RIVER SURVEYS

During 2023, biologists conducted seven semi-monthly (1 and 15 of May, June, and July; and 1 August) surveys of OCSW sites and the central Platte River spanning the AHR to count plover and tern adults, breeding pairs, nests, chicks, and fledglings.

Semi-Monthly OCSW Surveys

EDO and NPPD biologists conducted semi-monthly surveys at 18 Program-owned or partnered OCSW sites along the AHR during 2023 (Figure 2). Surveys were usually conducted on the same date across multiple sites over the entire AHR or within three days of each other. EDO biologists conducted semi-monthly surveys using spotting scopes and monitoring techniques from outside the nesting area on 1, 3, and 4 May; 15 and 18 May; 30–31 May and 1 June; 12 and 15–16 June; 28–29 June and 1 July; 10–11 and 13–14 July; and 31 July and 3 August 2023. NPPD biologists conducted surveys of the Blue Hole and NPPD Lexington sites on 3 and 15 May; 2, 14, and 29 June; 12 and 14 July; and 1 August. NPPD biologists conducted surveys of the Johnson site on 8, 18, and 31 May; 16 June; and 4 July.

Semi-Monthly River Surveys

Three EDO biologists (one driver; two surveyors) used an airboat to conduct semi-monthly river surveys spanning the stretch of river between the J-2 Return, located east of Lexington, and the Chapman bridge, located west of Chapman, Nebraska. We included channels >200 ft wide that could safely be navigated in the survey. We conducted surveys on 2–3 May; 16–17 May; 30–31 May; 13–14 June; 29 June; 12–14 July; and 1–2 August during 2023. Surveys on 2–3 May and 1–2 August were affected by dry conditions in which some of the stretches of the main channel typically monitored during river surveys were mostly or completely dry. High river discharge affected surveys on 29 June, which made the river unsafe for surveys by canoe and unnavigable by airboat.

EDO staff conducted point count surveys at accessible locations (e.g., bridges; boat ramps) when segments of the river were unnavigable due to low flow. On the 2–3 May survey, biologists did not survey river segments between Odessa and Kearney, Kearney and Minden, and Highway 281 and South Locust bridge. Biologists conducted point counts at the Bartels boat ramp for the beginning of the Elm Creek to Odessa segment, and at Rowe Sanctuary for the Minden to Gibbon segment. On the 1–2 August survey, EDO staff did not survey river segments between Kearney and Minden, Overton and Elm Creek, Wood River and Alda, and Highway 281 and South Locust bridge. Additionally, segments between Odessa and Kearney, Gibbon and Shelton, and Highway 34 and South Locust bridge were partially surveyed. Biologists conducted point counts at the Minden bridge, Rowe Sanctuary, and the Wood River bridge.

EDO staff also conducted point count surveys at predefined locations including Program properties providing access to the river and bridges across the entire stretch of river between the J-2 Return and Chapman bridge during the 29 June survey affected by high river discharge. Between the Lexington to Alda stretch of the central Platte River, biologists conducted point count surveys at the Dyer property, Overton bridge, Cottonwood Ranch property, Elm Creek bridge, NPPD diversion, Bartels property, Odessa bridge, Kearney bridge, Kearney Broadfoot South OCSW site, north Wyoming property, Kearney hike and bike bridge, Minden bridge, Gibbon bridge, Dippel property, Shelton bridge, Rowe Sanctuary, Wood River bridge, Binfield property, and Alda bridge. Between Alda and Chapman, biologists conducted point count surveys at the Alda bridge, Martin Meadows, Highway 281 bridge, South Locust bridge, Highway 34 bridge, Babb property, and Chapman bridge.

SEMI-WEEKLY NEST AND CHICK MONITORING

In addition to semi-monthly surveys of the river and all 18 OCSW sites, EDO and NPPD biologists monitored any OCSW or river site with active nests or broods on a semi-weekly basis throughout the nesting season. Upon location of an active nest, biologists monitored from outside the nesting area to observe nests and/or chicks twice per week until the nest or brood failed, or the chicks fledged. Biologists recorded numbers of adults, nests, chicks, and fledglings during each survey.

Each survey outside of the nesting area consisted of ≥30 minutes of observation using binoculars and/or spotting scopes at a distance that did not cause disturbance to nesting birds (usually >165 ft., but closer or farther as terrain dictated). Biologists made observations from multiple vantage points to allow observation of as much of the site as possible. Biologists often located nests and chicks by first observing adult birds. Biologists recorded date, observation start and stop times, and the number of plover and tern adults, nests, broods, chicks, and fledglings present during each semi-weekly site visit. When biologists observed chicks or fledglings, we estimated the date of hatching or fledging based on current and previous nest and chick observations. When the nest or brood failed, biologists attempted to determine the cause of failure and assign a nest/brood failure fate as abandoned, flooded, predation, weather, or unknown. Unknown causes of nest/brood failure were assigned when loss stage was known, but there was not enough evidence to assign a specific fate.

METRICS AND BREEDING PAIR ESTIMATION

For each semi-monthly river and OCSW site survey, we totaled the number of adults, breeding pairs, nests, chicks, and fledglings observed. These numbers provided seven snapshots of plover and tern relative abundance during the 2023 nesting season without accounting for detection probability. We used semi-weekly and semi-monthly survey data for OCSW sites with and without nests, respectively, to calculate the total number of plover and tern adults enumerated at all 18 OCSW sites based on the maximum count of adults observed at each site on any one survey. We calculated the total number of nests as the total unique nests observed across all sites and brood count as the total number of successful nests (≥one chick hatched) across all sites. We calculated the total number of chicks (<15 days old) and fledglings (21 days old for terns; 28 days old for plovers) based on the maximum number of chicks and fledglings that were associated with each unique nest and summed across all nests.

We calculated plover and tern breeding pair estimates (BPE) for nesting observed on the river channel and at OCSW sites according to the methods described by Baasch et al. (2015). The Program's BPE was found to be the most appropriate estimator of breeding pairs based on our monitoring protocol and sampling effort (Baasch et al. 2015). We calculated plover and tern BPE by adding the number of active or recently failed nests (within the species-defined renest interval) to the number of active or recently failed or fledged broods (within the species-defined renest or post fledge interval, respectively) observed on a given date. We determined plover breeding pair counts by assuming: (1) plover nests did not hatch within 28 days of being initiated; (2) plovers did not re-nest within five days of losing a nest or brood or fledging chicks; (3) plover chicks fledged at 28 days of age (defined fledging age for 2010–2023); (4) plover chicks that survived to 15 days of age (fledging age for 2007–2009) also fledged. We obtained tern breeding pair estimates by assuming: (1) tern nests did not hatch within 21 days of being initiated; (2) terns did not re-nest within five days of losing a nest or brood; (3) tern chicks fledged at 21 days of age (defined fledging age for 2010–2023); (4) tern chicks that survived to 15 days of age (fledging age for 2007–2009) also fledged; and (5) terns did not re-nest after fledging chicks.

The Program reports peak BPE when numbers of plover and tern breeding pairs observed during a single observation period within the entire Program AHR first peaked. Thus, peak breeding pair estimates are associated with a specific date. We also calculated peaks in BPE for each OCSW site, which represents the highest number of estimated breeding pairs at a single site during a single observation period regardless of the date when breeding pairs peaked over the entire AHR.

SURVIVAL RATES

We separately estimated daily survival rates of plover and tern nests located on OCSW sites and on islands in the river channel that were monitored during 2023 by Program staff and personnel from NPPD. We defined nest success as any nest that hatched ≥1 chick. We considered the incubation period for terns and plovers to be 21 and 28 days, respectively, from when nests were determined to have been initiated. When the fate of a nest was unknown, we assigned a "failed" status to the nest if the date of determination (date first observed inactive) was <21 days (tern) or <28 days (plover) after the date the nest was initiated, and we failed to observe chicks of appropriate age near the nest bowl. For example, if a plover nest was observed to be active and intact 12 days after it was initiated, and then was found to be empty (no eggs) four days later (16 days after it was initiated) with no sign of chicks of appropriate age in the area, we fated the nest at 14 days (midpoint of the two observation periods) and assigned a "failed" status to the nest as it likely did not hatch within 16 days of initiation. If, however, a plover nest with an unknown fate was last observed to be active 25 days after it was initiated, but then four days later (29 days after it was initiated) we observed an empty nest bowl, no sign of chicks of appropriate age in the area, but with appropriate evidence (including pipping on the previous visit, chick poop, pipping fragments, etc.) we assigned the fate of the nest on day 27 (midpoint of the two observation periods) as "successful". Our assumption was that, on average, we discarded survived and failed intervals in the same proportion they occurred in the data.

We also separately estimated daily survival rates of plover and tern broods monitored during 2023. As the exact date of hatching was occasionally unknown, we considered the brooding period for tern and plover chicks to be 21 and 28 days from the date we first observed nestlings, respectively. A successful brood was defined as any brood with ≥1 chick that was observed fledged or that survived 21 days (terns) or 28 days (plovers). Like nest survival methods, when the fate of a brood was unknown, we assigned the fate of the brood at the midpoint of when a brood was last observed active and first documented as an "unknown" status. We assigned a failed status to a brood if the date of fate determination was <21 or <28 days after we first observed tern or plover chicks, respectively, and a successful status to the brood otherwise.

We used mixed-effects nest fate logistic exposure models to estimate daily survival rates (DSRs) of plover nests and broods at OCSW and in-channel sites (Shaffer 2004). We conducted separate analyses to estimate DSRs of tern nests and broods at OCSW sites. We developed three models for each of the four analyses. First, we estimated nest or brood survival as a constant (i.e., null model). Second, we evaluated whether nest or brood survival was different for nests at Program and non-Program managed sites (i.e., ownership model). Third, we evaluated whether nest or brood survival was different across sites (i.e., site model). We included site as a random effect in each model to account for a potential lack of independence of nest fates at each site. We used the *glmer* function in package *lme4* (Bates et al. 2015) in Program R (R Core Team 2021) to fit models and estimate coefficients.

RESULTS

PIPING PLOVERS

2023 Seasonal Summary

During the 2023 plover nesting season, we observed the: highest peak estimated number of breeding pairs (41 pairs) since 2019; most successful nests (40) since 2016; highest apparent nest success (0.83) and hatch ratio based on number of nests (2.98 chicks/nest) during the contemporary 2010–2023 monitoring period; and highest number of fledglings (58) since 2012 (Tables 1 and 2). We observed higher fledge ratios in 2023 than 2022 with increases from 1.37 chicks/BPE to 1.41 chicks/BPE, and 0.95 chicks/nest to 1.21 chicks/nest (Table 2).

- Plovers nested at 10 of 18 OCSW sites with a high amount of variability in reproductive effort and success (Table 3). There was a total of 256 ac of potential nesting habitat available at the 18 OCSW sites in 2023.
- We observed the first plover nest on an island in the Platte River channel since 2016. The nest was depredated by a raccoon (*Procyon lotor*) five days after plovers laid eggs.
- The peak AHR breeding pair estimate for plovers was 41 pairs (Table 2). Plover nests produced 143 chicks (<15 days old) and 58 fledglings (≥28 days old), resulting in a hatch ratio based on BPE of 3.49 chicks/BPE and fledge ratio of 1.41 chicks/BPE (Table 2).
- Plovers established 48 nests, resulting in a hatch ratio based on nests of 2.98 chicks/nest and fledge ratio of 1.21 chicks/nest (Table 2).
- Dyer, Blue Hole, Newark East, and Kearney Broadfoot South were the most productive OCSW nesting sites for plovers in 2023 with fledge ratios ≥1 chicks/BPE and producing more than 10 plover fledges at each site (Table 3). These four sites were also the most productive during 2022 (PRRIP 2023).

- The other six OCSW sites at which we observed plover nesting had between one and three successful nests (Table 3). Fledge ratios at these six sites ranged between 0.0 chicks/BPE and 2.0 chicks/BPE (Table 3).
- The proportion of nests that failed due to unknown causes remained low at 0.188 during 2023. Use of shoreline, nesting site, and nest cameras to monitor predators and nest fates has allowed us to significantly reduce the proportion of nest failures attributed to unknown causes, which peaked during the 2017–2019 period prior to use of remote camera monitoring.

Semi-Monthly OCSW Surveys

Biologists observed the majority of plover breeding pairs, nests, and fledglings on OCSW sites during 2023 (Tables 4, 5, 6, 7), which was similar to previous years. Based on the twice monthly OCSW surveys, the number of plover adults, chicks, and fledglings observed peaked at 55 adults and 51 chicks on the 1 July survey, and two fledglings on the 15 July survey (Table 6). The number of plover nests counted was highest on the 1 June survey at 35 nests (Table 6). Since 2010, the number of adult plovers enumerated during twice monthly OCSW surveys generally was highest during the 1 June, 15 June, or 1 July surveys (Figure 7).

Semi-Monthly River Surveys

EDO staff observed one plover nest on-channel during 2023 (Tables 5 and 7), which was the first nest observed on the central Platte River by the Program since 2016. The nest, which was located on an island in the river on the Program's Dippel property, was first observed during the 31 May river survey at the beginning of the EA flow release. EDO staff located the nest on a raised sandbar that had been previously disked and managed. However, the island was not manufactured specifically for plover nesting. Plovers built the nest near the highest elevation on the island and the nest remained well above the water surface elevation during the EA flow release.

Based on the twice monthly river surveys, the number of adult plovers observed peaked on the 15 May survey at seven birds (Table 7). No plover chicks or fledglings were observed during river surveys in 2023 (Table 7). The number of adult plovers observed during river surveys has varied greatly across years and surveys (Figures 8 and 9). Other than the one nesting pair, we assumed adult plovers observed on the river were generally foraging from nearby OCSW sites due to the lack of nesting behavior witnessed on the river and the proximity of plover river locations to nearest OCSW sites. The 15 May survey corresponded to a discharge of 1,280 cfs at the Kearney gage, which was near the maximum discharge recorded throughout May, but well below the nesting season maximum of 6,490 cfs on 2 July (Figure 3). Most in-channel sandbars and potential nesting habitat were inundated during the periods of high flow during June and July, and did not meet the Program's requirements towards in-channel nesting habitat (Figure 5; PRRIP 2015).

Nest Monitoring, Brood Monitoring, and Survival Rates

Biologists observed plover nesting at 10 of 18 OCSW sites and the one in-channel site during semi-monthly monitoring in 2023. In total, biologists enumerated 47 plover nests at OCSW sites and one nest at the in-channel site (Table 2, Figure 10). Biologists then monitored nests and broods at the 10 OCSW sites and one in-channel site were then monitored on a semi-weekly basis (Table 3, Figure 11).

Breeding Pairs — Across OCSW and river sites, the number of estimated plover breeding pairs peaked at 41 pairs on 8 June. Biologists enumerated a maximum of 82 adults across all sites (Table 2). Plover BPE was highest across all OCSW sites at 41 pairs on 11 June (Table 4, Figure 3), and highest at in-channel sites at one pair on 31 May (Table 5). The peak BPE of 41 pairs represented the highest plover BPE observed by the Program since 2019 (Table 2, Figure 12). Plover BPE in recent years has increased markedly compared to those observed during 2001–2009 due in part to construction, rehabilitation, and maintenance of OCSW sites (Figure 12). Annual peak plover BPE was positively correlated with the total area of potential nesting habitat available at OCSW sites during 2001–2023 (Figure 13). For every acre increase in potential nesting habitat at OCSW sites, there was an increase of 0.146 (95% confidence interval [CI] = 0.106, 0.186) plover breeding pairs (Figure 13).

Nests — Biologists observed and monitored a total of 48 plover nests during 2023 (Table 2, Figure 14). Of the 10 OCSW sites that had plover nesting, Newark East had the most at 11 nests (Table 3, Figure 11). Three of the 10 OCSW sites (Leaman; NPPD Lexington; Trust Wildrose East) and the on-channel site (Dippel) each had only one plover nest (Table 3, Figure 11). The first plover nest was observed on 3 May and the last nest was first observed on 3 July. Forty of the 48 nests were successful, resulting in an apparent nest success of 0.83, which was the highest apparent nest success during the 2010–2023 period and highest since 2003 (Table 2, Figure 15). The on-channel nest was not successful and failed due to predation during the incubation stage after five days. The number of plover nests has followed a generally increasing trend over time as the total area of potential nesting habitat at OCSW sites increased (Figure 13).

The overall DSR of plover nests across all monitored OCSW and on-channel sites was 0.992 (95% CI: 0.984, 0.996) during 2023 (Tables 2 and 8). The DSR of the single on-channel nest was 0.014 (95% CI: 0.000, upper limit non-estimable due to single nest fate). We found no significant difference in nest DSR between Program and non-Program sites (Table 9). The DSR of plover nests was 0.993 (95% CI: 0.965, 0.999) at Program sites and 0.989 (95% CI: 0.957, 0.997) at non-Program sites (Table 9). We also found no significant difference in nest DSR across sites with DSR ranging between 0.972 and 0.999 for the seven OCSW sites with >1 plover nest (Table 8). Although the DSR of the single on-channel nest was 0.014 and lower than the DSRs at OCSW sites, a statistical comparison was not feasible given a sample size of only one nest. Likewise, only one plover nest was observed at Leaman, NPPD Lexington, and Trust Wildrose East, making statistical comparisons not feasible with other sites.

The overall incubation period (28-day) survival rate of nests on all monitored sites was 0.800 (95% CI: 0.640, 0.895; Tables 2 and 8). Incubation period survival was 0.816 (95% CI: 0.367, 0.960) at Program sites and 0.732 (95% CI: 0.290, 0.925) at non-Program sites (Table 9). Across monitored OCSW sites, incubation period survival ranged from 0.449 to 1.00 (Table 8).

Broods — Biologists enumerated 143 chicks from the 40 broods from successful nests, which represented the highest number of chicks <15 days old observed since the onset of monitoring in 2001 (Tables 1 and 2). Likewise, the hatch ratio of 2.98 chicks/nest was the highest observed since monitoring began (Tables 1 and 2). When using BPE instead of nest as a metric, the hatch ratio of 3.49 chicks/BPE was the highest observed since 2014 (3.87 chicks/BPE; Table 2). The first nest observed to hatch occurred on 2 June, while the last nest observed to hatch occurred on 21 July. Of the 143 chicks, biologists observed 65 chicks that survived ≥15 days (Table 2). Brood counts have followed a generally increasing trend over time (Figure 12).

Across the 10 OCSW sites with ≥1 plover brood, overall DSR for broods was 0.987 (95% CI: 0.976, 0.993; Tables 2 and 10). We found no significant difference in brood DSR for broods on Program (DSR = 0.984; 95% CI: 0.843, 0.999) compared to non-Program (DSR = 0.994; 95% CI: 0.948, 0.999) sites (Table 11). Likewise, we found no significant difference in brood DSR across the 10 OCSW sites with brood DSR ranging from 0.001 to 1.00 (Table 10).

The overall brooding period (28-day) survival rate was 0.685 (95% CI: 0.506, 0.811; Tables 2 and 10). Brooding period survival was 0.643 (95% CI: 0.009, 0.963) at Program sites and 0.845 (95% CI: 0.223, 0.982) at non-Program sites (Table 11). Across monitored OCSW sites, brooding period survival ranged from 0.000 to 1.00 (Table 10).

<u>Fledges</u> — Of the 143 chicks from the 40 nests, 58 chicks made it to the 28-day fledging age resulting in a fledge ratio of 1.21 chicks/nest or 1.41 chicks/BPE (Table 2). The proportion of successful chicks was 0.41 (Figure 15). When using nests as a unit of measure, the fledge ratio of 1.21 chicks/nest was the highest observed since the Program recorded 1.28 chicks/nest in 2014 and an increase over the 0.95 chicks/nest observed in 2022 (Table 2). When using breeding pairs, the fledge ratio of 1.41 chicks/BPE was similar to that observed in 2022 (1.37 chicks/BPE) due to renesting that occurred during 2022 (Table 2, Figure 16). Biologists first observed a plover fledgling on 24 June and the last known plover chick to fledge did so on 17 August.

Nest and Brood Fates

We successfully assigned nest fates to 37 of the 48 plover nests observed during 2023 (Figure 17). Twenty-nine nests successfully fledged (0.604 of nests), two nests failed due to abandonment (0.042), and five nests and one brood failed due to predation (0.125; Figure 17). Nine broods failed due to unknown causes (0.188) and the fates of one nest and one brood were unknown (Figure 17). Due to increased effort of remote camera monitoring of plover nests, we have been able to reduce uncertainty regarding nest and brood fates on Program managed sites since 2020 (Figure 17). Additional predator monitoring in the form of site-level cameras and shoreline track surveys has allowed us to gather more fating evidence, which has also improved our ability to fate nests (see Predator Management and Monitoring section for more detail).

Incidental Take Summary and Mortality

In its 2006 Biological Opinion (USFWS 2006) and 2018 Supplemental Biological Opinion (USFWS 2018) on the Program, the USFWS developed an incidental take statement addressing incidental take for plovers and terns associated with operation of existing and new water-related activities, and habitat alteration or monitoring conducted in the Platte River basin covered by the Program. Such take includes killing, harming, and harassing which could include the loss of habitat, individuals (adults, eggs and/or chicks), and recruitment. In this incidental take statement, the USFWS described five types of losses reasonably foreseeable to occur as a result of the implementation of the Program and established allowable take under each category. Quantification of allowable take is also identified in the individual section 10(a)(1)(A) federal permits issued to researchers. The Service acknowledged "Acts of God" or "Acts of Nature" as beyond operational control of Program participants, with that type of take not included as incidental take.

Since the Program's initiation in 2007, incidental take has been minimal (Table 12). The Program observed one habitat restoration and land management-related plover chick mortality during 2014 due to electrocution in a predator deterrent fence (Cahis and Baasch 2015). The Program observed one research-related plover chick mortality during 2011 due to flushing the chick into the water where it was consumed by a fish (Baasch 2012) and one research-related plover chick mortality during 2013 due to a chick attempting to fly and landing into the water where it was consumed by a fish (Baasch 2014). In 2022, incidental take was observed at an inland lake as a single nest containing four plover eggs was inundated at Lake Minatare as the lake was filled in preparation for delivery of irrigation water (PRRIP 2023). Across the entire AHR encompassing both Program and non-Program sites, there was no documented research related mortality in 2023.

Between 2007 and 2016, a limited amount of nest and chick predation was observed and did not exceed the Service's threshold at any Program owned or managed off-channel sand and water nesting site in any year (Table 12; USFWS 2018). Increased effort to monitor predator activities began in 2017, which has resulted in more documented predation than during the First Increment. However, losses of plover nests and chicks to predation have not exceeded the Service's established threshold (i.e., the loss of 70% of nests or 80% of chicks to predation in three of five years for sites that average at least three plover nests; Table 12). The percentages provided in Table 12 for losses of nests due to predation are based on the total number of nests observed at each site during each year and percentages for losses of chicks are based on the total number of chicks observed at each site during each year.

Conclusions

Results from our 2023 plover monitoring efforts indicate continued increases in plover nest productivity metrics on monitored sites across the central Platte River from recent lows observed during 2018 and 2019. The number of plover fledglings and fledge ratios observed during 2023 were the highest since 2012 and 2014, respectively, which was shortly after the Program began constructing and adding more potential nesting habitat at OCSW sites (Figure 16). Additionally, we documented the highest apparent nest success (0.83), hatch ratio (2.98 chicks/nest), incubation-period survival rate (0.80), and number of chicks (<15 days old) during the contemporary 2010–2023 monitoring period (Table 2). These increases in nest success and productivity were likely attributable to fewer severe weather events during summer 2023 and a decrease in predation of nests and chicks relative to previous years.

Plover fledge ratios at monitored sites during 2023, including the one nest observed on an island in the river that failed due to predation, were 1.41 chicks/BPE and 1.21 chicks/nest. Fledge ratios are one of the indicators used by the Program to measure reproductive success of plovers over time and we have observed a positive trend in fledge ratios over the past several years after a low of 0.62 chicks/BPE and 0.49 chicks/nest in 2018. Fledge ratios based on the peak number of estimated breeding pairs are higher than fledge ratios based on fledglings per nest primarily due to potential plover renesting that may occur after early nest failure. We observed 48 nests and 58 fledglings with a peak of 41 estimated breeding pairs in 2023. In contrast, in 2022, when plovers renested after early nest failures due to severe weather, we observed 55 nests and 52 fledglings with a peak of 38 estimated breeding pairs, resulting in a fledge ratio of 1.37 chicks/BPE and 0.95 chicks/nest. Despite the increase in fledge ratios between 2022 and 2023, we observed a decrease in brooding period survival rate from 0.79 in 2022 to 0.69 in 2023. However, the 0.69 brooding period survival rate was within the range of historical variability for plovers in our study area.

We have observed a significant, positive relationship between the estimated number of plover breeding pairs and area of potential nesting habitat at OCSW sites since 2001 (Figure 13). Plovers are territorial when establishing and defending nests, and this behavior requires sufficient spacing between nests (Haffner et al. 2009). Numbers of plover breeding pairs, nests, and broods increased markedly after the Program began constructing and managing more potential nesting habitat in 2010. As the area of potential nesting habitat at OCSW sites has increased and plateaued at ~250 ac over the past several years, we have seen annual variability in the estimated number of breeding pairs fluctuate between 32 and 45 pairs. Plovers exhibit strong fidelity to breeding sites (Ledee et al. 2010) and previous breeding success may influence faithfulness to sites (Friedrich et al. 2015; but see Wiens and Cuthbert 1988). Annual variability in breeding pairs at OCSW sites is likely related to a combination of the quantity of available habitat, density of plovers on each site as migratory birds arrive, and previous nest success.

The most productive plover OCSW nesting sites in 2023 were Dyer, Blue Hole, Newark East, and Kearney Broadfoot South (Table 3). These four sites were also the most productive during 2022 (PRRIP 2023). We observed no plover nesting on eight OCSW sites (Table 3), seven of which did not have observed plover nesting in 2022 (PRRIP 2023). We observed eight of nine nests to be successful at the Dyer site that produced 16 fledglings with a fledge ratio of 1.78 chicks/BPE (1.78 chicks/nest). The Blue Hole site had five successful nests out of seven that produced 10 fledglings, resulting in a fledge ratio of 1.67 chicks/BPE (1.43 chicks/nest). Ten of 11 nests at the Newark East site were successful and produced 11 fledglings with a fledge ratio of 1.38 chicks/BPE (1.00 chicks/nest). We observed 13 fledglings from seven successful nests out of eight at Kearney Broadfoot South and the site had a fledge ratio of 1.63 chicks/BPE (1.63 chicks/nest). High apparent nest success and fledge ratios at each of these sites was largely due to limited predation of nests and chicks. At the Dyer site, one nest was depredated by a great horned owl (*Bubo virginianus*) during the incubation stage and chicks from one brood did not fledge due to predation. One of the two nest failures at the Blue Hole site was due to raccoon predation. The one nest failure at Newark East was due to coyote (*Canis latrans*) predation; however, three broods failed before fledging due to unknown causes. The only nest that failed at Kearney Broadfoot South was due to abandonment. Productivity at Kearney Broadfoot South, which is one of our nesting sites with additional predator management and deterrents, has improved over the past two years after multiple years of high initial reproductive investment (i.e., nests), but low productivity with documented predation leading to nest and chick losses. Fledge ratios over the past four years at Kearney Broadfoot South were 0.5 chicks/BPE (0.333 chicks/nest) in 2020, 0.25 chicks/BPE (0.154 chicks/nest) in 2021, 1.14 chicks/BPE (0.80 chicks/nest) in 2022, and 1.63 chicks/BPE (1.63 chicks/nest) in 2023, suggesting predator management and deterrent efforts initiated at the site in 2021 may be having a positive impact. During 2024, we will analyze multiple years of data to evaluate the effectiveness of additional predator management efforts in conjunction with abiotic and biotic factors on nest success and productivity at our sites.

The continued use of remote camera monitoring of shorelines, nesting sites, and nests on Program-managed sites has allowed us to more accurately fate nests and, to a lesser extent broods. Camera monitoring began in 2020 and, as a result, the proportion of nests and broods that failed due to unknown causes has concurrently decreased from a maximum of 0.566 of nest fates in 2019 (Figure 17). In 2023, the proportion of nests that failed due to unknown causes was 0.188 (Figure 17). Video and images from cameras and information from track surveys helped us assign fates to seven of the eight plover nests that failed. Five plover nests (0.125 of nests) failed due predation and two nests (0.04) failed due to abandonment. We were not able to assign a fate to only one plover nest due to uncertainty about whether the nest failed before or after hatching, but shoreline and site evidence suggested predation was a cause in the failure of either the nest or brood. Of the 40 successful plover nests, 11 broods failed with the failure of nine of these broods attributed to unknown causes and one due to predation. The cause of brood losses remains one of the information gaps of our monitoring. Cameras have been effective at documenting predation on recently hatched chicks at the nest, but once chicks begin spending time away from the nest, then our cameras provide limited information on predation of broods. We documented no nest or brood losses due to severe weather or flooding during 2023. Overall, the data accumulated on plover nest and brood fates will be used to inform future management decisions to continue to improve adult survival and plover nest productivity along the AHR.

LEAST TERNS

2023 Seasonal Summary

Terns have positively responded to Program habitat creation, rehabilitation, and management along the AHR during 2001–2023 (Tables 13 and 14). Tern nesting and reproductive success was similar in 2023 to that observed during 2022 in terms of peak estimated number of breeding pairs, number of nests observed and successful nests, and hatch ratio (Table 14). Although the fledge ratio decreased slightly from 2022 to 2023, the ratios of 1.38 chicks/BPE and 1.00 chicks/nest observed in 2023 were still above the average (1.18 chicks/BPE; 0.86 chicks/nest) during 2010–2022 (Table 14). As with previous years, we continued to observe a high amount of variability in reproductive effort and success across OCSW nesting sites (Table 15). We observed the following during the 2023 nesting season.

- Terns nested at eight of 18 OCSW sites (Table 15). There was a total of 256 ac of potential nesting habitat available at the 18 OCSW sites in 2023.
- The peak AHR breeding pair estimate for terns was 90 pairs (Table 14). Tern nests produced 207 chicks (<15 days old) and 124 fledglings (≥21 days old), resulting in a hatch ratio of 2.30 chicks/BPE and fledge ratio of 1.38 chicks/BPE based on BPE (Table 14).
- Terns established 124 nests, resulting in a hatch ratio of 1.67 chicks/nest and fledge ratio of 1.00 chicks/nest based on the number of nests (Table 14).
- Of the eight OCSW sites that had tern nesting, we observed a greater number of nests established at the Newark East, Blue Hole, Kearney Broadfoot South, Dyer, and OSG Lexington sites. Of these five sites, four had fledge ratios ≥1 chicks/BPE during 2023

(Table 15). The fledge ratio at Kearney Broadfoot South was lower in 2023 (0.67 chicks/BPE) compared to 2022 (1.58 chicks/BPE).

- The three OCSW sites at which we observed <10 tern nests had fledge ratios ≥1 chicks/BPE during 2023 (Table 15).
- The proportion of nests that failed due to unknown causes was higher in 2023 than 2022, but still lower than the 2017–2019 period prior to implementation of shoreline, nesting site, and nest camera monitoring.

Semi-Monthly OCSW Surveys

Biologists observed all tern breeding pairs, nests, and chicks on OCSW sites during 2023 (Tables 16, 17, 18, 19). Based on the twice monthly OCSW surveys, the number of tern adults, chicks, and fledglings observed peaked at 115 adults on the 15 June survey, 90 chicks on the 1 July survey, and 10 fledglings on the 15 July survey (Table 18). The number of tern nests counted reached a maximum of 67 nests on the 15 June survey (Table 18). Since 2010, the number of adult terns observed during twice monthly OCSW surveys generally has been highest during the 15 June or 1 July surveys (Figure 19).

Semi-Monthly River Surveys

EDO staff observed no on-channel tern nesting during 2023 (Tables 17 and 19), which was similar to previous years. The last tern nest at an on-channel island site was documented by the Program in 2016 (Table 17). EDO staff counted a maximum of 43 adults and 57 fledglings on the 1 August river survey and it was assumed these birds came to forage along the river from nearby OCSW sites because no nests or chicks were observed on-channel prior to that survey. This date of peak tern river use corresponded to a period of low Platte River discharge with a documented flow of 124 cfs at the Kearney gage (Figure 3). Migratory terns arrive to the central Platte River later than plovers with low tern foraging use of the river documented during early May river surveys since 2010 (Figure 21). Periods of peak tern foraging use of the river vary annually, but generally occur prior to nesting in late May or early June and again after chicks fledge in late July or early August (Figures 20 and 21).

Nest Monitoring, Brood Monitoring, and Survival Rates

Biologists observed tern nesting at eight of 18 OCSW sites during semi-monthly monitoring in 2023 (Table 14). Biologists then monitored nests and broods at the eight sites on a semi-weekly basis and enumerated a total of 124 tern nests in 2023 (Table 15; Figures 22 and 23).

<u>Breeding Pairs</u> — The estimated number of tern breeding pairs peaked at 90 pairs on 24 June and biologists enumerated a maximum of 157 adults across all sites (Table 14). The BPE of 90 pairs represented the highest tern BPE observed by the Program since 95 pairs observed in 2019 (Table 14, Figure 24). After peaks in numbers of tern nests, breeding pairs, and broods that occurred in 2015 after the construction, rehabilitation, and maintenance of OCSW sites, these metrics have remained relatively constant the last several years aside from annual fluctuations (Figure 24). As with plovers, we have observed a significant, positive relationship between annual peak tern BPE with the total area of potential nesting habitat available at OCSW sites during 2001–2023 (Figure 25). However, the amount of variability explained by the data was higher for plovers (R^2 = 0.73)

than for terns (R^2 = 0.55), and the relationship between BPE and area had a greater slope for terns. For every acre increase in potential nesting habitat at OCSW sites, there was an increase of 0.298 (95% CI = 0.176, 0.421) tern breeding pairs (Figure 25).

<u>Nests</u> — Biologists observed and monitored a total of 124 tern nests during 2023 (Table 14, Figure 26). The OCSW sites with the most tern nests were Newark East (41 nests), Blue Hole (20), Kearney Broadfoot South (18), Dyer (14), and OSG Lexington (11; Table 15). The remaining three sites with nests had between five and nine tern nests (Table 15). Biologists observed the first tern nest on 22 May and the final nest on 3 August. Eighty-three of the 124 nests were successful for an apparent nest success of 0.67, which was the same as that for 2022 and similar to values observed in 2020 and 2021 (Table 14). After a peak of 187 nests in 2015, the number of tern nests has ranged between 99 and 132 with an average of 118 nests over the eight-year span (Table 14, Figure 26).

The overall DSR of tern nests across all monitored OCSW sites was 0.980 (95% CI: 0.974, 0.986) during 2023 (Tables 14 and 20). We found no significant difference in nest DSR between Program and non-Program sites (Table 21). The DSR of tern nests was 0.983 (95% CI: 0.966, 0.991) at Program sites and 0.972 (95% CI: 0.953, 0.984) at non-Program sites (Table 21). We also found no significant difference in nest DSR across sites with DSR ranging between 0.908 and 1.00 for the 10 OCSW sites with ≥1 tern nest (Table 20).

The overall incubation period (21-day) survival rate of tern nests on all monitored sites was 0.661 (95% CI: 0.571, 0.736; Tables 14 and 20). Incubation period survival was 0.691 (95% CI: 0.488, 0.827) at Program sites and 0.557 (95% CI: 0.360, 0.716) at non-Program sites (Table 21). Across monitored OCSW sites, incubation period survival ranged from 0.132 to 1.00 (Table 20).

<u>Broods</u> — Biologists enumerated 207 chicks from the 83 broods from successful nests, which represented the highest number of chicks <15 days old observed since 2015 (Table 14). Hatch ratios for terns over the past three years have been among the highest since 2010 with a ratio for 2023 of 2.30 chicks/BPE and 1.67 chicks/nest (Table 14). The first nest observed to hatch occurred on 12 June, while the last nest observed to hatch occurred on 11 August. Of the 207 chicks, biologists observed 126 chicks that survived ≥15 days (Table 14). As with the number of nests, tern brood counts peaked in 2015 and have since varied annually between 63 and 86 broods (mean = 74; Figure 24).

Across the eight OCSW sites with ≥1 tern brood, overall DSR for broods was 0.992 (95% CI: 0.973, 0.998; Tables 14 and 22). We found no significant difference in DSR for broods on Program (DSR = 0.988; 95% CI: 0.881, 0.999) compared to non-Program (DSR = 0.997; 95% CI: 0.973, 1.00) sites (Table 23). We also found no significant difference in brood DSR across the eight OCSW sites with brood DSR ranging from 0.959 to 1.00 (Table 22).

The overall brooding period (21-day) survival rate was 0.852 (95% CI: 0.565, 0.956; Tables 14 and 22). Brooding period survival for terns was 0.774 (95% CI: 0.069, 0.977) at Program sites and 0.946 (95% CI: 0.568, 0.995) at non-Program sites (Table 23). Across monitored OCSW sites, brooding period survival for terns ranged from 0.414 to 1.00 (Table 22).

Fledges — Of the 207 chicks from the 83 nests, 124 chicks made it to the 21-day fledging age resulting in a fledge ratio of 1.38 chicks/BPE or 1.00 chicks/nest (Table 14). Biologists first observed a tern fledgling on 3 July and the last known tern chick to fledge did so on 17 August. The proportion of successful chicks was 0.60, which was lower than the 0.73 observed in 2022, but within the range of recent annual variability in the metric (Figure 27). The fledge ratio of 1.00 chicks/nest is also in line with fledge ratios of recent years except 2019 when the ratio dropped to a low of 0.54 chicks/nest, which represented the minimum observed during the contemporary 2010–2023 monitoring period (Table 14). Based on BPE, the 1.38 chicks/BPE from 2023 was lower than the 1.68 chicks/BPE observed during 2022, but above the values from recent years (Table 14, Figure 28). The three-year moving average of tern fledge ratios during 2021–2023 was 1.41 chicks/BPE, which is the highest the three-year average has been since 2010–2012 period (Figure 28).

Nest and Brood Fates

We successfully assigned nest fates to 84 of the 124 tern nests observed during 2023 (Figure 29). Sixty-four nests successfully fledged (0.516 of nests); two nests and one brood failed due to abandonment (0.024); one nest failed due to flooding (0.008); one nest failed due to weather (0.008); and 15 nests failed due to predation (0.121; Figure 29). A total of 20 nests and 18 broods failed due to unknown causes (0.306) and the fate of two nests was unknown (Figure 29). If we were unable to determine fates of these nests or broods, then they were categorized as unknown failures.

Incidental Take Summary and Mortality

Incidental take of terns was minimal during the Program's First Increment and did not exceed the Service's threshold under any category of allowable take in any year (USBR 2018). With the removal of the tern from the federal list of threatened and endangered species on 12 February 2021, the Program's Governance Committee, including the USFWS, agreed that the provisions of the Incidental Take Statement specific to terns in the 2006 Biological Opinion (USFWS 2006) and 2018 Supplemental Biological Opinion (USFWS 2018) no longer apply (PRRIP 2021a). Across the entire AHR, spanning both Program and non-Program sites, there was no documented research related mortality during 2023.

Conclusions

Our 2023 monitoring efforts documented that terns breeding on OCSW sites along the central Platte River continued to nest in high numbers with above-average productivity relative to 2010–2022 averages. We observed the highest estimated number of tern breeding pairs (90 pairs) since 2019, and the total number of nests and successful nests were comparable to those recorded in 2022 (Table 14). The hatch ratio of 1.67 chicks/nest was the highest observed during the contemporary 2010–2023 monitoring period, whereas the hatch ratio based on breeding pairs of 2.30 chicks/BPE was comparable to the 2022 value (Table 14). We observed 124 tern fledglings, which was the highest since the year of peak tern nesting in 2015. Fewer severe weather events in 2023 likely resulted in more chicks fledging during 2023 than in 2022. Severe weather events led to the failure of 13% of tern nests in 2022; however, <1% of nests failed due to weather during 2023.

Tern fledge ratios were lower in 2023 than 2022, but still above the average (1.18 chicks/BPE; 0.86 chicks/nest) observed during 2010–2022 (Table 14). We recorded fledge ratios of 1.68 chicks/BPE and 1.12 chicks/nest during 2022, which were the highest documented during the contemporary 2010–2023 monitoring period (Figure 28). Fledge ratios decreased to 1.38 chicks/BPE and 1.00 chicks/nest in 2023; however, these were still among the highest fledge ratios observed since 2010 (Figure 28). Brooding period survival rates for tern broods during 2023 was 0.85, which was comparable to the 0.84 observed during 2022 (Table 14). Tern fledge ratios reached a low of 0.75 chicks/BPE and 0.54 chicks/nest in 2019, but have since followed a positive trend with a three-year average of 1.42 chicks/BPE during 2021–2023 (Figure 28). This three-year average represented a maximum during the 2010–2023 period (Figure 28).

As with plovers, there was a positive relationship between the estimated number of tern breeding pairs and area of potential nesting habitat at OCSW sites (Figure 25). For every acre OCSW habitat increased, we observed an increase of 0.298 tern breeding pairs (95% CI: 0.176–0.421). Numbers of tern breeding pairs, nests, and broods increased and eventually peaked in 2015 after the Program began constructing and managing more potential nesting habitat (Figure 24). Since 2015, annual variability in the estimated number of tern breeding pairs has ranged between 77 and 95 pairs (Figure 24). Likewise, the number of broods has ranged between 63 and 86 with annual fluctuations (Figure 24). Although the slope of the relationship between breeding pairs and OCSW habitat area was greater for terns than plovers, the amount of variability explained by the data was higher for plovers ($R^2 = 0.73$) than terns ($R^2 = 0.55$). This may be due to differences in nesting behavior as terns nest colonially whereas plovers are territorial.

We continued to observe high variability in use and productivity across OCSW sites. At the Newark East site, which has become one of the Program's most consistent sites for higher tern productivity, we observed 34 of 41 tern nests to be successful that produced 45 fledglings for a fledge ratio of 1.32 chicks/BPE (1.10 chicks/nest; Table 15). For comparison, we observed a fledge ratio of 1.62 chicks/BPE (1.14 chicks/nest) at Newark East in 2022 (PRRIP 2023). Eleven of 20 tern nests at the Blue Hole site were successful and produced 17 fledglings for a fledge ratio of 1.31 chicks/BPE (0.85 chicks/nest; Table 15), which was lower than the 2.17 chicks/BPE (2.0 chicks/nest) in 2022 (PRRIP 2023). Kearney Broadfoot South, which had fledge ratios of 0.40 chicks/BPE (0.30 chicks/nest) and 1.58 chicks/BPE (1.12 chicks/nest) in 2021 and 2022, respectively, fledged 0.67 chicks/BPE (0.44 chicks/nest) in 2023 (Table 15; PRRIP 2022b, PRRIP 2023). Dyer produced 19 fledglings from eight successful nests out of 14 total for a fledge ratio of 1.58 chicks/BPE (1.36 chicks/nest), which was higher than the 0.83 chicks/BPE (0.31 chicks/nest) observed in 2022 (PRRIP 2023) but comparable to the 1.88 chicks/BPE (1.68 chicks/nest) in 2021 (PRRIP 2022b). During 2023, we also observed tern fledge ratios >1 for Cottonwood Ranch (2.83 chicks/BPE; 17 fledglings; six successful nests); Newark West (2.00 chicks/BPE; eight fledglings; five successful nests); and Hooker Brothers Southeast (1.14 chicks/BPE; eight fledgings; six of nine nests successful; Table 15). The OSG Lexington site produced only two fledglings from two successful nests out of 11 that were established, which was in contrast to the 19 fledglings from eight successful nests observed at the site during 2022 (Table 15; PRRIP 2023). Overall, daily nest survival rates for terns remained high across all OCSW sites during 2023 (Table 20).

As with plovers, we have been able to reduce uncertainty regarding tern nest and, to a lesser extent, brood fates on Program managed sites since 2020 (Figure 29). However, the proportion of tern nests that failed due to unknown causes was higher for terns than plovers, which was likely due to multiple related reasons. First, since the delisting of terns from the ESA, we have preferentially used nest cameras to determine the fate of plover nests given their continued protection under the ESA. As a result, we do not have as much information regarding nest fates of tern nests and must rely on shoreline and site cameras, track surveys, and evidence from the nesting site to determine tern nest fates. Second, the proximity of nests to one another may result in multiple nests incurring the same fate if a predator accesses the site or a severe weather event occurs. Therefore, we may have had unknown fates for several nests within a colony.

PREDATOR MANAGEMENT AND MONITORING

The Program implemented several long-term management strategies to reduce the risk of predation at 10 Program-managed OCSW sites during their construction and/or rehabilitation. We selected off-channel nesting sites with peninsulas surrounded by water to manage and provide a ≥100 ft water deterrent to terrestrial predators. We installed permanent and temporary electrified fences across the land entrance to each nesting area. We positioned non-electrified fence-panel wings on the ends of the electrified fence and extended them between three and seven ft in the water to deter terrestrial predators from swimming from the mainland to the nesting peninsula. To reduce the potential for avian predation, we removed all trees within a ≥492 ft radius of the nesting site and placed avian spikes on all potential perches that could not be removed. Finally, we trapped and removed terrestrial predators from around the periphery of the site on an annual basis from March through August.

The Program again used additional predator monitoring in 2023 to reduce the number of nest and brood losses attributed to unknown causes and increase our understanding of the impacts of predation on plovers and terns. This was the third year of our predator monitoring study after a 2020 pilot study, which was enacted due to low plover fledge ratios observed during 2018 and 2019, a decrease in the proportion of successful plover chicks over time, and concerns about predation impacts on plovers. Predator monitoring efforts at six OCSW sites included track surveys along the shoreline and remote camera monitoring at the shoreline, on the nesting site, and at individual nests. We considered three of these six OCSW sites to use basic predator management techniques and the other three to employ additional predator management strategies.

For the 2023 season, the basic design and implementation remained the same as in 2021 and 2022 (PRRIP 2022b, PRRIP 2023). We deployed additional predator management efforts on three Program-managed sites (Kearney Broadfoot South; Leaman; Newark West) that included additional predator exclusion fences surrounding entire nesting peninsulas and predator deterrent lights (see details below). We used basic predator management at the Cottonwood Ranch, Dyer, and Newark East sites. The Program will continue implementing additional predator management strategies through 2024 to provide a multi-year data set that will be analyzed and used to inform future management decisions.

PREDATOR MANAGEMENT

METHODS

Terrestrial Mammal Trapping

The United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) Wildlife Services (WS) conducted terrestrial mammal trapping and lethal removal at 10 Program-owned and NPPD off-channel nesting sites in 2023 (Table 24). Personnel from USDA-APHIS-WS deployed traps from late March through mid-August at each site. Traps deployed included live cage traps, dog proof leg-hold traps, and leg-hold/foot-hold traps (Jaw traps), and body-hold snares (Table 24). Firearms were used when deemed necessary (Table 24). Personnel from USDA-APHIS-WS recorded the date on which each trap was deployed, trap type, trap identification number, and OCSW site, and kept daily trapping logs to record the date and time of trap checks, trap type and number of traps checked, number of empty closed traps, number of traps closed with caught animal, and number of traps set to be checked the next day. When a terrestrial mammal was captured, USDA-APHIS-WS personnel identified the species, the trap in which it was captured, time, and date, and then lethally removed the mammal from the site.

We calculated trapping effort at each site as the number of trap days, which was the total number of days each trap was open summed over all traps at each site. Because visits to traps were not conducted daily and because traps may have closed between visits, we determined the number of trap days when the trap closed between visits as one-half of the number of days since the trap was last checked. We did not include firearm usage in trapping effort. We used the total number of mammals captured at the site divided by the total number of trap days to calculate the number of captures per unit effort (i.e., trap days).

Predator Exclosure Fencing

In addition to our predator exclusion fences that were deployed across nesting peninsula entrances, in 2021 we installed and maintained additional predator exclusion fencing that surrounded our nesting areas on two OCSW sites, Kearney Broadfoot South and Newark West. On the interior shoreline of the nesting area at Kearney Broadfoot South, we installed an interior 4-ft woven wire predator fence with two electrified wires (Figure 30). The fence had 4-in x 4-in openings to allow plovers and terns to easily move through but prevent medium- and large-sized mammalian predators from accessing the site. We mounted one wire 3-in above the fence and along the tops of the fence posts to prevent avian predator perching and minimize mammals from climbing over the fence. We mounted the second wire at approximately the same height as the top of woven wire fence but offset to the outside to prevent mammals from climbing over. We deployed an exterior 4-ft high woven wire predator exclusion fence at Newark West that surrounded the outside of the water moat along the property line (Figure 31). We mounted one electrified wire offset to the outside of the fence and approximately 3-ft above the ground. Because the fence was located outside the nesting and foraging areas, we used a fence that had 2-in x 4-in openings.

Predator Deterrent Lighting

We deployed predator deterrent lights at three Program monitored and managed sites. At Kearney Broadfoot South, we deployed four motion-activated lights (Luposwiten Solar Motion Sensor Lights, Luposwiten Direct, Shenzhen, Guangdong), four random pattern lights (Foxlights Solar Night Predator Deterrent, Foxlights International PTY LTD, Bexley North, Australia), and 28 blinking walking lights (RISOON Solar Strobe Lights, RISOON; Figure 30). We mounted the blinking walking lights to the interior predator exclusion fence and set each to flash at alternate times to give the illusion of movement along the fence. We deployed motion-activated and random pattern lights in pairs of two across the site at a density of approximately one set per four ac. We installed these lights on top of a 7-ft high post with avian spikes placed on top of the lights to prevent them from being used as predator perches. At Newark West, we deployed four motion-activated and four random pattern lights distributed across the two nesting peninsulas (Figure 31). Finally, we deployed three sets of motion activated and random pattern lights distributed across the Leaman site (Figure 32).

PREDATOR MONITORING

The Program monitored predator presence and predation events at six OCSW nesting sites during 2023: Dyer, Cottonwood Ranch, Kearney Broadfoot South, Newark West, Newark East, and Leaman. We documented predator presence using a combination of USDA-APHIS-WS trapping of terrestrial mammals outside of the nesting peninsulas, track surveys along peninsula shorelines, remote cameras set along peninsula shorelines and within nesting sites, and remote cameras placed to monitor individual nests. We documented predation events using the remote cameras.

METHODS

Terrestrial Mammal Trapping

We used daily trapping logs to provide information on potential terrestrial predator presence along external shorelines and along the outside of nesting peninsulas. We identified the species present at the site and the number of captures per species per trap day as an indicator of relative abundance.

Track Surveys

EDO biologists and technicians conducted track surveys along peninsula shorelines at the six nesting sites once per week from May through early August to document avian and terrestrial predator presence and any predators that accessed the nesting peninsula. We summarized track survey effort at each site by totaling the number of surveys completed during the nesting season. Two observers began track surveys at the nesting peninsula entrance and walked the entirety of the shoreline while searching for evidence of predator species presence. Presence included tracks along the shoreline, digs (i.e., disturbed sand under a fence due to animal digging), fence turn backs (i.e., the animal walked to the fence and retreated), and scat. If observers found more than one sign of presence for any one species, then they recorded only one unique species register due to uncertainty as to the number of individuals of that species that were present. Tracks from Canada geese (*Branta canadensis*) were recorded during these surveys due to the potential for them to step on nests. Observers attempted to identify the species responsible for animal digs when possible; otherwise, they attributed them to an unknown species. If other species' tracks were found during the same survey, observers did not count the animal dig as a unique register because it was likely caused by one of the identified species. Observers cleared tracks in the sand after each survey to prevent double counting upon the next weekly survey.

Remote Trail and Video Cameras

EDO biologists attached shoreline trail cameras to 3-ft tall metal posts placed every 1,200 linear ft along the shorelines of the six nesting sites. Biologists attached avian spikes to the top of each post to prevent avian predator perching. When the 1,200 linear feet spacing did not provide camera coverage of shorelines, then the distance between shoreline cameras was shortened to improve coverage. We quantified shoreline camera monitoring effort at each site as the number of days each shoreline camera was deployed (camera days) totaled over all cameras at each site. We programmed trail cameras to take motion-triggered photos followed by a 30-sec video. We identified animals registered on cameras to the species level but did not attempt to identify individuals. Because multiple cameras at a single site could have photographed the same individual several times, we limited our final dataset to include only unique potential predator registers captured by shoreline cameras. We defined a unique register as a photo/video of a single species separated by at least 24-hours from a previous register of the same species. We considered multiple photos of the same species taken by shoreline cameras at the same site within a 24-hour period to be a single unique register. We also considered a photo/video of multiple individuals of the same species to be a single unique register. We added the number of unique potential predator registers over the entire nesting season by site to calculate the total number of unique potential predator registers for each site. We divided the number of unique shoreline registers for each site by the total number of shoreline camera days to obtain a measure of registers per unit effort.

EDO biologists attached site-level trail cameras to 4-ft tall PVC pipes at each of the six nesting sites at a density of one camera every four ac near the edges of the peninsula facing inland to document potential predator presence on the nesting site. Biologists placed avian spikes on the top of each PVC pipe to prevent avian predator perching. Biologists programmed site-level cameras to take motion-triggered photos followed by a 30-sec video. We calculated and defined monitoring effort, number of camera days, and unique registers the same as for shoreline cameras. We divided the number of unique site-level registers for each site by the total number of site-level camera days to obtain a measure of registers per unit effort.

EDO biologists placed nest-level trail cameras (Bushnell; Overland Park, KS) and cellular video cameras (Arlo; Carlsbad, CA) at active plover and tern nests (i.e., adults were tending the nest until the nest was successful or failed) at the same six nesting sites to document potential predator presence and predation events occurring at the nest. Biologists placed nest-level cameras at a density of approximately one camera every two ac and only placed them at established nests (i.e., the nest contained ≥1 egg in the nest bowl). The number of cameras allocated per site was established before the nesting season with five to ten cameras deployed per site. Biologists preferentially placed cameras at plover nests before tern nests and not every nest was monitored by a camera to allow investigation of potential camera effects on nest survival and success. Biologists removed the camera once the nest was no longer active (i.e., successful or failed) and used the camera at another nest if needed.

Biologists placed trail cameras ~5 ft from plover nests and ~7 ft from tern nests to minimize disturbance to nesting adults. Biologists attached trail cameras to 2-ft tall metal posts with avian spikes placed on top to prevent avian predator perching. Biologists placed cellular video cameras closer to the nest (i.e., 1.5–2 ft) with the purpose of documenting detailed nesting information (i.e., adult nesting behavior, hatching, predation, and weather events) that trail cameras sometimes miss. Each nesting site was designated one cellular video camera placed only at plover nests to obtain more detailed information for this species and because terns were not tolerant of cameras close to their nest. Biologists programmed site-level cameras to take motion-triggered photos followed by a 30-sec video. We calculated nest-level camera monitoring effort and number of nest-level camera days using the same methods described above for shoreline and site-level cameras. We categorized photos/videos from each nest-level camera as a predator register (i.e., potential predator documented without depredating the nest) or predation event (i.e., predator documented depredating the nest). For predation events, we recorded the date, time, type of predation (ate egg[s], chick[s], or adult[s]), and predator behavior/activity. If we documented more than one predation event by the same predator species in 24-hr at the nesting site (at ≥1 nest[s]), we considered it as one unique predation event. However, we included all information from the predation event (e.g., total number of nests, eggs, or chicks eaten) when totaling numbers of plover and tern nests, eggs, and chicks depredated during 2023. We added the number of unique nest-level registers to the number of unique nest-level predation events and divided by the total number of nest-level camera days for each site to obtain a measure of nest-level registers per unit effort. We also separately divided the number of unique nest-level predation events for each site by the total number of nest-level camera days to obtain a measure of events per unit effort.

We used mixed-effects nest fate logistic exposure models to calculate DSR of nests at the six OCSW sites to determine whether the presence of nest cameras affected nest survival rates. Using data from the six sites, we conducted an analysis using all plover and tern nests combined and developed three models. First, we evaluated whether survival was different for nests with and without cameras (i.e., camera model). Second, we evaluated whether survival was different for nests with and without cameras and across sites (i.e., camera + site model). Third, we evaluated whether survival was different for nests with and without cameras, across sites, and within sites (i.e., camera + site + camera*site model). We conducted two additional analyses using data only from plover nests and from tern nests to separately fit the camera model. We included site as a random effect in each model to account for a potential lack of independence of nest fates at each site. We used package *lme4* (Bates et al. 2015) in Program R (R Core Team 2021) to fit models and estimate coefficients. We also made an overall and site-by-site comparison between DSR of nests with and without cameras in 2023 to the combined average DSR of all plover and tern nests calculated using data from 2010–2016 prior to any camera usage at sites.

RESULTS

Trapping of Terrestrial Mammals

There has been a high amount of variability among years and across OCSW sites based on trapping of potential mammalian predators during 2012–2023 (Figure 33). This variability is due to differences in trapping effort across years and sites prior to 2021 and may be related to changes in predator communities over time. During 2023, personnel from USDA-APHIS-WS deployed 244 traps across 10 sites with the number of traps per site ranging between 10 and 34 (Table 24). The first traps were set on 23 March and the last traps to be deployed were set on 8 May. Traps were first removed on 25 June due to flooding and the final traps were removed on 30 August 2023. Total number of trap days per site ranged from 1,026 days at Follmer to 4,417 days at Newark

West (mean = 2,836; standard error [SE] = 353) and totaled 28,363 days across all 10 sites (Table 25).

Traps captured 307 terrestrial animals encompassing nine species and USDA-APHIS-WS personnel used a firearm to remove two bull snakes (*Pituophis catenifer sayi*) and one woodchuck (*Marmota monax*), resulting in an overall trapping efficiency of 0.011 captures/trap day (Table 25). Across the 10 sites, trapping efficiency ranged between 0.005 captures/trap day at Leaman and 0.017 captures/trap day at Cottonwood Ranch (mean = 0.011; SE = 0.001; Table 25). We observed mean trapping efficiencies of 0.013 and 0.010 captures/trap day at the three sites with basic predator management and additional predator management, respectively (Figure 34). Raccoons were the most frequently captured terrestrial mammal at every site with a total of 283 raccoons captured over all sites (Tables 26 and 27; Figure 35). Other species captured in traps included a badger (*Taxidea taxus*), beavers (*Castor canadensis*), coyotes, Virginia opossums (*Didelphis virginiana*), red fox (*Vulpes vulpes*), river otters (*Lontra canadensis*), a striped skunk (*Mephitis mephitis*), and woodchucks (Figure 35).

Shoreline Track Surveys

EDO biologists and technicians conducted a total of 92 shoreline track surveys across the six OCSW sites during 2023, ranging from 12 weekly surveys at Leaman to 18 weekly surveys at Newark East, and recorded 222 total unique track registers (2.41 track registers/survey; Table 28). Number of unique track registers per survey ranged from 1.42 track registers/survey at Leaman to 3.43 track registers/survey at Kearney Broadfoot South (mean = 2.39; SE = 0.335; Table 28). We observed more tracks per survey at sites with basic predator management (2.58 track registers/survey) than at those with additional predator management (2.21 track registers/survey); Table 28).

Tracks from avian species were most frequently observed at all sites except Kearney Broadfoot South, at which tracks from mammalian species were most frequently observed outside the predator fence along shorelines (Figure 36). Mammal tracks were generally more frequently observed than tracks from reptilian species at all sites except at Dyer and Cottonwood Ranch (Figure 36). Across all sites, we observed 1.28 avian track registers/total survey effort, 0.674 mammalian track registers/total survey effort, and 0.457 reptilian track registers/total survey effort. Among avian species, we most frequently observed tracks from Canada geese (0.772 track registers/total survey effort) when considering total survey effort at all six sites combined. On a site-by-site basis, we most frequently observed tracks from Canada geese and great blue herons (*Ardea herodias*) at all six sites (Figure 37a). Among mammalian species, we most frequently observed tracks from raccoons (0.152 track registers/total survey effort) when combining data from all sites. However, the frequency and composition of tracks observed from mammals varied greatly by site (Figure 37b). We most frequently observed raccoon tracks at Dyer, white-tailed deer (*Odocoileus virginianus*) tracks at Cottonwood Ranch, and striped skunk tracks at Kearney Broadfoot South (Figure 37b). Among reptiles and amphibians, we most frequency observed turtles (Family Trionychidae) overall (0.380 track registers/total survey effort) and at all sites except Leaman, at which no reptile or amphibian tracks were recorded (Figure 37c).

Shoreline Camera Monitoring

EDO biologists deployed 29 shoreline cameras for a total of 3,347 camera days across the six sites during 2023 (Table 29). Number of shoreline cameras deployed per site ranged from three cameras totaling 324 camera days at Leaman to seven cameras totaling 722 camera days at Kearney Broadfoot South (Table 29). EDO biologists deployed six cameras at Dyer for a total of 739 camera days, which represented the highest number of camera days among all sites (Table 29). Shoreline cameras recorded 802 unique predator registers resulting in 0.240 unique registers/camera day across all six sites. We observed a low of 0.136 registers/camera day at Cottonwood Ranch and high of 0.380 registers/camera day at Newark West (mean = 0.247 registers/camera day, SE = 0.036; Table 29). We observed 0.185 registers/camera day at the three sites with basic predator management compared to 0.305 registers/camera day at sites with additional predator management.

We documented avian species most frequently on shoreline cameras across all six sites (Figure 38). We most frequently observed avian registers at Newark West (0.351 registers/camera day) and Leaman (0.299 registers/camera day), which were two additional predator management sites (Figure 38a). We documented mammals less frequently than avian species, but more frequently than reptiles on shoreline cameras (Figure 38). We observed mammals on shoreline cameras most frequently at Kearney Broadfoot South (0.046 registers/camera day; Figure 38b). We most frequently observed reptiles and amphibians on shoreline cameras at Dyer (0.007 registers/camera day) and did not record reptiles on cameras at Newark East, Newark West, and Leaman (Figure 38c).

We documented 11 different avian species on shoreline cameras with Canada geese (0.125 registers/total camera days) and great blue herons (0.035 registers/total camera days) observed most frequently across the six sites (Figure 39a). Among mammals, we documented nine different species on shoreline cameras with the frequency of observation varying among the six sites (Figure 39b). We observed turtles and amphibian species on shoreline cameras at Dyer and only turtles on shoreline cameras at Cottonwood Ranch and Kearney Broadfoot South (Figure 39c).

Site-Level Camera Monitoring

EDO biologists deployed 25 site-level cameras for a total of 3,084 camera days across the six sites during 2023 (Table 30). Number of site-level cameras deployed per site ranged from three cameras totaling 336 camera days at Leaman to five cameras totaling 686 camera days at Newark East (Table 30). Site-level cameras recorded 223 unique predator registers resulting in 0.072 unique registers/camera day across all six sites. We observed a low of 0.016 registers/camera day at Kearney Broadfoot South and high of 0.149 registers/camera day at Leaman (mean = 0.080 registers/camera day, SE = 0.019; Table 30). We observed 0.067 registers/camera day at the three sites with basic predator management compared to 0.080 registers/camera day at sites with additional predator management (Table 30).

We documented avian species most frequently on site-level cameras across all six sites (Figure 38). We most frequently observed site-level avian registers at Leaman (0.149 registers/camera day) and Newark West (0.108 registers/camera day; Figure 38a). The frequency of site-level mammal observations was similar across five sites, but we observed no mammals at Leaman (Figure 38b). We observed no reptilian or amphibian species on site-level cameras (Figure 38c).

Among the seven avian species observed on site-level cameras, we observed Canada geese (0.049 registers/total camera days) the most frequently across all six sites (Figure 40a). We observed six different mammals across five sites with high variability in the frequency of occurrence across sites (Figure 40b).

Nest-Level Camera Monitoring

EDO biologists deployed 36 nest-level cameras to monitor 71 nests for a total of 1,107 camera days across the six sites during 2023 (Table 31). Additionally, biologists placed one nest-level camera at the plover nest located on an island in the river channel at the Dippel property that added five camera days (Table 31). The 72 nests were comprised of 35 plover and 37 tern nests. Nest-level cameras documented 12 unique registers of predator species (e.g., within view of camera but did not depredate the nest; Table 32) and seven predation events resulting in 0.017 nest-level registers/camera day (Table 32). Among the six OCSW sites, we observed nest-level registers of avian species at Dyer, Newark East, and Kearney Broadfoot South, and mammalian species at Newark East and Kearney Broadfoot South (Figure 38). For avian species, we observed 0.024 nest-level registers/camera day at Dyer and 0.012 nest-level registers/camera day at Newark East (Figures 38 and 41). For mammals, we observed 0.004 nest-level registers/camera day at Kearney Broadfoot South and 0.002 nest-level registers/camera day at Newark East (Figures 38 and 41). We observed 0.010 nest-level registers/camera day of reptilian species at Cottonwood Ranch (Figures 38 and 41). In the five days of deployment, the camera located at the in-channel plover nest recorded registers of one raccoon and one juvenile bald eagle (*Haliaeetus leucocephalus*) before being depredated by a raccoon, resulting in 0.60 nest-level registers/camera day. In addition to the bald eagle at the in-channel nest, avian species observed on nest-level cameras included American crows (*Corvus brachyrhynchos*), European starlings (*Sturnus vulgaris*), Canada geese, and great horned owls (Figure 41a). On nest-level cameras, we observed a mouse (*Peromyscus* spp.) at Kearney Broadfoot South and a coyote at Newark East (Figure 41b). Among reptilian and amphibian species, we observed only a bull snake on nest-level cameras at Cottonwood Ranch (Figure 41c).

Nest-level cameras documented seven predation events resulting in 0.006 predation event registers/camera day across all six sites and the in-channel site (Tables 31 and 32). Of the seven predation events, one was at a site with additional predator management (Kearney Broadfoot South), five were at sites with basic predator management (Cottonwood Ranch; Dyer; Newark East), and one was at the in-channel site with no predator management (Tables 31 and 32). We observed predation events more frequently at sites with basic predator management (0.007 predation events/total camera days at basic sites) than at those with additional predator management (0.003 predation events/total camera days at additional sites). We also documented three predation events (two at nests with cameras) that were not captured on a nest-level cameras through use of a combination of additional predator monitoring techniques (i.e., track surveys; shoreline and site-level cameras; outside nest site monitoring; Tables 32 and 33). Overall, nine plover and tern nests failed due to predation and the final egg from one plover nest was depredated after chicks had hatched and were away from the nest during the predation event (Tables 32 and 33).

Use of nest-level cameras allowed us to accurately determine the fate of plover nests at the six OCSW sites and one in-channel site (Table 33). We placed nest-level cameras at 35 of 36 plover nests observed at these sites and documented 29 successful nests, one successful nest with predation, four nests that failed due to predation, and one nest that failed due to abandonment (Table 33). The one plover nest without a camera was determined to be successful through our other monitoring efforts (Table 33). Across the seven sites during the plover incubation period, we observed predation of 17 eggs and failure of three eggs due to abandonment (Table 34). Additionally, three eggs had unknown fates and nine eggs were abandoned from successful nests (Table 34). During the brood-rearing period, we observed mortality of two chicks due to weather and five chicks experienced an unknown fate (Table 34).

We placed nest-level cameras at 37 of 84 tern nests observed at the six OCSW sites and documented 30 and 35 successful nests at nests with and without cameras, respectively (Table 33). We documented four camera-monitored tern nests that failed due to predation and were able to document predation on one additional nest that was not monitored by a camera. In contrast to plovers, we recorded nine tern nests that failed due to unknown reasons and one nest with an unknown outcome, with all these unknowns arising from nests without cameras (Table 33). Across the six sites during the tern incubation period, we observed predation of 13 eggs, failure of two eggs due to weather, failure of six eggs due to abandonment, and failure of one egg due to unknown reasons (Table 34). During the brood-rearing period, seven chicks experienced an unknown fate (Table 34).

Plover nests were depredated by great horned owls (two nests), a bull snake, a coyote, and a raccoon (Table 35, Figure 42). All depredations occurred when eggs were present. Among the five plover nests depredated, the predation event occurred at an average on day 18 of incubation, which represents 62% of the 28-day incubation period for plovers (Table 35, Figure 42). Tern eggs were depredated by great horned owls (three nests; one without a nest camera), a bull snake, and a Canada goose that stepped on eggs (Table 35, Figure 42). Among the four tern nests with cameras, the predation occurred on average at day nine of incubation (Table 35, Figure 42).

Effect of Nest-level Cameras on Daily Survival Rates

EDO biologists placed nest cameras at 72 of 120 (60%) plover and tern nests at the six OCSW sites and one on-channel site in 2023 (Table 33). Fifty-nine of the 72 nests with cameras and 36 of 48 nests without cameras were successful (Table 33). Across the six sites, there was only one nest at Leaman that was successful and at which biologists deployed a camera (Table 33). Additionally, all eight nests at Newark West were successful, four of which were monitored by cameras (Table 33). The one nest at the on-channel site at Dippel failed and was monitored by a camera (Table 33). Therefore, site-specific estimation of DSR for both species was not possible when including Leaman and Dippel, and DSR = 1 for nests with and without cameras for Newark West. For both plover and tern nests combined, we found no significant difference in DSR for nests with (DSR = 0.991; 95% CI: 0.984, 0.996) or without cameras (DSR = 0.986; 95% CI: 0.979, 0.993; Figure 43). We also found no difference in DSR within and among the four sites that had nests with and without cameras that had both nest success and failure (Table 36, Figure 44).

Biologists deployed cameras at 35 of 36 plover nests at the six OCSW sites and one on-channel site (Table 33). One nest at Kearney Broadfoot South did not have a camera and was successful (Table 33). Therefore, a meaningful comparison of DSR for plover nests with and without cameras was not possible (Figure 45). Biologists deployed cameras at 37 of 84 tern nests at the six sites (Table 33). We found no significant difference in DSR for tern nests with (DSR = 0.989; 95% CI: 0.976, 0.997) or without cameras (DSR = 0.987; 95% CI: 0.974, 0.997; Figure 45). Combined average DSR for plover and tern nests during 2010–2016 across all six sites prior to camera deployment was 0.968 (95% CI: 0.932, 1.00), which was lower than our DSR estimates for nests with and without cameras during 2023. However, the 95% CIs of average DSR during 2010–2016 included the 95% CIs of DSR estimates for 2023. By site, DSR estimates for nests with cameras during 2023 were generally higher than mean DSR during 2010–2016, but within the 95% CIs for 2010–2016 (Figure 46). The DSR for nests with cameras during 2023 was higher at Cottonwood Ranch, Newark West, Leaman, and Kearney Broadfoot South than the combined average nest DSR for these sites during 2010–2016 (Figure 46). The average DSR for nests with cameras at Dyer was 0.987 during 2023, which was lower than the 2010–2016 combined average of 0.990, but within the 95% CIs for 2010–2016 (Figure 46). At Newark East, the 2010–2016 combined average nest DSR was 1.00 with a sample size of two nests, which was higher than the 2023 DSR of 0.995 for nests with cameras (Figure 46).

DISCUSSION

We used a combination of predator monitoring techniques in 2023, which was our third full year employing these methods, to help reduce uncertainty of plover and tern nest fates, better understand predator communities at nesting sites, and evaluate the effectiveness of additional predator management efforts. We observed reduced predation of both plover and tern nests in 2023 compared to 2022 despite recording more registers/camera day of potential predators at shoreline at site-level cameras in 2023 (PRRIP 2023). We documented more registers of potential predator species at shoreline cameras than at site-level cameras, and more registers at site-level cameras than nest-level cameras during 2023 (Figure 38), which would be expected for an effective predator deterrent management strategy. We have documented increasing fledge ratios for plovers since 2021 at the six OCSW sites with predator management (three with basic management and three with additional management) and monitoring. This increase was concurrent with increasing plover fledge ratios at sites across the AHR. Average plover fledge ratios across the six sites have increased from 0.780 chicks/nest (0.878 chicks/BPE) in 2021, to 0.798 chicks/nest (0.975 chicks/BPE) in 2022, to 0.900 chicks/nest (1.19 chicks/BPE) in 2023. Overall, our results illustrate the importance of intensive and non-invasive monitoring of nests of avian species of concern to better understand the role of predation on nest success and productivity.

At the three sites with basic predator management, we observed an increase from an average of 1.18 chicks/nest (1.23 chicks/BPE) in 2021 to 1.33 chicks/nest (1.57 chicks/BPE) in 2022, before decreasing to 1.15 chicks/nest (1.72 chicks/BPE) in 2023. At individual sites, we documented more variability across years. Fledge ratios at Cottonwood Ranch were 0.0 chicks/nest (0.0 chicks/BPE) in 2021, 1.0 chicks/nest (1.0 chicks/BPE) in 2022, and 0.667 chicks/nest (2.0 chicks/BPE) in 2023. At Dyer, we documented fledge ratios of 1.13 chicks/nest (1.29 chicks/BPE) in 2021, 1.27 chicks/nest (2.0 chicks/BPE) in 2022, and 1.78 chicks/nest (1.78 chicks/BPE) in 2023. Finally, we observed a decrease in fledge ratios over time at Newark East from 2.4 chicks/nest (2.4 chicks/BPE) in 2021, to 1.71 chicks/nest (1.71 chicks/BPE) in 2022, to 1.0 chicks/nest (1.38 chicks/BPE) in 2023.

We have observed more variability in fledge ratios at sites with additional predator management over the three-year period, largely due to a lack of nest success at Newark West due to predation and low nest success at the Leaman site in 2022 due to severe storms. Average fledge ratios at the three sites with additional predator management were 0.385 chicks/nest (0.527 chicks/BPE) in

2021, 0.267 chicks/nest (0.380 chicks/BPE) in 2022, and 0.653 chicks/nest (0.653 chicks/BPE) in 2023. Despite the lower fledge ratios at sites with additional predator management, we have observed a marked increase and positive trend in plover fledge ratios at Kearney Broadfoot South since 2021 with increases from 0.154 chicks/nest (0.250 chicks/BPE) in 2021, to 0.800 chicks/nest (1.14 chicks/BPE) in 2022, to 1.63 chicks/nest (1.63 chicks/BPE) in 2023. Prior to implementation of additional predator management, we observed a plover fledge ratio of 0.333 chicks/nest (0.500 chicks/BPE) in 2020 at Kearney Broadfoot South, suggesting predator management and deterrent efforts initiated at the site in 2021 may be having a positive impact. Given the high amount of interannual variability in plover fledge ratios, more detailed analyses are required to understand the influence of our predator management efforts relative to contributions from abiotic and biotic factors in affecting fledge ratios.

We have also documented increasing tern fledge ratios at the six OCSW sites since 2021 from an average of 1.26 chicks/nest (1.36 chicks/BPE) in 2021 to 1.47 chicks/nest (1.68 chicks/BPE) in 2023. In 2022, average fledge ratios decreased to 0.803 chicks/nest (1.24 chicks/BPE) due to all six nests failing at Leaman from a severe hailstorm. We have observed more site-by-site variability in tern fledge ratios since the beginning of our predator management in 2021. At sites with basic predator management, average tern fledge ratios were 1.76 chicks/nest (1.91 chicks/BPE) in 2021, 1.05 chicks/nest (1.53 chicks/BPE) in 2022, and 1.76 chicks/nest (1.91 chicks/BPE) in 2023. In contrast, average fledge ratios were 0.761 chicks/nest (0.810 chicks/BPE) in 2021, 0.558 chicks/nest (0.943 chicks/BPE) in 2022, and 1.02 chicks/nest (1.33 chicks/BPE) in 2023 at sites with additional predator management. The variability was evident in some of the more productive tern nesting sites. At Newark East, a basic management site, we observed decreasing tern fledge ratios over time of 1.83 chicks/nest (1.94 chicks/BPE) in 2021, 1.14 chicks/nest (1.62 chicks/BPE) in 2022, and 1.10 chicks/nest (1.32 chicks/BPE) in 2023. Tern fledge ratios at Dyer went from a high of 1.68 chicks/nest (1.88 chicks/BPE) in 2021 to a low of 0.313 chicks/nest (0.83 chicks/BPE) in 2022, before recovering to 1.36 chicks/nest (1.58 chicks/BPE) in 2023. In contrast, we observed fledge ratios at Kearney Broadfoot South of 0.300 chicks/nest (0.400 chicks/BPE) in 2021, 1.12 chicks/nest (1.58 chicks/BPE) in 2022, and 0.444 chicks/nest (0.667 chicks/BPE) in 2023. Factors beyond effective predator management have contributed to the variability in tern fledge ratios. For example, hail from a severe storm led to nest failures at Leaman and other sites in 2022.

We accurately fated each of the 35 plover nests we monitored with cameras at the six OCSW sites and one in-channel site, including one nest that successfully produced chicks and then had one egg depredated by a great horned owl. Likewise, we accurately fated each of the 37 tern nests we monitored with cameras. This reduction in the uncertainty of nest fates at the six OCSW sites contributed to a study area wide trend that began in 2020 of decreasing proportion of plover and tern nests that failed due to unknown causes over time (Figures 17 and 29). At sites without camera monitoring, there has been more uncertainty about the fates of nests, particularly for terns (Figure 29). As in previous years, we found no negative effect of camera presence on daily nest survival rates (Figure 43). During our other monitoring efforts on the nesting sites and review of camera footage, we observed no avoidance, no abnormal nesting behavior, and no nest abandonment due to placement of the cameras or predator management activities.

We documented 29 of 35 plover nests at the six OCSW sites to be successful in 2023 compared to 19 successful out of 39 total nests in 2022 (PRRIP 2023). Similarly, we observed higher tern nest success in 2023 with 65 of 84 nests successful compared to 58 of 95 in 2022 (PRRIP 2023). The increase in nest success occurred despite more potential predator activity documented on our shoreline and site-level cameras. We did observe potential predators that did not depredate the nest (i.e., nest-level registers) less frequently on our nest-level cameras at the six sites in 2023 (0.009 registers/camera day) than 2022 (0.011 registers/camera day; PRRIP 2023). Likewise, the frequency of predation events at the six sites was 0.005 predation events/camera day in 2023 compared to 0.012 predation events/camera day in 2022 (PRRIP 2023). Since initiating our camera monitoring, we have observed variability in the rates of predation events across years and the types of predators (PRRIP 2022b, PRRIP 2023). Although great horned owls depredated five of 10 nests in 2023, nest depredation and failures of the other five nests was attributed to four different species including a Canada goose that stepped on eggs. In contrast, in 2022, we observed nest depredations predominantly caused by badgers and great horned owls (PRRIP 2023).

We observed decreasing frequency of potential predator registers from outside the nesting site, across the nesting site, and to the nest itself across all six OCSW sites and all types of predator species during 2023 (Figure 38). The frequency of potential predator registers decreased from shoreline cameras to site-level cameras, and from site-level cameras to nest-level cameras (Figure 38). This contrasted with 2022 when we observed this pattern only for avian species (PRRIP 2023). Decreasing frequency of avian registers from the shoreline to the site-level may be due to multiple factors, most notably availability of forage and prey in the water and at the water's edge for Canada geese and great blue herons, which we observed most frequently (Figure 39a and 40a). The largest decrease in avian registers between shoreline and site-level cameras occurred at Kearney Broadfoot South from 0.211 registers/camera day at shoreline cameras to 0.009 registers/camera day at site-level cameras (Figure 38a). The Kearney Broadfoot South site is unique because it is located on a large peninsula enclosed by a fence and surrounded by extensive water, and the site is adjacent to several islands separated from the primary nesting site. Therefore, it is possible that Canada geese focused their use of shorelines on the other islands rather than on the nesting peninsula itself. It is also likely that the fence surrounding the peninsula kept nesting geese off the peninsula due to the lack of shoreline access for non-fledged goose chicks. We will be conducting analyses of all three years of predator monitoring data in 2024 to quantitatively address the effect of predator deterrents and site variability on the frequency of camera detections.

The decrease in mammalian registers from shoreline to nest-level cameras that we observed in 2023 was expected given our layers of predator deterrents from outside to inside the nesting site. We did observe a greater decrease in the frequency of detection of mammals at our additional predator management sites compared to our sites with basic predator management (Figure 38b). At Newark West, we observed a decrease from 0.029 registers/camera day at shoreline cameras to 0.008 registers/camera day at site-level cameras. Also, we documented a decrease from 0.046 to 0.007 registers/camera day between shoreline and site-level cameras at Kearney Broadfoot South (Figure 38b). Although we observed decreases in the frequency of mammal detections between shoreline and site-level cameras at sites with basic predator management (Cottonwood Ranch, Dyer, Newark East), the decreases were not as large as those at sites with additional management

(Figure 38b). Therefore, it is possible that our additional predator exclosure fencing and lighting deterrents at Kearney Broadfoot South and Newark West were more effective during 2023 at reducing the frequency of potential predator detections than in previous years (PRRIP 2023).

Differences in the mammalian predator communities at and around each OCSW site may also affect the frequency of detection at shoreline, site-level, and nest-level cameras. Data from trapping efforts, track surveys, and shoreline cameras lends some insight to the composition of mammalian predators at each site. Raccoons were most frequently caught in traps across all sites due largely to the use of cage traps and dog proof traps. Of the 244 traps deployed in 2023, 93 were cage traps and 133 were dog proof traps. During 2023, personnel from USDA-APHIS-WS deployed only 10 leg hold traps, which are more effective at capturing canids, and 12 snares.

We observed a high amount of variability in the mammals detected through track surveys and shoreline cameras across sites. We documented more mammalian tracks per survey at Kearney Broadfoot South than any other site with tracks consisting primarily of those from beavers, coyotes, raccoons, striped skunks, and white-tailed deer (Figure 37b). Shoreline cameras at Kearney Broadfoot South most frequency documented beavers and coyotes (Figure 39b). At our other two additional predator management sites, we observed tracks of raccoons and striped skunks most frequently at Newark West and only skunks at Leaman (Figure 37b). Shoreline cameras at Newark West most frequently documented mice and striped skunks, and no mammals were observed on shoreline cameras at Leaman (Figure 39b). Among our basic predator management sites, at Dyer we most frequently observed raccoon, badger, and white-tailed deer tracks, with badgers and opossums most frequently observed on shoreline cameras (Figure 39b). We most frequently observed white-tailed deer tracks at Cottonwood Ranch and Newark East (Figure 37b). Shoreline cameras detected badgers most frequently at Cottonwood Ranch and raccoons and river otters most frequently at Newark East (Figure 39b).

Some of our 2023 results were different than in previous years of predator management and monitoring, which leads to questions regarding the effectiveness of our camera monitoring at detecting and documenting predator presence. For example, in 2022, we observed a higher frequency of mammal registers at nest-level cameras compared to site-level cameras at five of the six sites (PRRIP 2023). We observed the same for reptile and amphibian registers at Kearney Broadfoot South, Newark West, and Newark East in 2022 (PRRIP 2023). The detections that were recorded at the nest-level cameras, but missed at the site-level cameras could have occurred during periods of camera malfunctions in between site visits from our biologists. It is also possible the placement and density of cameras were not optimal given the field of view of each camera, such that potential predators were not detected when present on the site. Additional work to estimate area of coverage of cameras, account for the possibility of missing data when cameras were not functioning, and estimate predator density is needed to better compare predator occurrence data across years. In 2024, we will be conducting in-depth, multi-year analyses of nest success and camera data to better evaluate the effectiveness of our predator management and monitoring efforts over the first three years of our study.

PAST RESEARCH SYNTHESIS

Plover and tern monitoring and research conducted on the central Platte River since 2001 have been designed and implemented to provide information on an array of topics relevant to species management, including monitoring methods and protocol implementation; habitat use; reproductive success and survival; behavior; population demographics and dispersal; and predator monitoring and management. Reports produced by West Incorporated during 2001–2007 prior to Program implementation provided a general overview of plover and tern habitat use, nesting, and productivity (https://platteriverprogram.org/program-library; Target Species: piping plover or interior least tern; Keywords: least tern, piping plover, technical reports, protocol implementation). Upon Program implementation (2008–present), the surveillance monitoring protocol changed, and the resulting reports produced by EDO staff and partners contained more detailed information on implementation of the Program's surveillance monitoring protocol, conservation monitoring, and directed research. This directed research was used to address priority hypotheses developed in the Program's Adaptive Management Plan and evaluate progress toward the Program's First Increment and First Increment Extension management objectives. Design and implementation of research activities were guided by the EDO and the technical advisory committee (TAC), reviewed by the Program's Independent Scientific Advisory Committee (ISAC), and ultimately approved by the Program's Governance Committee (GC). Links to these studies and other research relevant to the Program's objectives and our understanding of plover and tern ecology are provided in the Appendix Table A1.

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ACKNOWLEDGEMENTS

Support for monitoring and research activities outlined in this report were provided by the Central Platte Natural Resources District, Nebraska Public Power District, and the Platte River Recovery Implementation Program. We extend a special thanks to non-governmental agencies and private landowners that allowed access to their properties and the many people who assisted in collecting data and provided technical guidance.

We would also like to acknowledge the privately-owned sand and gravel mining companies who allowed us access to their property to monitor and collect data on tern and plover activities. These companies included Broadfoot Sand and Gravel Corporation and Hooker Brothers Sand and Gravel.

TABLES

Table 1. Summary of piping plover reproductive effort and success at off-channel sand and water (OCSW) and river-island sites on the central Platte River in Nebraska, 2001–2009. Data collected during 2001–2009 used different monitoring protocols than 2010–2023. Changes adopted in 2010 included an increase of fledge age from 15 days to 28 days and an increase in monitoring effort.

	Piping Plover								
Reproductive Parameter	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Maximum adult count	25	40	34	51	48	47	66	45	47
Peak Breeding Pair Estimate (BPE)	10	13	14	11	14	13	16	13	12
Total no. nests observed	11	15	15	13	20	15	20	18	14
No. of successful nests (≥1 egg hatched)	9	13	13	9	15	11	15	8	9
Apparent nest success	0.82	0.87	0.87	0.69	0.75	0.73	0.75	0.44	0.64
Daily nest survival rate	1.00	0.99	0.99	0.98	0.98	0.98	0.99	0.98	0.99
Incubation period survival rate	1.00	0.75	0.85	0.63	0.64	0.65	0.71	0.58	0.67
No. of broods observed	9	13	13	9	15	11	15	8	9
No. of chicks observed (<15 days)	30	28	43	34	46	37	45	26	30
Hatch ratio (<15-day chicks/nest)	2.73	1.87	2.87	2.62	2.30	2.47	2.25	1.44	2.14
Hatch ratio (<15-day chicks/BPE)	3.00	2.15	3.07	3.09	3.29	2.85	2.81	2.00	2.50
Chicks (≥15 days)	25	28	22	23	28	29	27	10	12
Fledglings (28 days)	---[A]	---	---	---	---	---	---	---	---
Historic fledge ratio (≥15-day chicks/nest)	2.27	1.87	1.47	1.77	1.40	1.93	1.35	0.56	0.86
Fledge ratio (28-day chicks/nest)	---	---	---	---	---	---	---	---	---
Historic fledge ratio (≥15-day chicks/BPE)	2.50	2.15	1.57	2.09	2.00	2.23	1.69	0.77	1.00
Fledge ratio (28-day chicks/BPE)	---	---	---	---	---	---	---	---	---
Daily brood survival rate	---	---	---	---	---	---	---	0.94	0.98
Brooding period survival rate	---	---	---	---	---	---	---	0.42	0.79

[A] An "---" denotes years for which indicated data were not collected

Table 2. Summary of piping plover reproductive effort and success at off-channel sand and water (OCSW) and river island sites along the central Platte River in Nebraska, 2010–2023. Data collected during 2010–2023 used different monitoring protocols than 2001–2009. Changes adopted in 2010 included an increase of fledge age from 15 days to 28 days and an increase in monitoring effort.

	Piping Plover													
Reproductive Parameter	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Maximum adult count	96	71	73	94	108	99	108	77	74	88	71	67	74	82
Peak Breeding Pair Estimate (BPE)	20	28	30	27	30	40	43	40	37	45	32	36	38	41
Total no. nests observed	35	34	46	31	43	54	60	50	47	60	49	50	55	48
No. of successful nests (≥1 egg hatched)	21	27	32	23	34	34	40	30	35	31	28	30	30	40
Apparent nest success	0.60	0.79	0.70	0.74	0.79	0.63	0.67	0.60	0.74	0.52	0.57	0.60	0.55	0.83
Daily nest survival rate	0.98	0.99	0.99	0.99	0.99	0.98	0.99	0.98	0.99	0.98	0.98	0.98	0.97	0.99
Incubation period survival rate	0.54	0.77	0.69	0.73	0.77	0.64	0.69	0.61	0.68	0.51	0.51	0.54	0.48	0.80
No. of broods observed	21	27	32	23	34	34	40	30	35	31	28	30	30	40
No. of chicks observed (<15 days)	76	88	99	80	116	119	120	92	95	94	98	99	100	143
Hatch ratio (<15-day chicks/nest)	2.17	2.59	2.15	2.58	2.70	2.20	2.00	1.84	2.02	1.57	2.00	1.98	1.82	2.98
Hatch ratio (<15-day chicks/BPE)	3.80	3.14	3.30	2.96	3.87	2.98	2.79	2.30	2.57	2.09	3.06	2.75	2.63	3.49
Chicks (≥15 days)	50	61	68	43	67	73	70	53	36	42	52	45	65	65
Fledglings (28 days)	41	46	59	28	55	52	55	47	23	30	39	35	52	58
Historic fledge ratio (≥15-day chicks/nest)	1.43	1.79	1.48	1.39	1.56	1.35	1.17	1.06	0.77	0.70	1.06	0.90	1.18	1.35
Fledge ratio (28-day chicks/nest)	1.17	1.35	1.28	0.90	1.28	0.96	0.92	0.94	0.49	0.50	0.80	0.70	0.95	1.21
Historic fledge ratio (≥15-day chicks/BPE)	2.50	2.18	2.27	1.59	2.23	1.83	1.63	1.33	0.97	0.93	1.63	1.25	1.71	1.59
Fledge ratio (28-day chicks/BPE)	2.05	1.64	1.97	1.04	1.83	1.30	1.28	1.18	0.62	0.67	1.22	0.97	1.37	1.41
Daily brood survival rate	0.99	0.99	0.99	0.98	0.99	0.99	0.98	0.98	0.96	0.97	0.98	0.98	0.99	0.99
Brooding period survival rate	0.70	0.73	0.78	0.62	0.69	0.68	0.55	0.63	0.29	0.44	0.58	0.51	0.79	0.69

Table 3. Site-specific numbers of adults, nests, chicks, and fledglings observed while monitoring off-channel sand and water (OCSW) nesting sites for piping plover reproduction during 2023. Numbers of estimated breeding pairs (BPE), apparent nest success, fledge ratios, and survey effort are provided for each site. Site numbers correspond with Figure 2.

Site Name and No.	Management[A]	No. Surveys	Hours of Observation	Peak BPE (AHR peak date[B])	Peak BPE (Site peak date[C])	Adult Counts	No. Nests	No. Nests Hatched	No. Chicks 0–14 days	No. Chicks 15–28 days	No. Fledglings	Apparent Nest Success	Fledge Ratio (AHR peak date[B])	Fledge Ratio (Site peak date[C])
							Piping Plover							
1. OSG Lexington	FHPT	31	21	2	2	6	3	2	6	6	2	0.67	1.00	1.00
2. NPPD Lexington	FPT	21	25	1	1	4	1	1	4	1	1	1.00	1.00	1.00
3. Dyer	FHPT	30	24	9	9	14	9	8	28	18	16	0.89	1.78	1.78
4. Cottonwood Ranch	FHPT	31	20	1	2	4	3	2	6	2	2	0.67	2.00	1.00
5. T&F Lakeside	N	6	3	0	0	0	0	0	0	0	0	---[D]	---	---
6. Blue Hole	PT	36	57	6	6	12	7	5	20	10	10	0.71	1.67	1.67
7. Johnson	FP	5	3	0	0	0	0	0	0	0	0	---	---	---
8. Ed Broadfoot and Sons	N	10	6	0	0	0	0	0	0	0	0	---	---	---
9. Kearney Broadfoot South	FHILPT	27	21	8	8	15	8	7	26	13	13	0.88	1.63	1.63
10. NAI Kearney Broadfoot South	T	10	6	0	0	1	0	0	0	0	0	---	---	---
11. Newark West	EFHLPT	32	15	3	3	6	3	3	11	1	1	1.00	0.33	0.33
12. Newark East	FHPT	37	27	8	9	12	11	10	35	12	11	0.91	1.38	1.22
13. Leaman	FHLPT	25	13	1	1	3	1	1	4	0	0	1.00	0.00	0.00
14. Trust Wildrose East	N	20	10	1	1	2	1	1	3	2	2	1.00	2.00	2.00
15. Follmer	HPT	7	3	0	0	0	0	0	0	0	0	---	---	---
16. DeWeese	N	7	3	0	0	0	0	0	0	0	0	---	---	---
17. Hooker Brothers Southeast	N	34	17	0	0	0	0	0	0	0	0	---	---	---
18. Hooker Brothers East	N	7	3	0	0	0	0	0	0	0	0	---	---	---

[A] Management actions include: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2022 herbicide (H), interior predator fencing (I), predator deterrent lights (L), no management (N), spring 2023 pre-emergent herbicide (P), or predator trapping (T). See the Management Section of this report for a detailed description of management actions taken at each site.

[B] Peak estimated number of breeding pairs (BPE) at each site as calculated using the Program's BPE calculator (pg. 9 of this report) on 8 June, when numbers of piping plover breeding pairs observed within the entire Program Associated Habitat Reach first peaked.

[C] Peak BPE (site peak date) represents the highest number of estimated pairs at a site during the nesting season, regardless of AHR Peak Breeding Pair dates.

[D] "---"Denotes cannot be calculated.

Table 4. Peak estimated number of breeding pairs (BPE), number of nests and successful nests, and productivity by year for piping plovers at off-channel sand and water (OCSW) sites along the central Platte River in Nebraska, 2001–2023.

			Piping Plover		
Year	**Off-Channel Peak BPE[A]**	**No. Nests**	**No. Successful Nests**	**No. Fledglings[B]**	**Fledglings Per Peak BPE[AB]**
2001	10	11	9	25	2.50
2002	13	15	13	28	2.15
2003	14	15	13	22	1.57
2004	11	13	9	23	2.09
2005	14	20	15	28	2.00
2006	13	15	11	29	2.23
2007	14	16	13	20	1.43
2008	10	13	10	7	0.70
2009	10	12	8	11	1.10
2010	18	22	3	31	1.72
2011	28	34	27	46	1.64
2012	29	45	31	55	1.90
2013	27	31	23	28	1.04
2014	29	41	33	55	1.90
2015	35	47	33	51	1.46
2016	42	58	39	54	1.29
2017	40	50	30	47	1.18
2018	37	47	35	23	0.62
2019	45	60	31	30	0.67
2020	32	49	28	39	1.22
2021	36	50	30	35	0.97
2022	38	55	30	52	1.37
2023	41	47	40	58	1.41
Mean	**25.5**	**33.3**	**22.4**	**34.7**	**1.48**

[A] BPE represents the peak recorded at off-channel sites. Peak BPE dates differ on-channel and off-channel and each may differ from the overall AHR peak BPE.

[B] The dotted black line represents a change in protocol between 2009 and 2010. Among other changes, in 2010 the Program began to use 28 days as the fledge age for piping plover chicks rather than the previous 15-day success to fledge interval.

Table 5. Peak estimated number of breeding pairs (BPE), number of nests and successful nests, and productivity by year for piping plovers at on-channel island sites on the central Platte River in Nebraska, 2001–2023.

		Piping Plover			
Year	**On-Channel Peak BPE**[A]	**No. Nests**	**No. Successful Nests**	**No. Fledglings**[B]	**Fledglings Per Peak BPE**[AB]
2001	0	0	0	0	---[C]
2002	0	0	0	0	---
2003	0	0	0	0	---
2004	0	0	0	0	---
2005	0	0	0	0	---
2006	0	0	0	0	---
2007	4	4	2	7	1.75
2008	3	5	1	3	1.00
2009	2	2	1	1	0.50
2010	5	13	18	10	2.00
2011	0	0	0	0	---
2012	1	1	1	4	4.00
2013	0	0	0	0	---
2014	2	2	1	4	2.00
2015	6	7	1	1	0.17
2016	1	2	1	1	1.00
2017	0	0	0	0	---
2018	0	0	0	0	---
2019	0	0	0	0	---
2020	0	0	0	0	---
2021	0	0	0	0	---
2022	0	0	0	0	---
2023	1	1	0	0	0.00
Mean	**1.09**	**1.61**	**1.13**	**1.35**	**1.38**

[A] BPE represents the peak recorded on the river channel. Peak BPE dates differ on-channel and off-channel and each may differ from the overall AHR peak BPE.
[B] The dotted black line represents a change in protocol between 2009 and 2010. Among other changes, in 2010 the Program began to use 28 days as the fledge age for piping plover chicks rather than the previous 15-day success to fledge interval.
[C] "---" denotes fledge ratios cannot be calculated for years when there were no breeding pairs and are not included in calculation of the mean.

Table 6. Number of piping plover adults, estimated number of piping plover breeding pairs (BPE), and numbers of piping plover nests, chicks, and fledglings documented from outside the nesting area (i.e., outside monitoring) during semi-monthly off-channel sand and water (OCSW) site surveys in 2023.

	Piping Plover				
Survey Date	**No. Adults**	**BPE[A]**	**No. Nests**	**No. Chicks**	**No. Fledglings**
1 May	34	0	1	0	0
15 May	35	26	17	0	0
1 June	52	39	35	4	0
15 June	48	39	12	44	0
1 July	55	32	6	51	0
15 July	18	14	1	18	2
1 August	3	4	0	8	2

[A] BPE represents the estimated number of breeding pairs present on OCSW sites on 1 and 15 May, 1 and 15 June, 1 and 15 July, and 1 August. Breeding pair counts were obtained using the Program's BPE calculator (pg. 9). Number of nests may be different from breeding pairs because semi-monthly surveys occurred over several days and breeding pair counts were determined on the 1st or 15th of the month.

Table 7. Number of piping plover adults, estimated number of piping plover breeding pairs (BPE), and numbers of piping plover nests, chicks, and fledglings observed during semi-monthly airboat surveys of the Platte River between Lexington and Chapman, Nebraska, in 2023.

	Piping Plover				
Survey Date	**No. Adults**	**BPE[A]**	**No. Nests**	**No. Chicks**	**No. Fledglings**
1 May	2	0	0	0	0
15 May [B]	7	0	0	0	0
1 June	4	1	1	0	0
15 June	4	0	0	0	0
1 July [C]	0	0	0	0	0
15 July [B]	1	0	0	0	0
1 August [B]	0	0	0	0	0

[A] BPE represents the estimated number of breeding pairs present on river islands on 1 and 15 May, 1 and 15 June, 1 and 15 July, and 1 August. Breeding pair counts were obtained using the Program's BPE calculator (pg. 9). Number of nests may be different from breeding pairs because semi-monthly surveys occurred over several days and breeding pair counts were determined on the 1st or 15th of the month.

[B] Some river sections not completed due to lack of flow in the channel that prevented access by airboat. Point counts at predefined locations (e.g., bridges) were conducted instead.

[C] Surveys were conducted by point counts at predefined locations due to high flow that resulted in safety concerns for use of boats.

Table 8. Daily and incubation-period survival rates and 95% lower (LCI) and upper confidence intervals (LCI) for piping plover nests monitored on OCSW sites and one on-channel site during 2023. Incubation-period nest survival rate = daily nest survival rate^{28}.

Site	Management[A]	No. Nests	No. Nests Failed	Exposure Days	Daily Nest Survival Rate	Daily Nest Survival Rate LCI	Daily Nest Survival Rate UCI	Incubation Period Survival Rate	Incubation Period Survival Rate LCI	Incubation Period Survival Rate UCI
OSG Lexington	FHPT	3	1	81	0.988	0.878	0.999	0.703	0.026	0.968
NPPD Lexington	FPT	1	0	28	0.999	0.000	NA[B]	1.00	0.000	NA[B]
Dyer	FHPT	9	1	196	0.995	0.946	0.999	0.866	0.213	0.987
Cottonwood Ranch	FHPT	3	1	37	0.972	0.759	0.997	0.449	0.000	0.929
Blue Hole	PT	7	2	129	0.984	0.940	0.996	0.640	0.176	0.894
Kearney Broadfoot South	FHILPT	8	1	177	0.994	0.941	0.999	0.852	0.180	0.985
Newark West	EFHLPT	3	0	54	0.999	0.000	NA	1.00	0.000	NA
Newark East	FHPT	11	1	260	0.996	0.959	0.999	0.897	0.310	0.990
Dippel (on-channel)	N	1	1	5	0.014	0.000	NA	0.000	0.000	NA
Leaman	FHLPT	1	0	27	0.999	0.000	NA	1.00	0.00	NA
Trust Wildrose East	N	1	0	26	0.999	0.000	NA	1.00	0.000	NA
All Sites		**48**	**8**	**1,020**	**0.992**	**0.984**	**0.996**	**0.800**	**0.640**	**0.895**

[A] Management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2022 herbicide (H), interior predator fencing (I), predator deterrent lights (L), no management (N), spring 2023 pre-emergent herbicide (P), or predator trapping (T).
[B] Confidence interval is not estimable due to either limited sample size or only one category of nest fate (successful or failed) at the site.

Table 9. Daily and incubation-period survival rates and 95% lower (LCI) and upper confidence intervals (LCI) for piping plover nests monitored on Program and non-Program OCSW sites and one on-channel site during 2023. Incubation-period nest survival rate = daily nest survival rate^{28}.

Ownership	No. Nests	No. Nests Failed	Exposure Days	Daily Nest Survival Rate	Daily Nest Survival Rate LCI	Daily Nest Survival Rate UCI	Incubation Period Survival Rate	Incubation Period Survival Rate LCI	Incubation Period Survival Rate UCI
Program[A]	39	6	837	0.993	0.965	0.999	0.816	0.367	0.960
Non-Program[B]	9	2	183	0.989	0.957	0.997	0.732	0.290	0.925
All Sites	**48**	**8**	**1,020**	**0.992**	**0.984**	**0.996**	**0.800**	**0.640**	**0.895**

[A] Program sites: OSG Lexington, Dyer, Cottonwood Ranch, Kearney Broadfoot South, Newark West, Newark East, Leaman, and Dippel.
[B] Non-Program sites: NPPD Lexington, Blue Hole, and Trust Wildrose East.

Table 10. Daily and brooding-period survival rates and 95% lower (LCI) and upper confidence intervals (LCI) for observed piping plover broods (≥1 chicks) monitored on OCSW sites during 2023. Brooding-period survival rate = daily brood survival rate^{28}.

Site	Management[A]	No. Broods	No. Broods Failed	Exposure Days	Daily Brood Survival Rate	Daily Brood Survival Rate LCI	Daily Brood Survival Rate UCI	Brooding Period Survival Rate	Brooding Period Survival Rate LCI	Brooding Period Survival Rate UCI
OSG Lexington	FHPT	2	1	43	0.976	0.720	0.998	0.509	0.000	0.958
NPPD Lexington	FPT	1	0	21	1.00	0.000	NA[B]	1.00	0.000	NA[B]
Dyer	FHPT	8	2	177	0.989	0.887	0.999	0.725	0.035	0.971
Cottonwood Ranch	FHPT	2	1	34	0.969	0.663	0.998	0.410	0.000	0.944
Blue Hole	PT	5	1	111	0.991	0.939	0.999	0.773	0.171	0.964
Kearney Broadfoot South	FHILPT	7	0	185	1.00	0.000	NA	1.00	0.000	NA
Newark West	EFHLPT	3	2	35	0.939	0.583	0.994	0.173	0.00	0.849
Newark East	FHPT	10	3	205	0.985	0.873	0.998	0.656	0.023	0.957
Leaman	FHLPT	1	1	3	0.001	0.000	NA	0.000	0.000	NA
Trust Wildrose East	N	1	0	20	1.00	0.000	NA	1.00	0.000	NA
All Sites		**40**	**11**	**834**	**0.987**	**0.976**	**0.993**	**0.685**	**0.506**	**0.811**

[A] Management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2022 herbicide (H), interior predator fencing (I), predator deterrent lights (L), no management (N), spring 2023 pre-emergent herbicide (P), or predator trapping (T).
[B] Confidence interval is not estimable due to either limited sample size or only one category of brood fate (successful or failed) at the site.

Table 11. Daily and brooding-period survival rates and 95% lower (LCI) and upper confidence intervals (LCI) for piping plover broods (≥1 chicks) monitored on Program and non-Program OCSW sites during 2023. Brooding-period survival rate = daily brood survival rate^{28}.

Ownership	No. Broods	No. Broods Failed	Exposure Days	Daily Brood Survival Rate	Daily Brood Survival Rate LCI	Daily Brood Survival Rate UCI	Brooding Period Survival Rate	Brooding Period Survival Rate LCI	Brooding Period Survival Rate UCI
Program[A]	33	10	682	0.984	0.843	0.999	0.643	0.009	0.963
Non-Program[B]	7	1	152	0.994	0.948	0.999	0.845	0.223	0.982
All Sites	**40**	**11**	**834**	**0.987**	**0.976**	**0.993**	**0.685**	**0.506**	**0.811**

[A] Program sites: OSG Lexington, Dyer, Cottonwood Ranch, Kearney Broadfoot South, Newark West, Newark East, and Leaman.
[B] Non-Program sites: NPPD Lexington, Blue Hole, and Trust Wildrose East.

Table 12. Piping plover incidental take at Program and non-Program sites during 2007–2023 under five take categories as specified by USFWS 2006 and USFWS 2018. Each cell in the table is shaded as white (no data available); green (below established limit for allowable take for a given year); or red (exceeded established limit for allowable take for a given year). Green shaded cells without values had no documented take.

Allowable Take[A]	First Increment Year													Extension Year			
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Inundating Flow																	
Inland Lakes																1[B]	
Habitat Restoration and Land Management								1[C]									
Research and Monitoring					1[D]		1[E]										
Percent of Nests and Chicks Observed at Site Lost Due to Predation[F]																	
Off-channel Sand and Water Nesting Sites – Nests: OSG Lexington																	
NPPD Lexington					17			20							20	29	
Dyer														21		36	11
Cottonwood Ranch								50									33
Blue Hole	17		20					13		38	8	25		14	43	20	14
Johnson				33							100						
Ed Broadfoot and Sons																	
Kearney Broadfoot South									31					11	31		
NAI Kearney Broadfoot South																	
Newark West									17						25	88	
Newark East														17		14	9
Leaman														50	100		
Trust Wildrose East										25		50					
Hooker Brothers Southeast																	

Table 12 continued		First Increment Year													Extension Year			
		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Chicks	OSG Lexington																	
	NPPD Lexington														20			
	Dyer								33									14
	Cottonwood Ranch																	
	Blue Hole												61					
	Johnson																	
	Ed Broadfoot and Sons																	
	Kearney Broadfoot South									6						16		
	NAI Kearney Broadfoot South																	
	Newark West															27	100	
	Newark East																	
	Leaman																	
	Trust Wildrose East																	
	Hooker Brothers Southeast																	

[A] For Allowable Take information see USFWS 2006, USFWS 2018, and USBR 2018.

[B] One plover nest containing four plover eggs was inundated at Lake Minatare on 6/5/2022 (PRRIP 2023).

[C] The Program observed one habitat restoration and land management plover chick mortality during 2014 due to electrocution in a predator deterrent fence (Cahis and Baasch 2015).

[D] The Program observed one research-related plover chick mortality during 2011 due to flushing the chick into the water where it was consumed by a fish (Baasch 2012).

[E] The Program observed one research-related plover chick mortality during 2013 due to a chick attempting to fly and landing into the water where it was consumed by a fish (Baasch 2014).

[F] As of 12/31/2016, a limited amount of predation was observed and did not exceed the Service's threshold at any Program owned or managed off-channel sand and water nesting site in any year (USBR 2018). Increased effort to monitor predator activities began in 2017, which has resulted in more documented predation than during the First Increment but losses to predation have not exceeded the Service's established threshold (i.e., the loss of 70% of nests or 80% of chicks to predation in three of five years for sites that average at least three plover nests).

Table 13. Summary of least tern reproductive effort and success at off-channel sand and water (OCSW) and river-island sites on the central Platte River in Nebraska, 2001–2009. Data collected during 2001–2009 used different monitoring protocols than 2010–2023. Changes adopted in 2010 included an increase of fledge age from 15 days to 21 days and an increase in monitoring effort.

	Least Tern								
Reproductive Parameter	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Maximum adult count	45	117	105	133	184	122	133	145	114
Peak Breeding Pair Estimate (BPE)	22	33	38	39	45	33	38	36	42
Total no. nests observed	27	39	49	48	56	49	49	55	54
No. of successful nests (≥1 egg hatched)	19	27	31	33	38	19	22	29	29
Apparent nest success	0.74	0.69	0.63	0.69	0.68	0.39	0.45	0.53	0.54
Daily nest survival rate	0.98	0.98	0.98	0.98	0.98	0.96	0.97	0.98	0.99[A]
Incubation period survival rate	0.70	0.70	0.62	0.70	0.70	0.46	0.55	0.61	0.73[A]
No. of broods observed	19	27	31	33	38	19	22	29	29
No. of chicks observed (<15 days)	44	65	62	72	73	38	49	59	68
Hatch ratio (<15-day chicks/nest)	1.56	1.67	1.27	1.50	1.30	0.78	1.00	1.07	1.26
Hatch ratio (<15-day chicks/BPE)	1.91	1.97	1.63	1.85	1.62	1.15	1.29	1.64	1.62
Chicks (≥15 days)	42	59	57	60	62	25	40	44	46
Fledglings (21 days)	---[B]	---	---	---	---	---	---	---	---
Historic fledge ratio (≥15-day chicks/nest)	1.56	1.51	1.16	1.25	1.11	0.51	0.82	0.80	0.85
Fledge ratio (21-day chicks/nest)	---	---	---	---	---	---	---	---	---
Historic fledge ratio (≥15-day chicks/BPE)	1.91	1.79	1.50	1.54	1.38	0.76	1.05	1.22	1.10
Fledge ratio (21-day chicks/BPE)	---	---	---	---	---	---	---	---	---
Daily brood survival rate	---	---	---	---	---	---	---	0.98	0.98[C]
Brooding period survival rate	---	---	---	---	---	---	---	0.75	0.79[C]

[A] Does not include reproductive information from Mormon Island.
[B] "---" denotes years for which indicated data were not collected.
[C] Does not include reproductive information from Dinan Island.

Table 14. Summary of least tern reproductive effort and success at off-channel sand and water (OCSW) and river-island sites on the central Platte River in Nebraska, 2010–2023. Data collected during 2010–2023 used different monitoring protocols than 2001–2009. Changes adopted in 2010 included an increase of fledge age from 15 days to 21 days and an increase in monitoring effort.

	Least Tern													
Reproductive Parameter	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Maximum adult count	170	150	137	197	260	262	200	159	174	169	158	166	188	157
Peak Breeding Pair Estimate (BPE)	53	62	66	65	94	141	88	77	88	95	84	84	85	90
Total no. nests observed	76	90	88	96	146	187	122	118	112	132	105	99	128	124
No. of successful nests (≥1 egg hatched)	48	52	63	51	82	116	77	63	79	67	74	64	86	83
Apparent nest success	0.63	0.58	0.72	0.53	0.56	0.62	0.63	0.53	0.71	0.51	0.70	0.65	0.67	0.67
Daily nest survival rate	0.98	0.97	0.99	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Incubation period survival rate	0.64	0.58	0.76	0.56	0.52	0.63	0.71	0.61	0.65	0.61	0.72	0.65	0.64	0.66
No. of broods observed	48	52	63	51	82	116	77	63	79	67	74	64	86	83
No. of chicks observed (<15 days)	122	125	144	118	180	258	170	129	168	137	160	158	196	207
Hatch ratio (<15-day chicks/nest)	1.61	1.39	1.64	1.23	1.23	1.38	1.39	1.09	1.50	1.04	1.52	1.60	1.53	1.67
Hatch ratio (<15-day chicks/BPE)	2.30	2.02	2.18	1.82	1.91	1.83	1.93	1.68	1.91	1.44	1.90	1.88	2.31	2.30
Chicks (≥15 days)	76	101	95	70	104	158	91	78	117	74	107	100	141	126
Fledglings (21 days)	75	96	84	64	91	146	80	76	117	71	107	102	143	124
Historic fledge ratio (≥15-day chicks/nest)	1.00	1.12	1.08	0.73	0.71	0.84	0.75	0.66	1.04	0.56	1.02	1.01	1.10	1.02
Fledge ratio (21-day chicks/nest)	0.99	1.07	0.95	0.67	0.62	0.78	0.66	0.64	1.04	0.54	1.02	1.03	1.12	1.00
Historic fledge ratio (≥15-day chicks/BPE)	1.43	1.63	1.44	1.08	1.11	1.12	1.03	1.01	1.33	0.78	1.27	1.19	1.66	1.40
Fledge ratio (21-day chicks/BPE)	1.42	1.55	1.27	0.98	0.97	1.04	0.91	0.99	1.33	0.75	1.27	1.21	1.68	1.38
Daily brood survival rate	0.98	0.99	0.99	0.97	0.98	0.98	0.98	0.97	0.97	0.97	0.98	0.99	0.99	0.99
Brooding period survival rate	0.72	0.89	0.81	0.59	0.69	0.68	0.61	0.56	0.57	0.57	0.70	0.77	0.84	0.85

Table 15. Site-specific numbers of adults, nests, chicks, and fledglings observed while monitoring off-channel sand and water (OCSW) nesting sites for least tern reproduction during 2023. Numbers of estimated breeding pairs (BPE), apparent nest success, fledge ratios, and survey effort are provided for each site. Site numbers correspond with Figure 2.

				Least Tern										
Site Name and No.	**Management[A]**	**No. Surveys**	**Hours of Observation**	**Peak BPE (AHR peak date[B])**	**Peak BPE (Site peak date[C])**	**Adult Counts**	**No. Nests**	**No. Nests Hatched**	**No. Chicks 0–14 days**	**No. Chicks 15–21 days**	**No. Fledglings**	**Apparent Nest Success**	**Fledge Ratio (AHR peak date[B])**	**Fledge Ratio (Site peak date[C])**
1. OSG Lexington	FHPT	31	21	2	9	14	11	2	3	3	2	0.18	1.00	0.22
2. NPPD Lexington	FPT	21	25	0	0	4	0	0	0	0	0	---[D]	---	---
3. Dyer	FHPT	30	24	12	12	20	14	8	19	19	19	0.57	1.58	1.58
4. Cottonwood Ranch	FHPT	31	20	6	6	13	6	6	18	17	17	1.00	2.83	2.83
5. T&F Lakeside	N	6	3	0	0	0	0	0	0	0	0	---	---	---
6. Blue Hole	PT	36	57	13	16	24	20	11	25	15	17	0.55	1.31	1.06
7. Johnson	FP	5	3	0	0	0	0	0	0	0	0	---	---	---
8. Ed Broadfoot and Sons	N	10	6	0	0	0	0	0	0	0	0	---	---	---
9. Kearney Broadfoot South	FHILPT	27	21	12	15	18	18	11	29	9	8	0.61	0.67	0.53
10. NAI Kearney Broadfoot South	T	10	6	0	0	0	0	0	0	0	0	---	---	---
11. Newark West	EFHLPT	32	15	4	4	8	5	5	14	8	8	1.00	2.00	2.00
12. Newark East	FHPT	37	27	34	35	41	41	34	84	44	45	0.83	1.32	1.29
13. Leaman	FHLPT	25	13	0	0	2	0	0	0	0	0	---	---	---
14. Trust Wildrose East	N	20	10	0	0	0	0	0	0	0	0	---	---	---
15. Follmer	HPT	7	3	0	0	0	0	0	0	0	0	---	---	---
16. DeWeese	N	7	3	0	0	0	0	0	0	0	0	---	---	---
17. Hooker Brothers Southeast	N	34	17	7	7	11	9	6	15	11	8	0.67	1.14	1.14
18. Hooker Brothers East	N	7	3	0	0	0	0	0	0	0	0	---	---	---

[A] Management actions include: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2022 herbicide (H), interior predator fencing (I), predator deterrent lights (L), no management (N), spring 2023 pre-emergent herbicide (P), or predator trapping (T). See the Management Section of this report for a detailed description of management actions taken at each site.

[B] Peak estimated number of breeding pairs (BPE) at each site as calculated using the Program's BPE calculator (pg. 9 of this report) on 24 June, when numbers of least tern breeding pairs observed within the entire Program Associated Habitat Reach first peaked.

[C] Peak BPE (site peak date) represents the highest number of estimated pairs at a site during the nesting season, regardless of AHR Peak Breeding Pair dates.

[D] "---"Denotes cannot be calculated.

Table 16. Peak estimated number of breeding pairs (BPE), number of nests and successful nests, and productivity by year for least terns at off-channel sand and water (OCSW) sites along the central Platte River in Nebraska, 2001–2023. The mean for each metric during 2001–2023 is provided at the bottom of the table.

			Least Tern		
Year	**Off-Channel Peak BPE[A]**	**No. Nests**	**No. Successful Nests**	**No. Fledglings[B]**	**Fledges Per Peak BPE[AB]**
2001	22	27	20	45	2.05
2002	33	39	27	59	1.79
2003	38	49	31	57	1.50
2004	39	48	33	60	1.54
2005	45	56	38	62	1.38
2006	33	49	19	25	0.76
2007	30	36	20	38	1.27
2008	26	35	21	35	1.35
2009	38	46	24	42	1.11
2010	53	76	48	75	1.42
2011	62	90	52	96	1.55
2012	66	88	63	84	1.27
2013	65	96	51	64	0.98
2014	94	143	82	91	0.97
2015	133	174	113	146	1.10
2016	86	117	74	80	0.93
2017	77	118	63	76	0.99
2018	88	112	79	117	1.33
2019	95	132	67	71	0.75
2020	84	105	74	107	1.27
2021	84	99	64	102	1.21
2022	85	128	86	143	1.68
2023	90	124	83	124	1.38
Mean	**63.7**	**86.4**	**53.6**	**78.2**	**1.28**

[A] BPE represents the peak recorded at off-channel sites. Peak BPE dates differ on-channel and off-channel and each may differ from the overall AHR peak BPE.
[B] The dotted black line represents a change in protocol between 2009 and 2010. Among other changes, in 2010 the Program began to use 21 days as the fledge age for least tern chicks rather than the previous 15-day success to fledge interval.
[C] "---" denotes fledge ratios cannot be calculated for years when there were no breeding pairs and are not included in calculation of the mean.

Table 17. Peak estimated number of breeding pairs (BPE), number of nests and successful nests, and productivity by year for least terns at on-channel island sites on the central Platte River in Nebraska, 2001–2023. The mean for each metric during 2001–2023 is provided at the bottom of the table.

			Least Tern		
Year	**On-Channel Peak BPE**[A]	**No. Nests**	**No. Successful Nests**	**No. Fledglings**[B]	**Fledglings Per Peak BPE**[AB]
2001	0	0	0	0	---[C]
2002	0	0	0	0	---
2003	0	0	0	0	---
2004	0	0	0	0	---
2005	0	0	0	0	---
2006	0	0	0	0	---
2007	11	13	2	2	0.18
2008	10	20	8	9	0.90
2009	6	8	5	4	0.67
2010	0	0	0	0	---
2011	0	0	0	0	---
2012	0	0	0	0	---
2013	0	0	0	0	---
2014	2	2	0	0	0.00
2015	8	14	3	0	0.00
2016	2	2	0	0	0.00
2017	0	0	0	0	---
2018	0	0	0	0	---
2019	0	0	0	0	---
2020	0	0	0	0	---
2021	0	0	0	0	---
2022	0	0	0	0	---
2023	0	0	0	0	---
Mean	**1.70**	**2.57**	**0.78**	**0.65**	**0.29**

[A] BPE represents the peak recorded at sites on the river channel. Peak BPE dates differ on-channel and off-channel and each may differ from the overall AHR peak BPE.

[B] The dotted black line represents a change in protocol between 2009 and 2010. Among other changes, in 2010 the Program began to use 21 days as the fledge age for least tern chicks rather than the previous 15-day success to fledge interval.

[C] "---" denotes fledge ratios cannot be calculated for years when there were no breeding pairs and are not included in calculation of the mean.

Table 18. Number of least tern adults, estimated number of least tern breeding pairs (BPE), and numbers of least tern nests, chicks, and fledglings documented from outside the nesting area (i.e., outside monitoring) during semi-monthly off-channel sand and water (OCSW) site surveys in 2023.

			Least Tern		
Survey Date	**No. Adults**	**BPE[A]**	**No. Nests**	**No. Chicks**	**No. Fledglings**
1 May	0	0	0	0	0
15 May	14	0	0	0	0
1 June	97	59	51	0	0
15 June	115	74	67	13	0
1 July	103	87	31	90	0
15 July	55	81	8	33	10
1 August	19	66	0	14	5

[A] BPE represents the estimated number of breeding pairs present on OCSW sites on 1 and 15 May, 1 and 15 June, 1 and 15 July, and 1 August. Breeding pair counts were obtained using the Program's BPE calculator (pg. 9). Number of nests may be different from breeding pairs because semi-monthly surveys occurred over several days and breeding pair counts were determined on the 1st or 15th of the month.

Table 19. Number of least tern adults, estimated number of least tern breeding pairs (BPE), and numbers of least tern nests, chicks, and fledglings observed during semi-monthly airboat surveys of the Platte River between Lexington and Chapman, Nebraska, in 2023.

			Least Tern		
Survey Date	**No. Adults**	**BPE[A]**	**No. Nests**	**No. Chicks**	**No. Fledglings**
1 May	0	0	0	0	0
15 May [B]	33	0	0	0	0
1 June	26	0	0	0	0
15 June	16	0	0	0	0
1 July [C]	16	0	0	0	0
15 July [B]	36	0	0	0	16
1 August [B]	43	0	0	0	57

[A] BPE represents the estimated number of breeding pairs present on river islands on 1 and 15 May, 1 and 15 June, 1 and 15 July, and 1 August. Breeding pair counts were obtained using the Program's BPE calculator (pg. 9). Number of nests may be different from breeding pairs because semi-monthly surveys occurred over several days and breeding pair counts were determined on the 1st or 15th of the month.

[B] Some river sections not completed due to lack of flow in the channel that prevented access by airboat. Point counts at predefined locations (e.g., bridges) were conducted instead.

[C] Surveys were conducted by point counts at predefined locations due to high flow that resulted in safety concerns for use of boat.

Table 20. Daily and incubation-period survival rates and 95% lower (LCI) and upper confidence intervals (LCI) for least tern nests monitored on OCSW sites during 2023. Incubation-period nest survival rate = daily nest survival rate^{21}.

Site	Management[A]	No. Nests	No. Nests Failed	Exposure Days	Daily Nest Survival Rate	Daily Nest Survival Rate		Incubation Period Survival Rate	Incubation Period Survival Rate	
						LCI	UCI		LCI	UCI
OSG Lexington	FHPT	11	9	112	0.908	0.796	0.962	0.132	0.008	0.438
Dyer	FHPT	14	6	285	0.978	0.941	0.992	0.630	0.280	0.847
Cottonwood Ranch	FHPT	6	0	130	1.00	0.000	NA[B]	1.00	0.000	NA[B]
Blue Hole	PT	20	9	316	0.970	0.945	0.984	0.532	0.302	0.719
Kearney Broadfoot South	FHILPT	18	7	302	0.976	0.939	0.991	0.604	0.264	0.828
Newark West	EFHLPT	5	0	94	1.00	0.000	NA	1.00	0.000	NA
Newark East	FHPT	41	7	779	0.991	0.976	0.997	0.825	0.600	0.931
Hooker Brothers Southeast	N	9	3	137	0.977	0.921	0.994	0.618	0.179	0.877
All Sites		**124**	**41**	**2,155**	**0.980**	**0.974**	**0.986**	**0.661**	**0.571**	**0.736**

[A] Management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2022 herbicide (H), interior predator fencing (I), predator deterrent lights (L), no management (N), spring 2023 pre-emergent herbicide (P), or predator trapping (T).
[B] Confidence interval is not estimable due to either limited sample size or only one category of nest fate (successful or failed) at the site.

Table 21. Daily and incubation-period survival rates and 95% lower (LCI) and upper confidence intervals (LCI) for least tern nests monitored on Program and non-Program OCSW sites during 2023. Incubation-period nest survival rate = daily nest survival rate^{21}.

Ownership	No. Nests	No. Nests Failed	Exposure Days	Daily Nest Survival Rate	Daily Nest Survival Rate		Incubation Period Survival Rate	Incubation Period Survival Rate	
					LCI	UCI		LCI	UCI
Program[A]	95	29	1,839	0.983	0.966	0.991	0.691	0.488	0.827
Non-Program[B]	29	12	316	0.972	0.953	0.984	0.557	0.360	0.716
All Sites	**124**	**41**	**2,155**	**0.980**	**0.974**	**0.986**	**0.661**	**0.571**	**0.736**

[A] Program sites: OSG Lexington, Dyer, Cottonwood Ranch, Kearney Broadfoot South, Newark West, and Newark East.
[B] Non-Program sites: Blue Hole and Hooker Brothers Southeast.

Table 22. Daily and brooding-period survival rates and 95% lower (LCI) and upper confidence intervals (LCI) for observed least tern broods (≥1 chicks) monitored on OCSW sites during 2023. Brooding-period survival rate = daily brood survival rate^{21}.

Site	Management[A]	No. Broods	No. Broods Failed	Exposure Days	Daily Brood Survival Rate	Daily Brood Survival Rate		Brooding Period Survival Rate	Brooding Period Survival Rate	
						LCI	UCI		LCI	UCI
OSG Lexington	FHPT	2	0	38	1.00	0.000	NA[B]	1.00	0.000	NA[B]
Dyer	FHPT	8	0	147	1.00	0.000	NA	1.00	0.000	NA
Cottonwood Ranch	FHPT	6	0	115	1.00	0.000	NA	1.00	0.000	NA
Blue Hole	PT	11	2	179	0.994	0.961	0.999	0.889	0.437	0.984
Kearney Broadfoot South	FHILPT	11	6	152	0.959	0.736	0.995	0.414	0.002	0.898
Newark West	EFHLPT	5	2	69	0.970	0.745	0.997	0.529	0.002	0.944
Newark East	FHPT	34	9	539	0.985	0.891	0.998	0.728	0.088	0.961
Hooker Brothers Southeast	N	6	0	118	1.00	0.000	NA	1.00	0.000	NA
All Sites		**83**	**19**	**1,357**	**0.992**	**0.973**	**0.998**	**0.852**	**0.565**	**0.956**

[A] Management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2022 herbicide (H), interior predator fencing (I), predator deterrent lights (L), no management (N), spring 2023 pre-emergent herbicide (P), or predator trapping (T).
[B] Confidence interval is not estimable due to either limited sample size or only one category of brood fate (successful or failed) at the site.

Table 23. Daily and brooding-period survival rates and 95% lower (LCI) and upper confidence intervals (LCI) for least tern broods (≥1 chicks) monitored on Program and non-Program OCSW sites during 2023. Brooding-period survival rate = daily brood survival rate^{21}.

Ownership	No. Broods	No. Broods Failed	Exposure Days	Daily Brood Survival Rate	Daily Brood Survival Rate		Brooding Period Survival Rate	Brooding Period Survival Rate	
					LCI	UCI		LCI	UCI
Program[A]	66	17	1,178	0.988	0.881	0.999	0.774	0.069	0.977
Non-Program[B]	17	2	179	0.997	0.973	1.00	0.946	0.568	0.995
All Sites	**83**	**19**	**1,357**	**0.992**	**0.973**	**0.998**	**0.852**	**0.565**	**0.956**

[A] Program sites: OSG Lexington, Dyer, Cottonwood Ranch, Kearney Broadfoot South, Newark West, and Newark East.
[B] Non-Program sites: Blue Hole and Hooker Brothers Southeast.

Table 24. Number of traps by trap type deployed for terrestrial predator trapping at 10 Program and Nebraska Public Power District owned piping plover and least tern off-channel sand and water (OCSW) nesting sites during late March through early August 2023.

Site	Management[A]	Trap Type No. Cage Traps	No. Dog Proof Traps	No. Leg Hold Traps	No. Snare Traps	Total No. Traps
OSG Lexington	FHPT	12	16	4	0	28
NPPD Lexington	FPT	9	12	0	0	21
Dyer	FHPT	10	18	0	2	30
Cottonwood Ranch	FHPT	10	16	0	0	26
Blue Hole	PT	4	15	6	0	25
Kearney Broadfoot South	FHILPT	10	12	0	0	22
Newark West	EFHLPT	10	14	0	10	34
Newark East	FHPT	9	18	0	0	27
Leaman	FHLPT	9	12	0	0	21
Follmer	HPT	10	0	0	0	10
Total		**93**	**133**	**10**	**12**	**244**

[A] Management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2022 herbicide (H), interior predator fencing (I), predator deterrent lights (L), spring 2023 pre-emergent herbicide (P), and predator trapping (T).

Table 25. Summary of terrestrial predator trapping activities at 10 Program and Nebraska Public Power District owned piping plover and least tern off-channel sand and water (OCSW) nesting sites during late March through early August 2023. Provided for each site are the total number of trap days and corresponding total number of captures based on the total number of days each trap was deployed.

Site	Management[A]	No. Traps Deployed	Total No. Trap Days	Total No. Captures	Captures / Trap Day
OSG Lexington	FHPT	28	2,571	22	0.009
NPPD Lexington	FPT	21	1,373	19	0.014
Dyer	FHPT	30	4,033	56	0.014
Cottonwood Ranch	FHPT	26	3,511	61	0.017
Blue Hole[B]	PT	25	2,462	16	0.006
Kearney Broadfoot South	FHILPT	22	2,713	38	0.014
Newark West[B]	EFHLPT	34	4,417	40	0.009
Newark East	FHPT	27	3,841	37	0.010
Leaman	FHLPT	21	2,416	13	0.005
Follmer	HPT	10	1,026	8	0.008
Total[B]		**244**	**28,363**	**310**	**0.011**

[A] Management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2022 herbicide (H), interior predator fencing (I), predator deterrent lights (L), spring 2023 pre-emergent herbicide (P), and predator trapping (T).
[B] Removed two bull snakes at Blue Hole and one woodchuck at Newark West with a firearm. These captures were included in total captures, but not included in calculation of captures/trap day.

Table 26. Summary of terrestrial predator trapping activities at 10 Program and Nebraska Public Power District owned piping plover and least tern off-channel sand and water (OCSW) nesting sites during late March through early August 2023. Provided for each site are the numbers of each species captured, total number of captures at the site, total number of trap days, and number of captures per trap day.

Site	Management[A]	Badger	Beaver	Bull snake	Coyote	Opossum	Raccoon	Red fox	River otter	Striped skunk	Woodchuck	No. Captures	Trap Days	Captures / Trap Day
		Species Captured												
OSG Lexington	FHPT	0	0	0	4	0	16	2	0	0	0	22	2,571	0.009
NPPD Lexington	FPT	0	0	0	0	0	19	0	0	0	0	19	1,373	0.014
Dyer	FHPT	0	0	0	0	5	49	0	2	0	0	56	4,033	0.014
Cottonwood Ranch	FHPT	0	1	0	0	0	60	0	0	0	0	61	3,511	0.017
Blue Hole[B]	PT	0	0	2	1	1	12	0	0	0	0	16	2,462	0.006
Kearney Broadfoot South	FHILPT	0	1	0	0	0	37	0	0	0	0	38	2,713	0.014
Newark West[B]	EFHLPT	0	0	0	0	2	36	0	0	0	2	40	4,417	0.009
Newark East	FHPT	1	0	0	0	0	35	0	0	1	0	37	3,841	0.010
Leaman	FHLPT	0	0	0	0	1	12	0	0	0	0	13	2,416	0.005
Follmer	HPT	0	0	0	0	1	7	0	0	0	0	8	1,026	0.008
Total[B]		**1**	**2**	**2**	**5**	**10**	**283**	**2**	**2**	**1**	**2**	**310**	**28,363**	**0.011**

[A] Management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2022 herbicide (H), interior predator fencing (I), predator deterrent lights (L), spring 2023 pre-emergent herbicide (P), and predator trapping (T).

[B] Removed two bull snakes at Blue Hole and one woodchuck at Newark West with a firearm. These captures were included in total captures, but not included in calculation of captures/trap days.

Table 27. Total number of terrestrial predators captured by species and trap type at 10 Program and Nebraska Public Power District owned piping plover and least tern off-channel sand and water (OCSW) nesting sites during late March through early August 2023.

Species	No. Captures by Trap Type				Total No. Captures
	Cage Trap	Dog Proof Trap	Firearm[A]	Leg Hold / Snare	
Badger	1	0	0	0	1
Beaver	2	0	0	0	2
Bull snake	0	0	2	0	2
Coyote	0	0	0	5	5
Opossum	5	2	0	3	10
Raccoon	86	192	0	5	283
Red fox	0	0	0	2	2
River otter	1	0	0	1	2
Striped skunk	1	0	0	0	1
Woodchuck	0	0	1	1	2
Total	**96**	**194**	**3**	**17**	**310**

[A] Removed two bull snakes at Blue Hole and one woodchuck at Newark West with a firearm. These captures were included in total captures, but not included in calculation of captures/trap days.

Table 28. Summary of weekly track surveys conducted at six piping plover and least tern off-channel sand and water (OCSW) nesting sites during May through August 2023. The six nesting sites were located along the Platte River between Overton and Wood River, Nebraska.

Nesting Site	Management[A]	Total No. Track Surveys	Total Unique Track Registers	Track Registers / Survey
Dyer	FHPT	16	53	3.31
Cottonwood Ranch	FHPT	16	34	2.13
Kearney Broadfoot South	FHILPT	14	48	3.43
Newark West	EFHLPT	16	28	1.75
Newark East	FHPT	18	42	2.33
Leaman	FHLPT	12	17	1.42
Total		**92**	**222**	**2.41**

[A] Management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2022 herbicide (H), interior predator fencing (I), predator deterrent lights (L), no management (N), spring 2023 pre-emergent herbicide (P), and predator trapping (T).

Table 29. Summary of registers of potential predator species captured by shoreline cameras deployed at six off-channel sand and water (OCSW) piping plover and least tern nesting sites during May through August 2023. The six nesting sites were located along the Platte River between Overton and Wood River, Nebraska.

Nesting Site	Management[A]	No. of Shoreline Cameras	Total No. Shoreline Camera Days[B]	Total No. Unique Predator Registers	Unique Registers / Camera Day
Dyer	FHPT	6	739	129	0.175
Cottonwood Ranch	FHPT	4	478	65	0.136
Kearney Broadfoot South	FHILPT	7	722	186	0.258
Newark West	EFHLPT	4	482	183	0.380
Newark East	FHPT	5	602	142	0.236
Leaman	FHLPT	3	324	97	0.299
Total		**29**	**3,347**	**802**	**0.240**

[A] Management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2022 herbicide (H), interior predator fencing (I), predator deterrent lights (L), no management (N), spring 2023 pre-emergent herbicide (P), and predator trapping (T).
[B] Individual cameras were not functioning for a total of 17 days at Dyer; 22 days at Cottonwood Ranch; 62 days at Kearney Broadfoot South; 14 days at Newark West; and 93 days at Newark East.

Table 30. Summary of registers of potential predator species captured by site-level cameras deployed at six off-channel sand and water (OCSW) piping plover and least tern nesting sites during May through August 2023. The six nesting sites were located along the Platte River between Overton and Wood River, Nebraska.

Nesting Site	Management[A]	No. Site-level Cameras	Total No. Site-level Camera Days	Total No. Unique Predator Registers	Unique Registers / Camera Day
Dyer	FHPT	5	630	44	0.070
Cottonwood Ranch	FHPT	4	500	33	0.066
Kearney Broadfoot South	FHILPT	5	560	9	0.016
Newark West	EFHLPT	3	372	43	0.116
Newark East	FHPT	5	686	44	0.064
Leaman	FHLPT	3	336	50	0.149
Total		**25**	**3,084**	**223**	**0.072**

[A] Management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2022 herbicide (H), interior predator fencing (I), predator deterrent lights (L), no management (N), spring 2023 pre-emergent herbicide (P), and predator trapping (T).

[B] Individual cameras were not functioning for a total of nine days at Newark East.

Table 31. Summary of nest-level camera monitoring effort and registers of predation events captured by cameras deployed at piping plover and least tern nests at six off-channel sand and water (OCSW) nesting sites during May through August 2023. One camera was deployed at a piping plover nest located on an island in the river channel (Dippel). The seven nesting sites were located along the Platte River between Overton and Wood River, Nebraska.

Nesting Site	Management[A]	No. of Nest Cameras Allocated to Site	Max No. of Nest Cameras Used Concurrently	No. of Nests Monitored	Total No. Nest Camera Days	Total Unique Predation Events	Unique Predation Events / Camera Day
Dyer	FHPT	10	8	19	246	3	0.012
Cottonwood Ranch	FHPT	8	4	8	99	1	0.010
Kearney Broadfoot South	FHILPT	8	10[B]	14	265	1	0.004
Newark West	EFHLPT	7	4	4	57	0	0.000
Newark East	FHPT	8	9[C]	25	410	1	0.002
Leaman	FHLPT	5	1	1	30	0	0.000
Dippel (On-Channel)	N	1	1	1	5	1	0.200
Total		**47**	**37**	**72**	**1,112**	**7**	**0.006**

[A] Management actions applied to each site: disking (D), exterior predator fencing (E), peninsula entry predator fencing (F), fall 2022 herbicide (H), interior predator fencing (I), predator deterrent lights (L), no management (N), spring 2023 pre-emergent herbicide (P), or predator trapping (T).
[B] Ten nest-level cameras were deployed for one day at Kearney Broadfoot South. For all other days of monitoring, eight or fewer cameras were simultaneously in use.
[C] Nine cameras were deployed for a total of eight days at Newark East due to availability of cameras on other sites with few nests.

Table 32. Summary of numbers of unique predator registers and predation events at piping plover and least tern nests monitored by cameras during May through August 2023. Nest-level cameras were deployed at six off-channel sand and water (OCSW) nesting sites and one island in the river channel (Dippel). The seven nesting sites were located along the Platte River between Overton and Wood River, Nebraska.

Site	Date	Nest ID	Target Species Nest	Predator Type	Predator Species	Unique Predator Register[A]	Unique Predation Event[B]	Unique Predation Event Not Captured on Camera[C]	No. of Individual Predated Nests[D]	Total Unique Events[E]
Dyer	15 May	O-DS-01-23	Plover	Avian	Great horned owl	1				1
Dyer	10 Jun	O-DS-02-23	Plover	Avian	Great horned owl	1				1
Dyer	8 Jun	O-DS-05-23	Plover	Avian	Great horned owl	1				1
Dyer	18 Jun	O-DS-09-23	Tern	Avian	Great horned owl			1	1	1
Dyer	20 Jun	O-DS-06-23	Plover	Avian	Great horned owl		1[F]		1[F]	1
Dyer	22 Jun	O-DS-13-23	Plover	Avian	Great horned owl		1		1	1
Dyer	9 Jul	O-DS-22-23	Tern	Avian	Great horned owl		1		1	1
Dyer	18 Jul	O-DS-23-23	Tern	Avian	Great horned owl			1	1	1
Cottonwood Ranch	30 May	O-CWR-02-23	Plover	Reptilian	Bullsnake		1		1	1
Kearney Broadfoot South	22 May	O-BFS-02-23	Plover	Mammalian	Mouse	1				1
Kearney Broadfoot South	30 May	O-BFS-06-23	Plover	Avian	European starling	1				1

Kearney Broadfoot South	22 Jul	O-BFS-24-23	Tern	Avian	Canada goose		1		1	1
Dippel	2 Jun	O-DI-01-23	Plover	Mammalian	Raccoon	1				1
Dippel	4 Jun	O-DI-01-23	Plover	Avian	Bald eagle (juvenile)	1				1
Dippel	6 Jun	O-DI-01-23	Plover	Mammalian	Raccoon		1		1	1
Newark East	14 May	O-NE-03-23	Plover	Avian	European starling	1				1
Newark East	16 May	O-NE-02-23	Plover	Avian	European starling	1				1
Newark East	18 May	O-NE-02-23	Plover	Avian	European starling	1				1
Newark East	21 May	O-NE-02-23	Plover	Avian	Crow	1				1
Newark East	28 May	O-NE-05-23	Plover	Avian	European starling	1				1
Newark East	28 May	O-NE-07-23	Tern	Reptilian	Bullsnake			1	1	1
Newark East	11 Jun	O-NE-09-23	Plover	Mammalian	Coyote		1		1	1
			TOTAL			**12**	**7**	**3**	**10[F]**	**22**

[A] Predator species registered on the nest camera because they approached the nest and left without predating the nest (i.e., did not consume the eggs and/or chicks in the nest bowl).
[B] Predator predated the nest (i.e., consumed the eggs and/or chicks in the nest bowl).
[C] Predation event not documented due to camera malfunction, but nest was determined predated by using information from all predator monitoring methods (refer to pg. 24).
[D] Number of individual nests that were predated. This accounts for predation that occurred at multiple nests by the same predator species, within 24 hrs. at one nesting site.
[E] The sum of unique predator registers, predation events, and predation events not captured on nest camera.
[F] Nest predation occurred on one egg remaining after nest had successfully hatched chicks and chicks had left nest with adults for the night.

Table 33. Nest fate comparisons for piping plover and least tern nests that were and were not monitored by remote cameras during 2023 at six off-channel sand and water sites and one island (Dippel) in the Platte River channel. All monitoring sources (i.e., outside/inside observers; nest, site, and shoreline camera data; and track surveys) were used to determine nest fates. The seven nesting sites were located along the Platte River between Overton and Wood River, Nebraska.

Site	No. Nests		No. Successful Nests		No. Successful Nests w/Predation[A]		No. Nests Failed-Predation		No. Nests Failed-Unknown		No. Nests Failed-Abandoned		No. Nests Failed-Weather		Unknown Outcome	
	Camera	No Camera	Camera	No Camera	Camera	No Camera	Camera	No Camera	Camera	No Camera	Camera	No Camera	Camera	No Camera	Camera	No Camera
Piping Plover																
Dyer	9		7		1		1									
Cottonwood	3		2				1									
Kearney Broadfoot South	7	1	6	1							1					
Newark West	3		3													
Newark East	11		10				1									
Leaman	1		1													
Dippel On-Channel	1						1									
Total Plover	**35**	**1**	**29**	**1**	**1**	**0**	**4**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**
Least Tern																
Dyer	10	4	6	2			2	1					1		1	1
Cottonwood	5	1	5	1												
Kearney Broadfoot South	7	11	6	5			1			6						
Newark West	1	4	1	4												
Newark East	14	27	11	23			1		1	3	1	1				
Leaman																
Total Tern	**37**	**47**	**29**	**35**	**0**	**0**	**4**	**1**	**1**	**9**	**1**	**1**	**1**	**0**	**1**	**1**
Overall Totals	**72**	**48**	**58**	**36**	**1**	**0**	**8**	**1**	**1**	**9**	**2**	**1**	**1**	**0**	**1**	**1**

[A] Predation occurred at successful nests while eggs and chicks were present in the nest bowl.

Table 34. Nest, egg, and chick fates for piping plover and least tern nests that were monitored by remote cameras during 2023 at six off-channel sand and water sites and one island (Dippel) in the Platte River channel. All monitoring sources (i.e., outside/inside observers; nest, site, and shoreline camera data; and track surveys) were used to determine nest, egg, and chick fates. The seven nesting sites were located along the Platte River between Overton and Wood River, Nebraska.

	Nests			Eggs						Chicks			
Nesting Site	**No. Monitored**	**No. Successful**	**Total No. Camera Days**	**No. Laid**	**No. Hatch**	**No. Predated[A]**	**No. Unknown Fate**	**No. Failed-Weather**	**No. Abandoned[B]**	**No. Left Nest**	**No. Mortality-Predated**	**No. Mortality-Weather**	**No. Unknown Fate[C]**
Piping Plover													
Dyer	9	8	152	35	28	5			2	28			
Cottonwood Ranch	3	2	34	10	5	4			1	5			
Kearney Broadfoot South	7	6	158	27	22				5	22			
Newark West	3	3	39	12	9		2		1	7			2
Newark East	11	10	235	44	36	4	1		3	31		2	3
Leaman	1	1	30	4	4					4			
Dippel On-Channel	1		5	4		4							
Total Plover	**35**	**30**	**653**	**136**	**104**	**17**	**3**	**0**	**12**	**97**	**0**	**2**	**5**
Least Tern													
Dyer	10	6	94	26	14	8	1	2	1	14			
Cottonwood Ranch	5	5	65	15	15					12			3
Kearney Broadfoot South	7	6	107	18	15	2			1	15			
Newark West	1	1	18	3	3					3			
Newark East	14	12	175	39	32	3			4	28			4
Leaman													
Total Tern	**37**	**30**	**459**	**101**	**79**	**13**	**1**	**2**	**6**	**72**	**0**	**0**	**7**
Overall Total	**72**	**59**	**1,112**	**237**	**183**	**30**	**4**	**2**	**18**	**169**	**0**	**2**	**12**

[A] One predated plover egg came from a successful nest.
[B] Nine abandoned plover eggs and four abandoned tern eggs came from successful nests.
[C] Unknown if chicks successfully left the nest or suffered mortality before fledging because it was not documented on camera.

Table 35. Summary of predation events on piping plover and least tern nests that were monitored by remote cameras during 2023 at six off-channel sand and water sites and one island (Dippel) in the Platte River channel. Provided for each predated nest are the: predator species, nest status when predation occurred, development stage of the nest when predation occurred, number of predated eggs or chicks, and estimated day of incubation when the predation occurred. Percent incubation completed was calculated based on an assumed 28-day incubation period for piping plovers and 21-day incubation period for least terns. Tern nest ID O-DS-09-23 was not monitored by a camera and is not listed below, although it was assumed it depredated by a great horned owl near the end of the incubation period.

Nesting Site	Target Species	Nest ID	Predator Species	Nest Status When Predated	Developmental Stage when Predation Occurred	No. of Predated Eggs (Chicks)	Incubation Day when Predation Occurred	Percent Incubation Completed
Dyer	Plover	O-DS-06-23	Great horned owl	Successful	Eggs	1	30	100%
Dyer	Plover	O-DS-13-23	Great horned owl	Active	Eggs	4	23	82%
Dyer	Tern	O-DS-22-23	Great horned owl	Active	Eggs	3	5	24%
Dyer	Tern	O-DS-23-23[A]	Great horned owl	Active	Eggs	2	6	29%
Cottonwood Ranch	Plover	O-CWR-02-23	Bullsnake	Active	Eggs	4	7	25%
Kearney Broadfoot South	Tern	O-BFS-24-23	Canada goose	Active	Eggs	2	16	76%
Newark East	Tern	O-NE-07-23[A]	Bullsnake	Active	Eggs	3	7	33%
Newark East	Plover	O-NE-09-23	Coyote	Active	Eggs	4	21	75%
Dippel On-Channel	Plover	O-DI-01-23	Raccoon	Active	Eggs	4	6	21%
Average Incubation Completed for Piping Plovers							**17.4**	**62.1%**
Average Incubation Completed for Least Terns							**8.5**	**40.5%**

[A] Includes data from indicated nests where least tern nest/eggs were predated but the individual predator or predation event was not captured on camera because the camera malfunctioned (refer to pg. 24 for evidence).

Table 36. Covariate coefficient estimates, associated standard errors, and P-values for a model examining effects of nest cameras and site on daily survival rates of piping plover and least tern nests at four off-channel sand and water sites adjacent to the Platte River. Nest data from the Leaman site was not included in the model due to low sample size. Nest data from the Newark West site was not included in the model due to all four nests with cameras and all four nests without cameras being successful.

Covariate	Estimate	Standard Error	P-value
[a]Intercept (Site = Dyer)	3.83	0.715	<0.001
Camera = yes	0.478	0.845	0.571
Site = Cottonwood Ranch	13.9	133	0.917
Site = Kearney Broadfoot South	-0.509	0.827	0.539
Site = Newark East	1.09	0.874	0.212
Camera(yes)*Site(Cottonwood Ranch)	-13.2	133	0.921
Camera(yes)*Site(Kearney Broadfoot South)	1.20	1.18	0.309
Camera(yes)*Site(Newark East)	-0.629	1.10	0.569

[a] Intercept term includes Site = Dyer

FIGURES

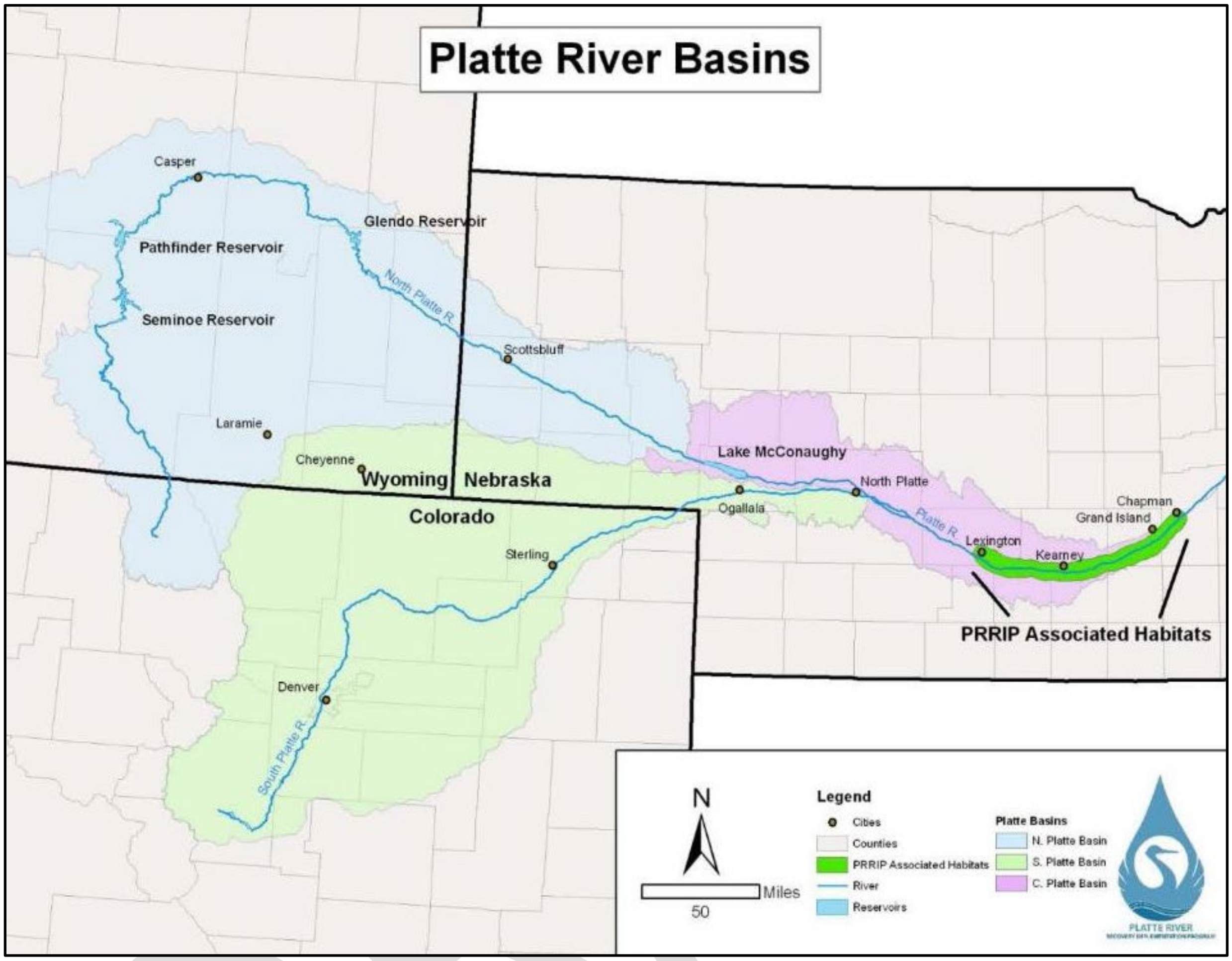


Figure 1. Platte River Basins extending from Colorado and Wyoming through Nebraska. The study area for our piping plover and least tern monitoring and research efforts was the PRRIP Associated Habitat Reach of the central Platte River located between Lexington and Chapman, Nebraska (in dark green).

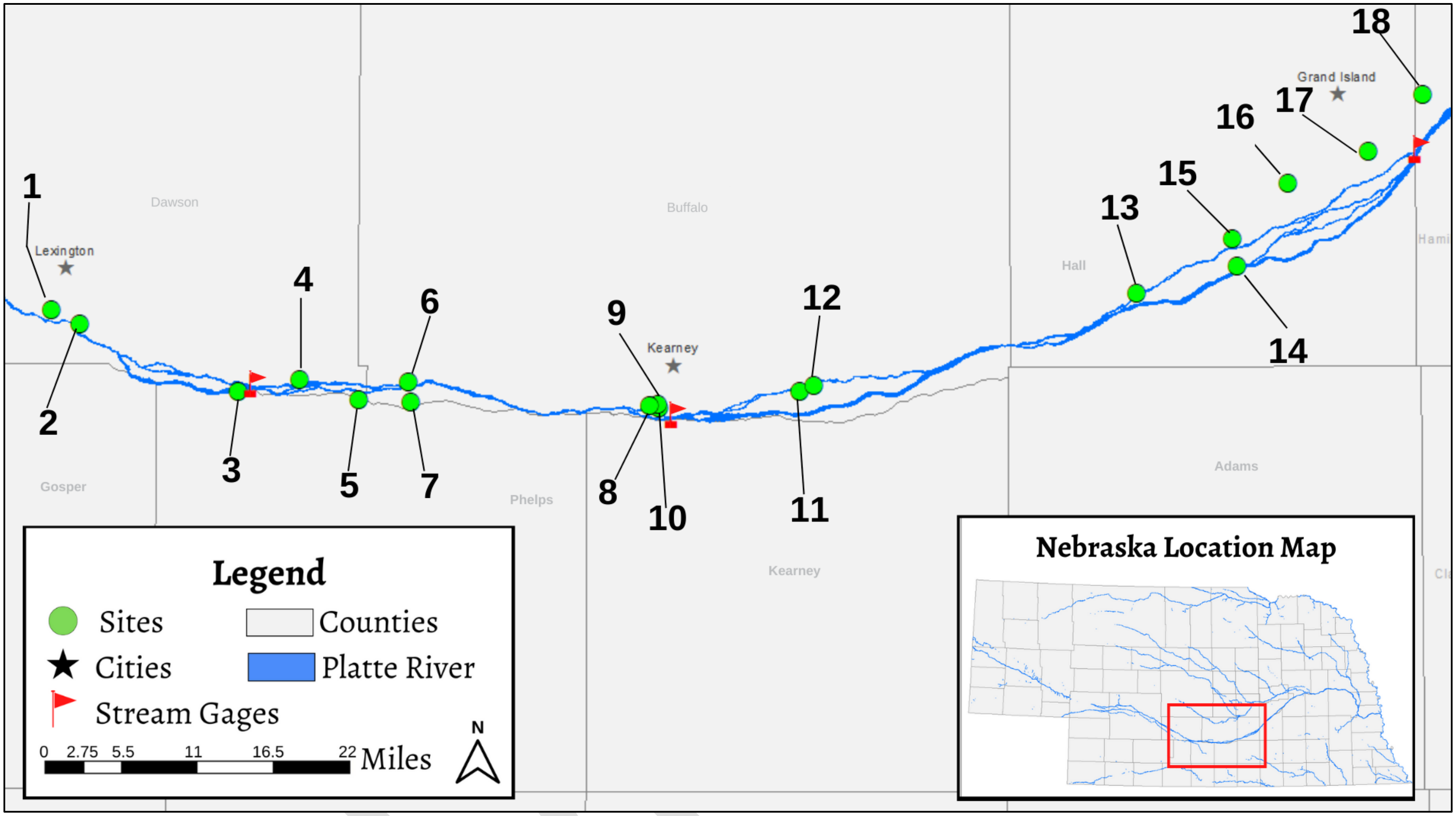


Figure 2. Distribution of 18 off-channel sand and water (OCSW) sites (green circles) and Platte River channels (blue) monitored for piping plover and least tern nesting and foraging activities during 2023 in our study area between Lexington and Chapman, NE. Locations of the three river gage stations along the central Platte River are depicted in red. Sites are: (1) OSG Lexington; (2) NPPD Lexington; (3) Dyer; (4) Cottonwood Ranch; (5) T&F Lakeside; (6) Blue Hole; (7) Johnson; (8) Ed Broadfoot and Sons; (9) Kearney Broadfoot South; (10) Non-Access Islands Kearney Broadfoot South; (11) Newark West; (12) Newark East; (13) Leaman; (14) Trust Wildrose East; (15) Follmer; (16) DeWeese; (17) Hooker Brothers Southeast; and (18) Hooker Brothers East.

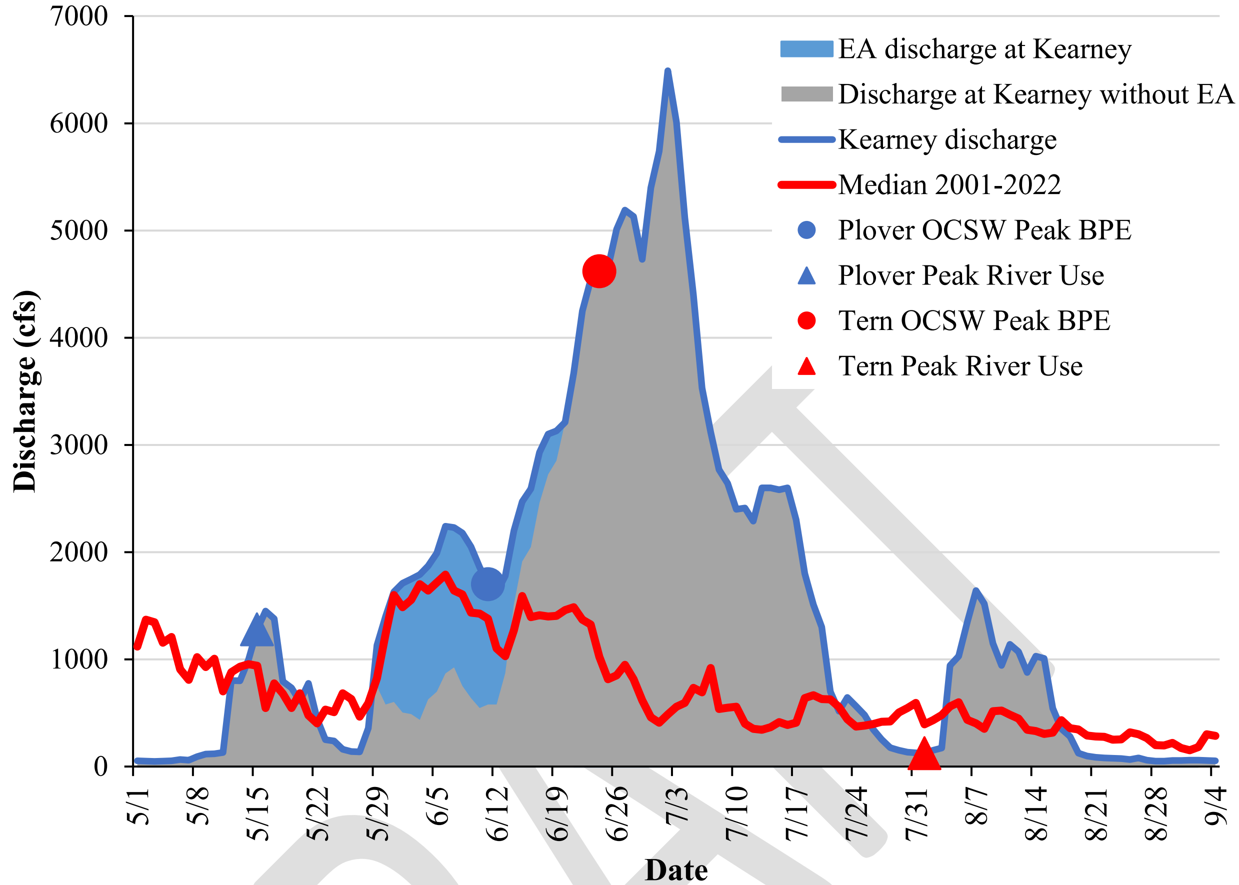


Figure 3. Daily discharge (cubic feet per second; cfs) at Kearney, Nebraska (USGS gage 06770200; USGS 2023) between 1 May and 4 September, 2023 (blue line). See Figure 2 for the location of gage stations within our study area. Also depicted in the figure are the: median daily discharge during 2001–2022 at Kearney (red line); 2023 daily discharge without the inclusion of the Environmental Account (EA) release (gray shaded area); and 2023 EA release daily discharge during 29 May to 19 June at Kearney (light blue shaded area). Discharge data are provisional and will be updated when approved. Dates on which estimated breeding pairs/nesting (BPE) and river use for piping plovers and least terns peaked are denoted with circle and triangles. Plover BPE peaked at off-channel sand and water (OCSW) sites across the Associated Habitat Reach (AHR) on 11 June (blue circle); tern BPE peaked at OCSW sites across the AHR on 24 June (red circle); and adult counts observed on river surveys peaked for plovers on 15 May (blue triangle) and terns on 1 August (red triangle).

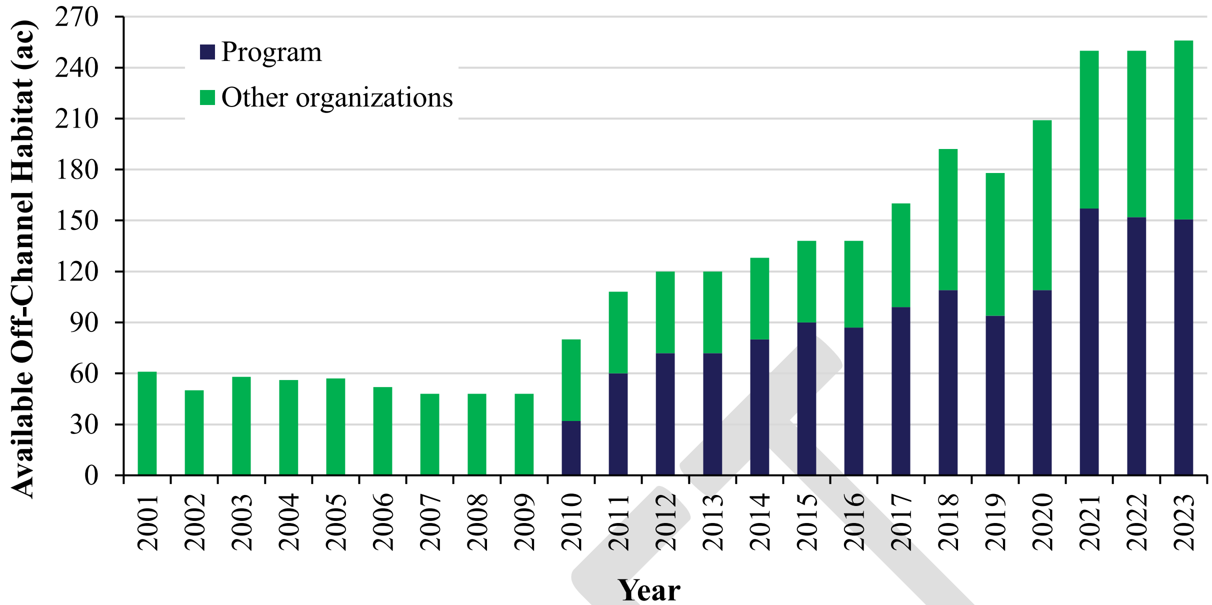


Figure 4. Availability of off-channel sand and water (OCSW) piping plover and least tern nesting habitat along the Associated Habitat Reach (AHR) between Lexington and Chapman, Nebraska, adjacent to the Platte River during 2001–2023. OCSW habitat is separated into sites owned and/or managed by the Program (indigo shaded bars) and by other organizations (green bars). The OCSW nesting habitat fits the accepted Program habitat requirements for piping plovers and least terns (PRRIP 2015). Due to access restrictions that limited monitoring at some sites, available OCSW habitat during 2001–2009 only included sites that were used in the reproductive and survival calculations each year.

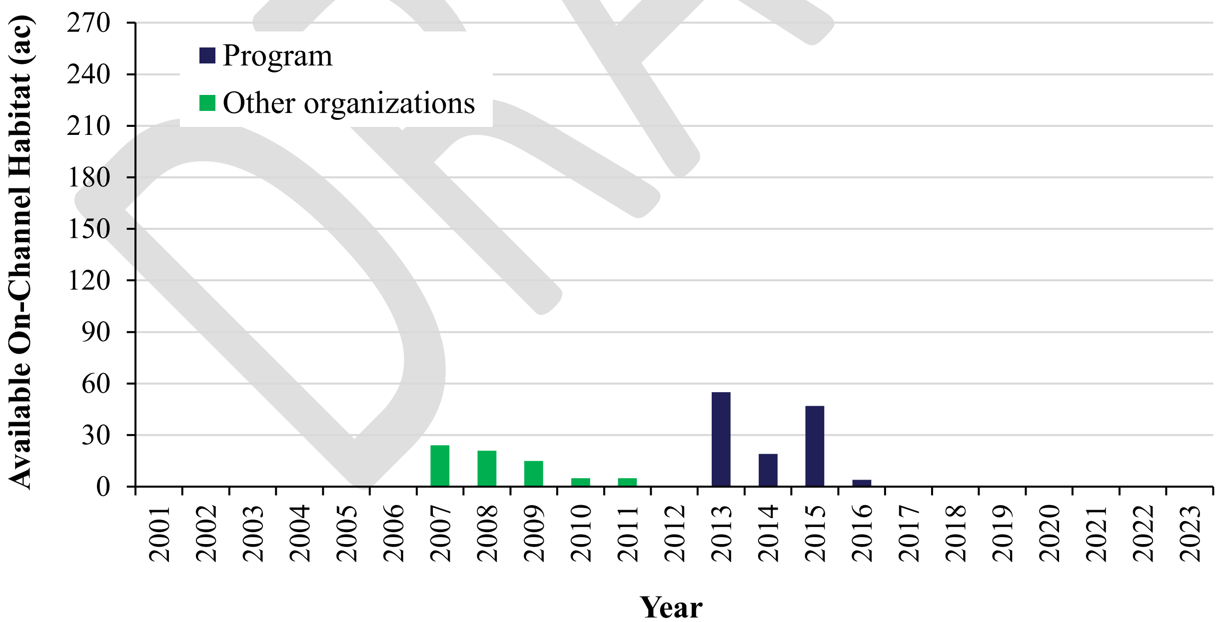


Figure 5. Monitored on-channel piping plover and least tern nesting habitat on the Platte River along the Associated Habitat Reach (AHR) between Lexington and Chapman, Nebraska, during 2001–2023 that was created, rehabilitated, and managed by the Program (indigo shaded bars) and other organizations (green bars). The on-channel nesting habitat fits the accepted Program habitat requirements (PRRIP 2015). On-channel habitat available during 2001–2006 only included sites that were used in reproductive and survival calculations each year; however, no nesting was observed during this period.

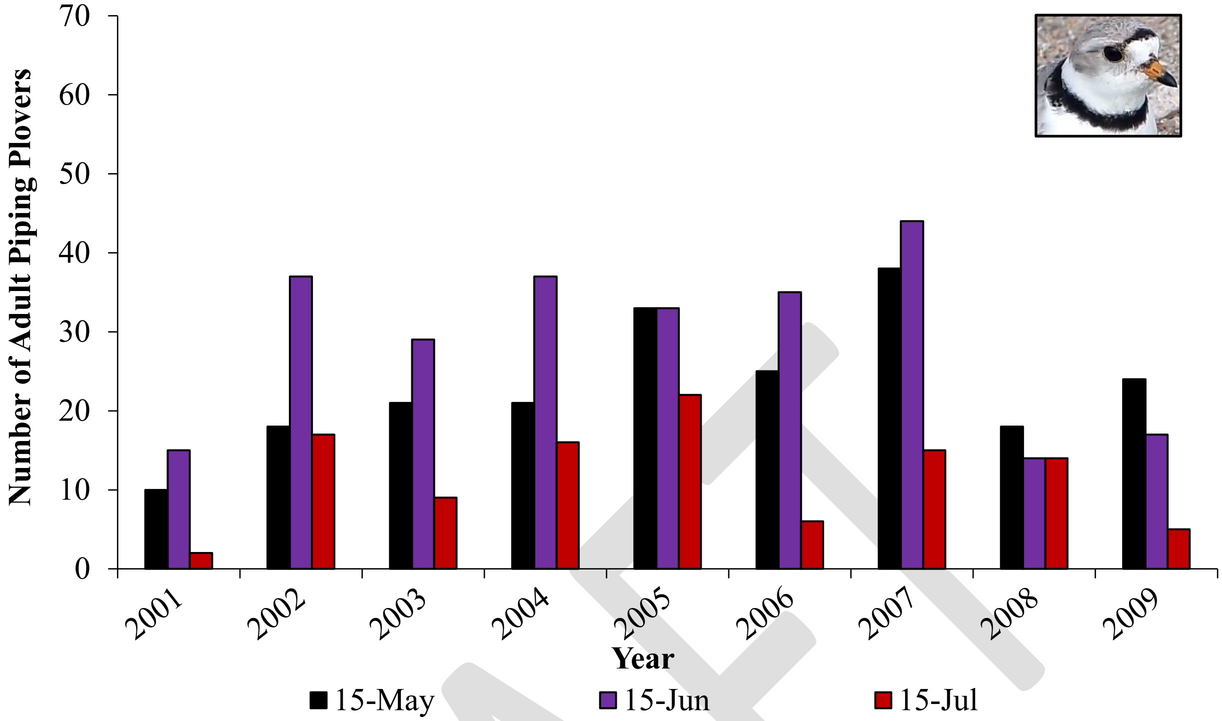


Figure 6. Number of adult piping plovers observed during three semi-monthly surveys of OCSW sites along the Platte River between Lexington and Chapman, Nebraska, 2001–2009. Numbers of adults include observations of both non-breeding and breeding piping plovers.

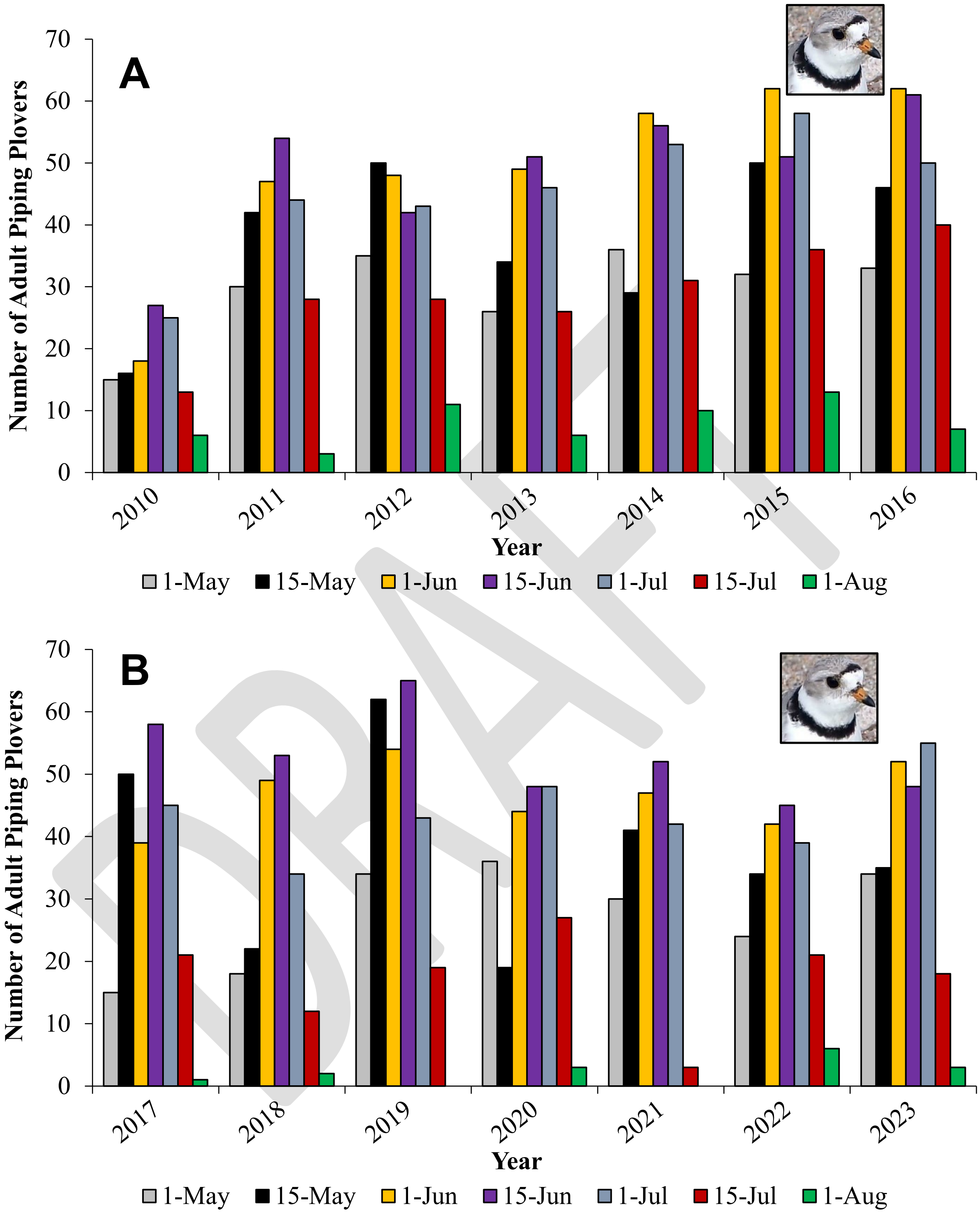


Figure 7. Number of adult piping plovers observed during semi-monthly surveys of off-channel sand and water (OCSW) sites along the Platte River between Lexington and Chapman, Nebraska, 2010–2023, during the periods of (a) 2010–2016, and (b) 2017–2023. Numbers of adults include observations of both non-breeding and breeding piping plovers.

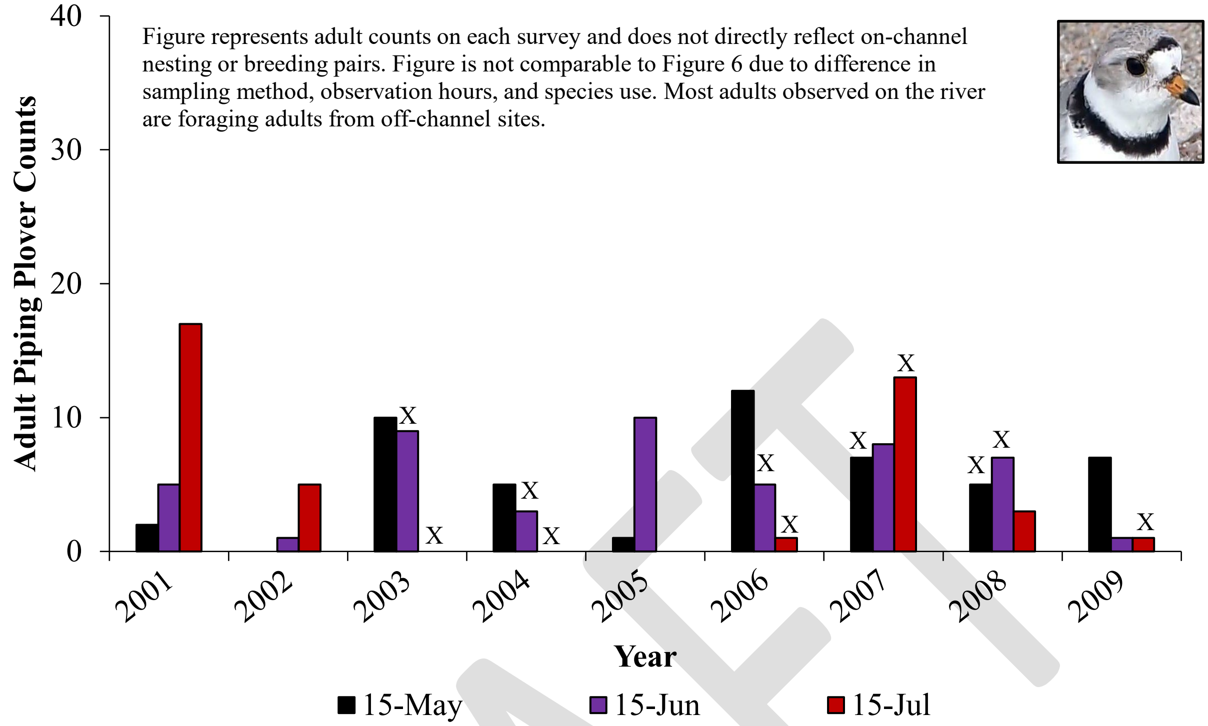


Figure 8. Number of adult piping plovers observed during three semi-monthly surveys of the Platte River between Lexington and Chapman, Nebraska, 2001–2009. Numbers of adults include observations of both non-breeding and breeding piping plovers. Sampling periods for which at least one section of the river was not completed due to lack of flow or high flow in the channel, or other restrictions are denoted with an "X." These survey dates include: 15 May 2007, 2008; 15 June 2003, 2004, 2006, 2008; and 15 July 2003, 2004, 2006, 2007, 2008.

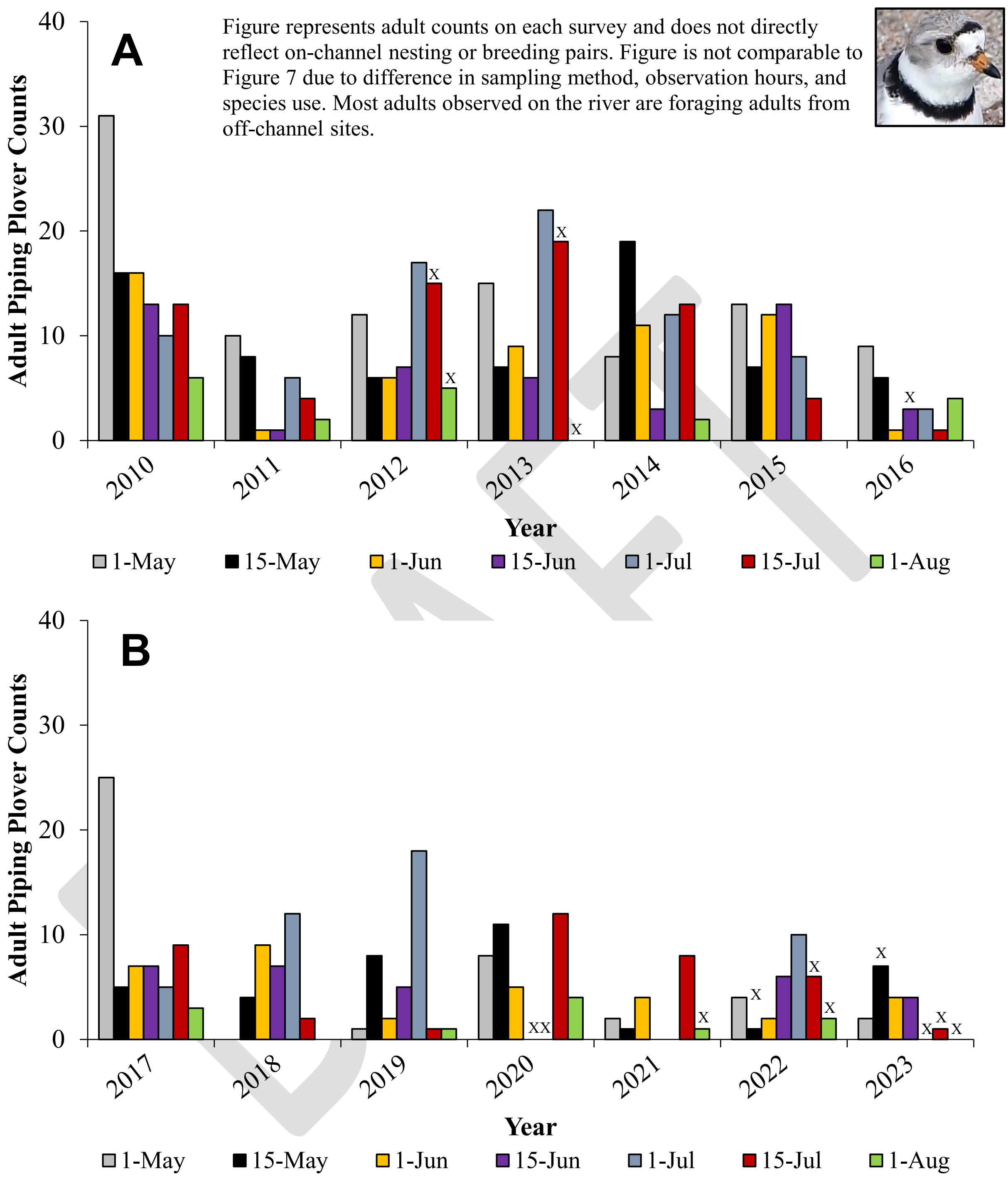


Figure 9. Number of adult piping plovers observed during semi-monthly surveys of the Platte River between Lexington and Chapman, Nebraska, 2010–2023, during the periods of (a) 2010–2016, and (b) 2017–2023. Sampling periods for which at least one section of the river was not completed due to lack of flow or high flow in the channel, or other restrictions are denoted with an "X." These survey dates include: 15 May 2022, 2023; 15 June 2016, 2020; 1 July 2020, 2023; 15 July 2012, 2013, 2022, 2023; and 1 August 2012, 2013, 2021, 2022, 2023.

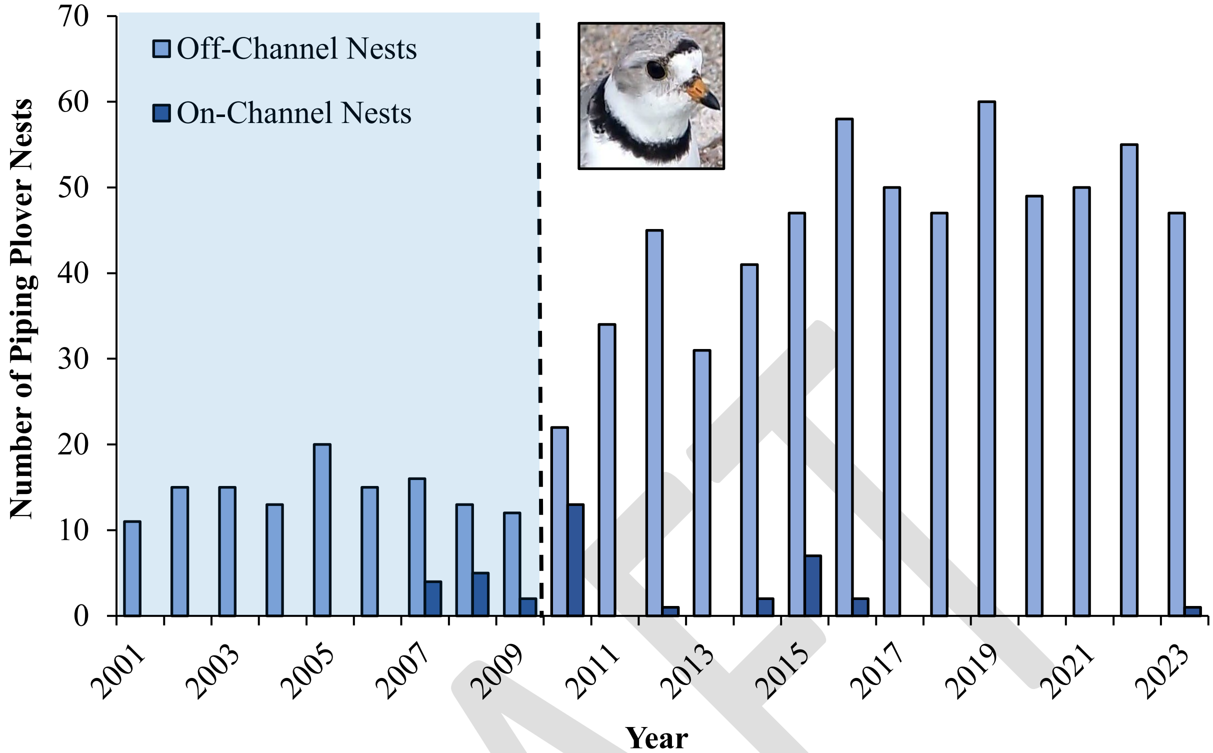


Figure 10. Comparison of numbers of piping plover nests found during off-channel (light blue bars) and on-channel (dark blue bars) surveys within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska, 2001–2023. The black dashed line represents changes in protocol between 2009 and 2010, including an increase in monitoring effort. The shaded area represents years in which nest totals are not comparable to recent totals.

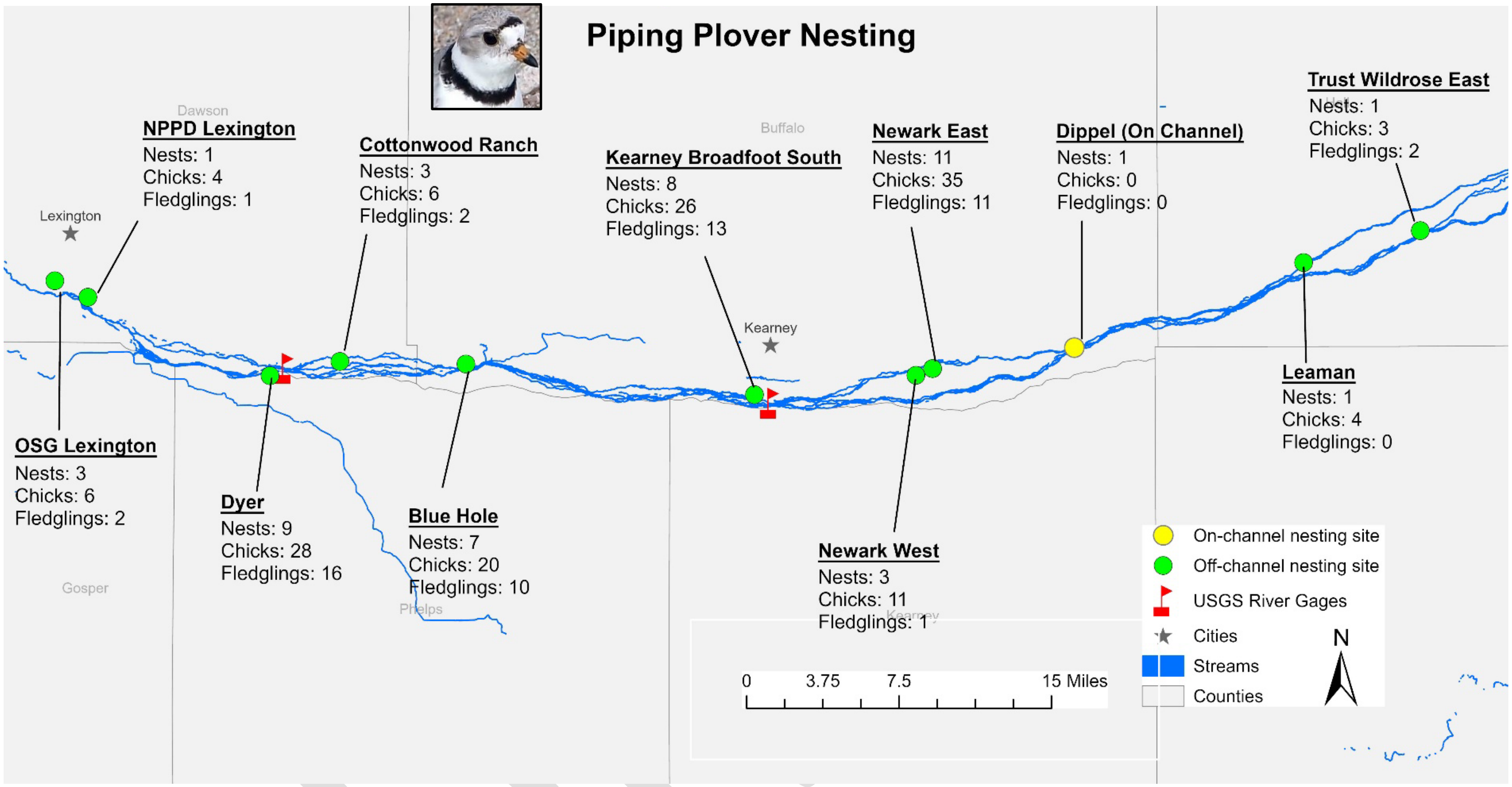


Figure 11. Distribution and numbers of piping plover nests, chicks, and fledglings observed within Program associated habitats during 2023 surveys along the Platte River between Lexington and Chapman, Nebraska. Piping plover nests and chicks were observed and monitored at 10 of 18 off-channel sites during 2023. One nest was observed on an island in the river and subsequently monitored (Dippel). The location of the Kearney river gage (USGS gage 06770200; USGS 2023) is marked with a red flag.

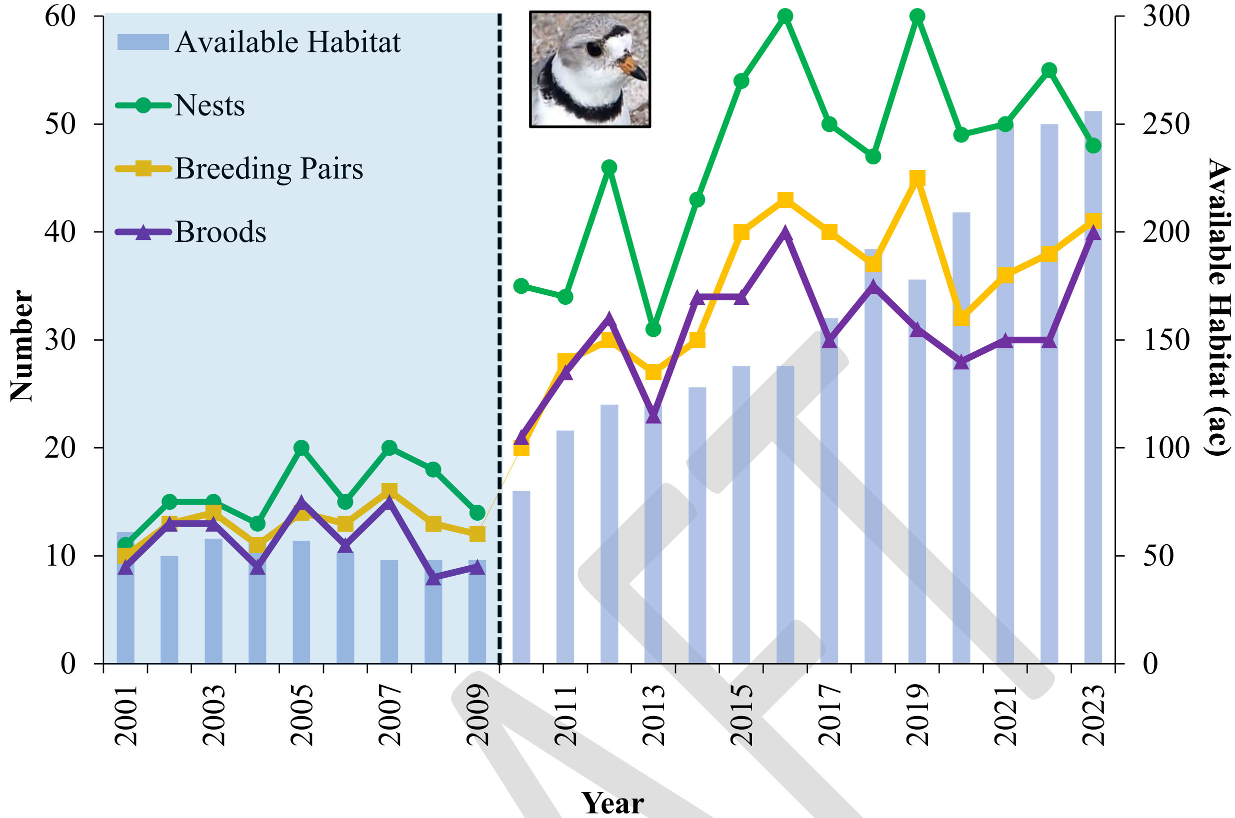


Figure 12. Annual variability in the total numbers of piping plover nests (green line), peak estimated breeding pairs (orange line), brood counts (purple line), and total on- and off-channel habitat available (acres; blue bars) observed within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska during 2001–2023. The black dotted line represents changes in protocol that occurred between 2009 and 2010, including an increase in monitoring effort. Data from 2001–2009 (shaded area) may not be comparable to data from 2010–2023. Due to access restrictions that limited monitoring at some sites, available habitat from 2001–2009 only included sites that were used in the reproductive and survival calculations each year.

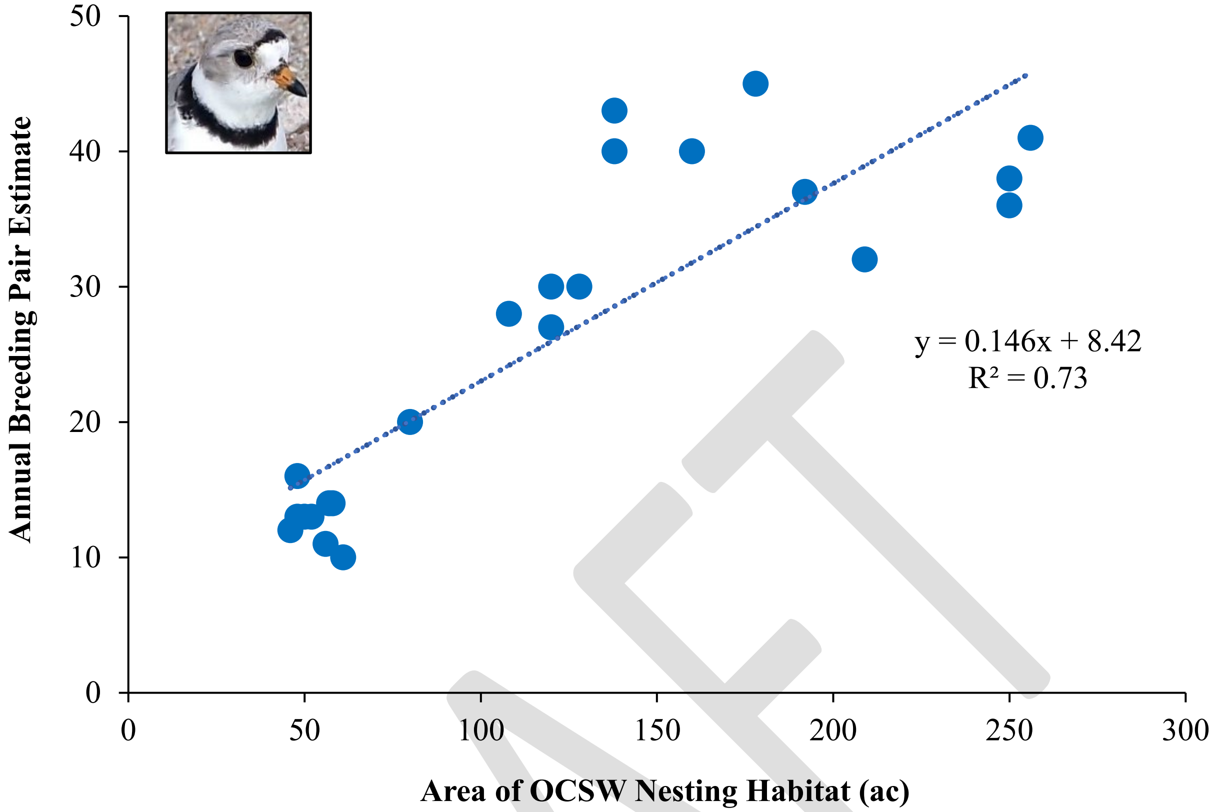


Figure 13. Relationship between the annual estimated number of piping plover breeding pairs and availability (acres) of monitored off-channel habitat (OCSW sites) within the Program Associated Habitat Reach between Lexington and Chapman, Nebraska during 2001–2023. For every acre of OCSW habitat increase, an increase of 0.146 piping plover breeding pairs occurred (95% CI: 0.106–0.186 breeding pairs) at OCSW sites in the AHR and the results were statistically significant ($P < 0.001$). The linear line of best fit with corresponding equation and R^2 value are depicted. Due to access restrictions that limited monitoring at some sites, available habitat from 2001–2009 only included sites that were used in the reproductive and survival calculations each year.

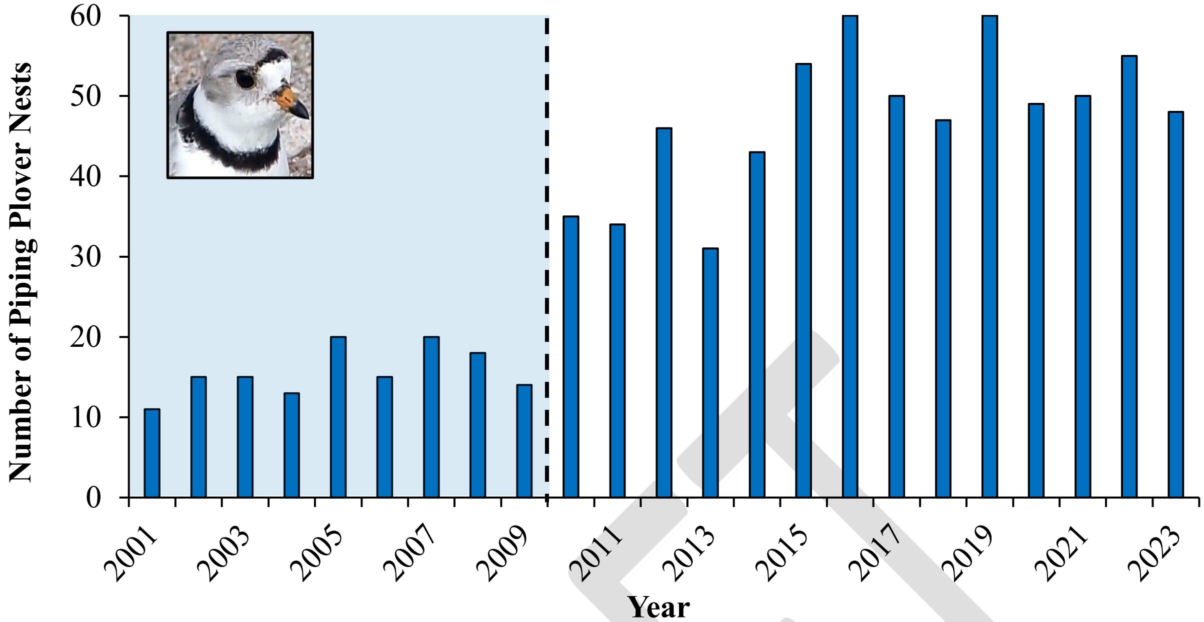


Figure 14. Total number of piping plover nests observed during on- and off-channel surveys within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska, 2001–2023. The black dashed line represents changes in protocol between 2009 and 2010, including an increase in monitoring effort. The shaded area represents years in which nest totals are not comparable to recent totals.

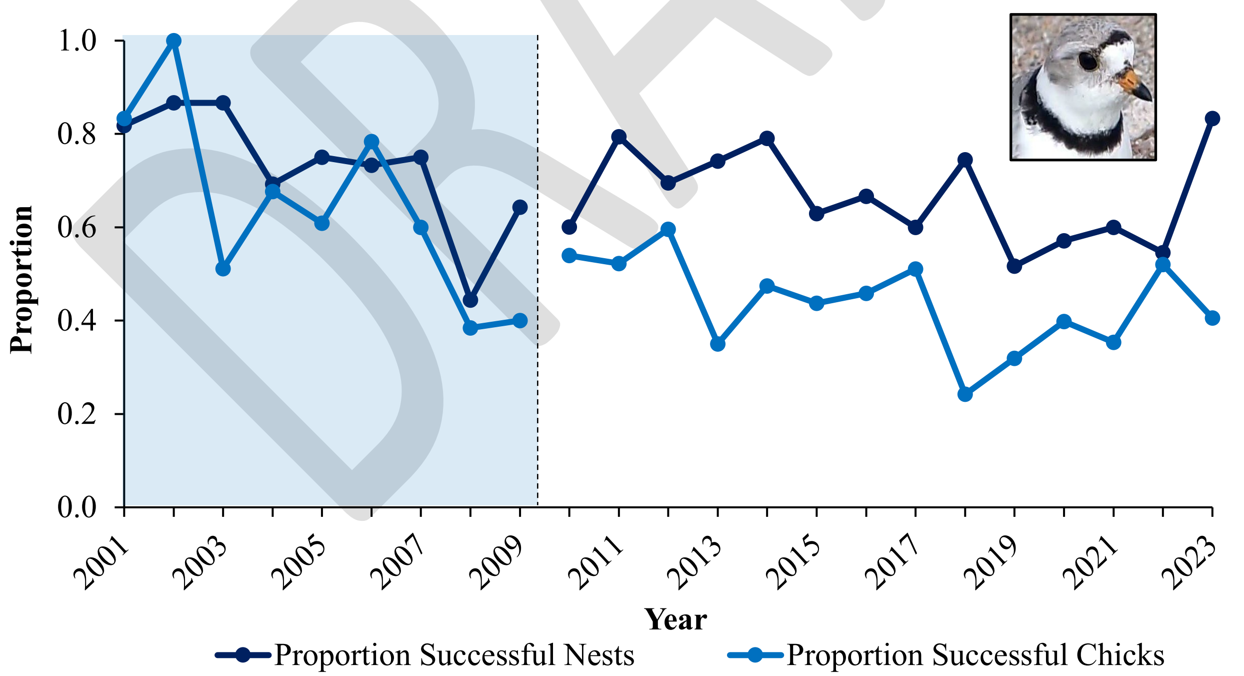


Figure 15. Proportion of successful nests (apparent nest success) and proportion of successful chicks (chicks fledged) for piping plover nests monitored during 2001–2023 within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska. The black dotted line represents changes in protocol between 2009 and 2010, including adjusting the fledge age from a 15-day success benchmark to 28 days for plovers. The shaded area represents years in which nest totals are not comparable to recent totals.

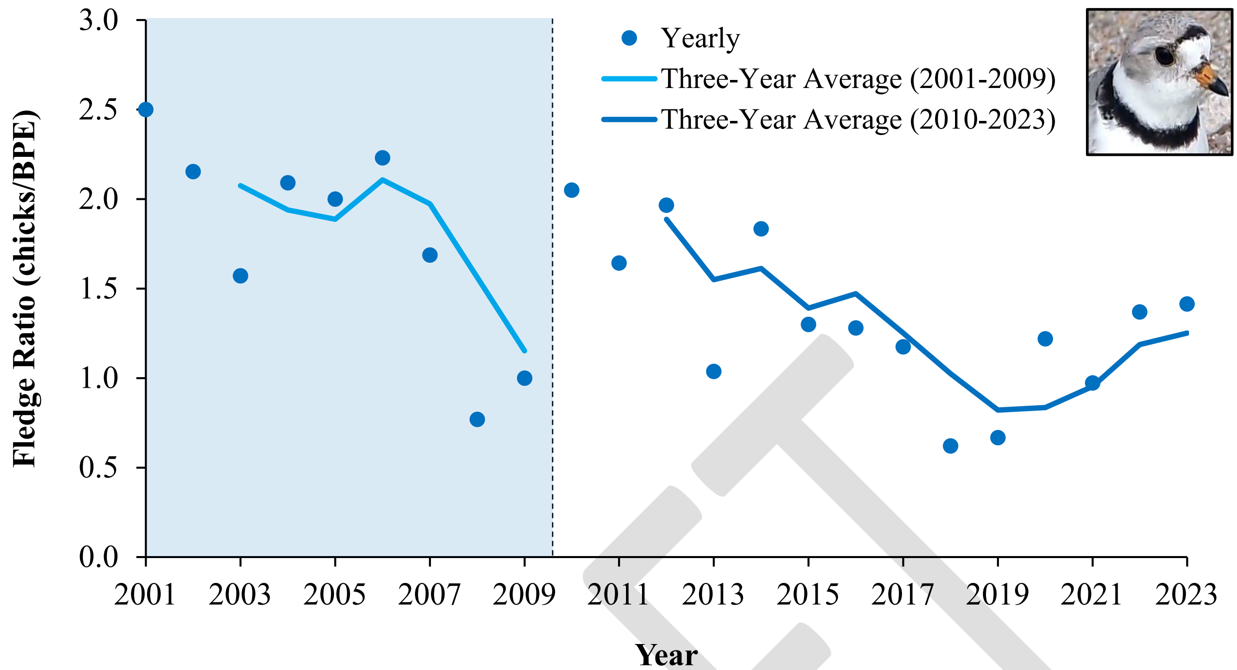


Figure 16. Piping plover fledge ratios (chicks fledged/estimated breeding pair [BPE]) on annual (point) and three-year running average (lines) bases during 2001–2009 and 2010–2023 within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska. The black dotted line represents changes in protocol between 2009 and 2010, including the fledge age being increased from 15-days to 28-days for piping plover chicks. The shaded area represents years in which fledge ratios are not comparable to recent fledge ratios.

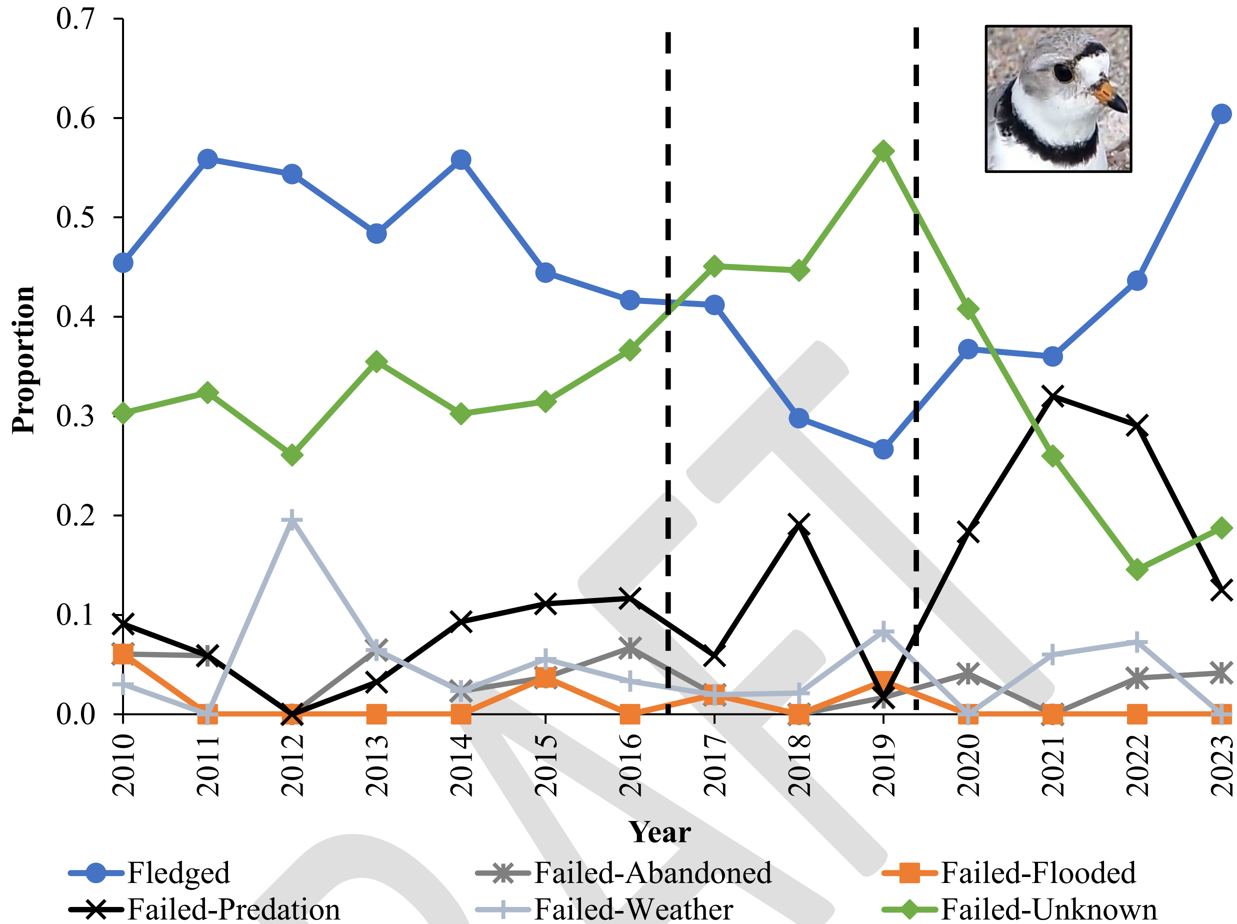


Figure 17. Proportion of piping plover nest successes with fledglings and nest failures (incurred during incubation or before fledging) by year during 2010–2023 across the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska. Each nest success or failure represents a unique reproductive attempt. Assigned causes of nest failures include abandonment, flooding, predation, weather, and failed due to unknown causes. The dotted black lines represent changes in monitoring protocol that occurred between 2016 and 2017, and 2019 and 2020. During 2010–2016, monitoring protocols included twice weekly inside and outside surveys at all sites with nesting and twice monthly river surveys. During 2017–2019, monitoring included twice weekly outside surveys at all sites with nesting, use of incidental evidence to fate nests, and twice monthly river surveys. During 2020–2023, monitoring included twice weekly outside surveys at all sites with nesting, camera monitoring at a sample of nests, nest sites, and shorelines to fate nests, use of incidental evidence to fate nests, additional predator management, and twice monthly river surveys.

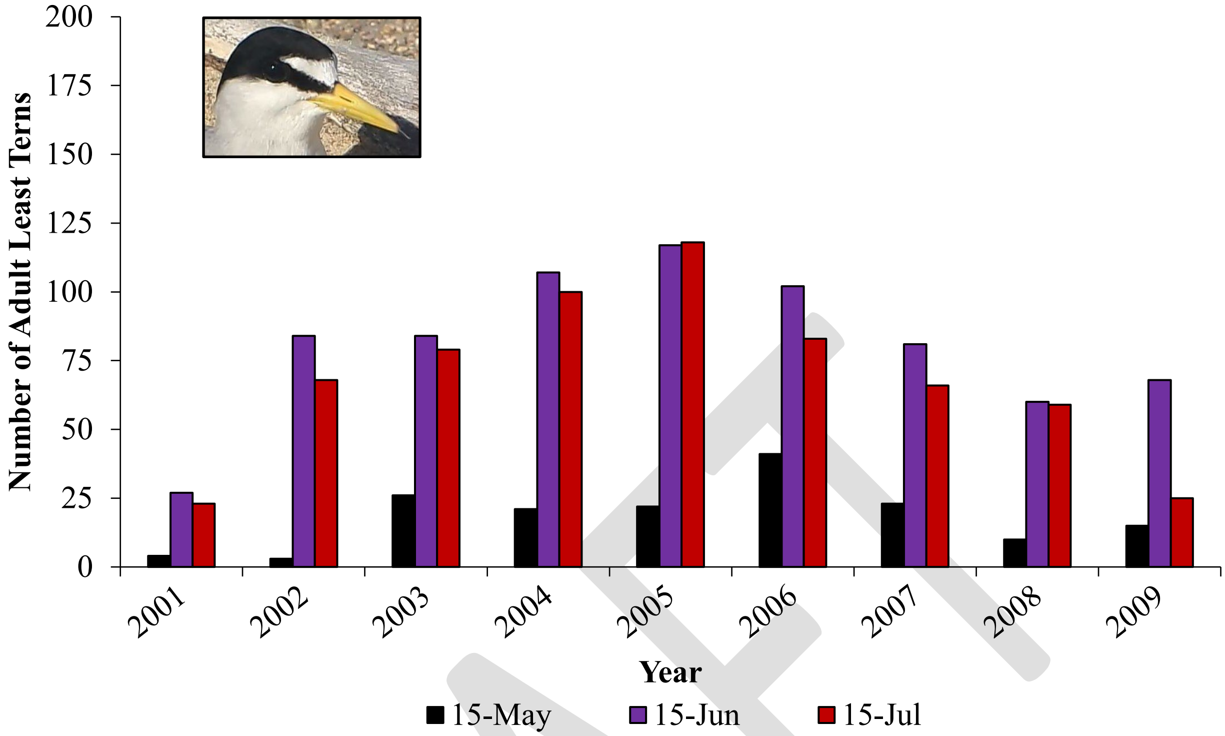
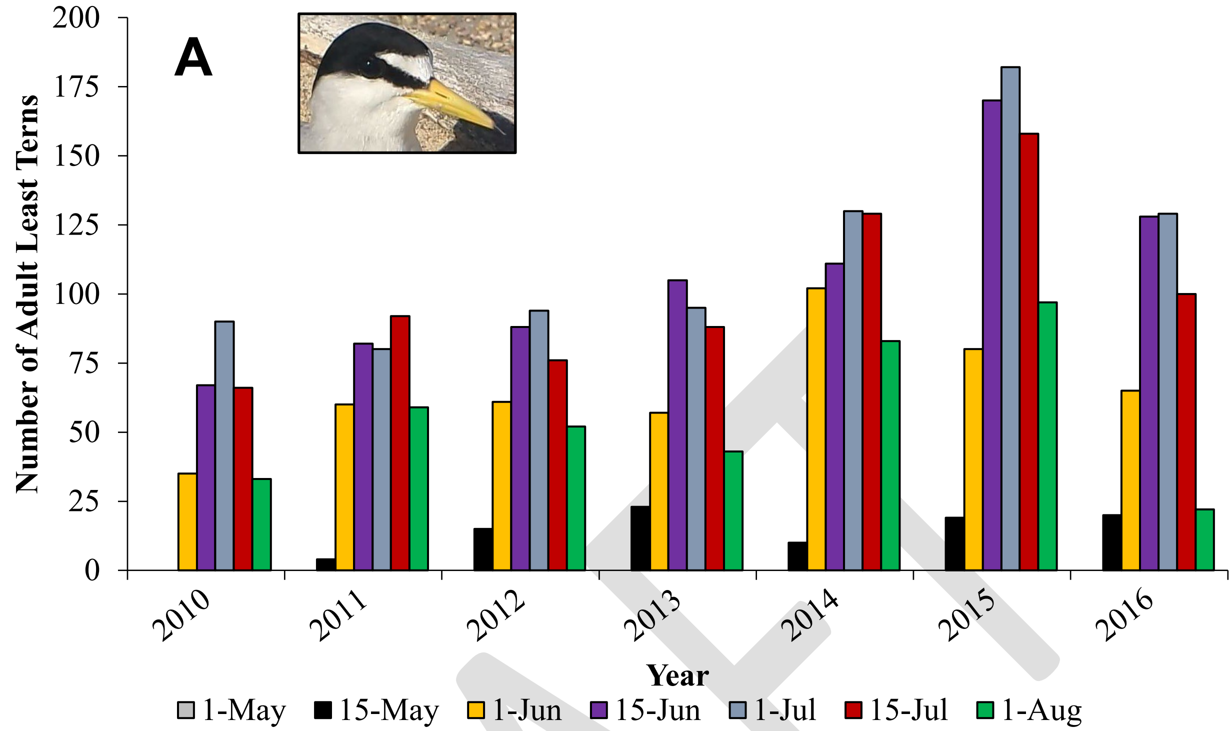


Figure 18. Number of adult least terns observed during three semi-monthly surveys of off-channel sand and water (OCSW) sites along the Platte River between Lexington and Chapman, Nebraska, 2001–2009. Numbers of adults include observations of both non-breeding and breeding least terns.



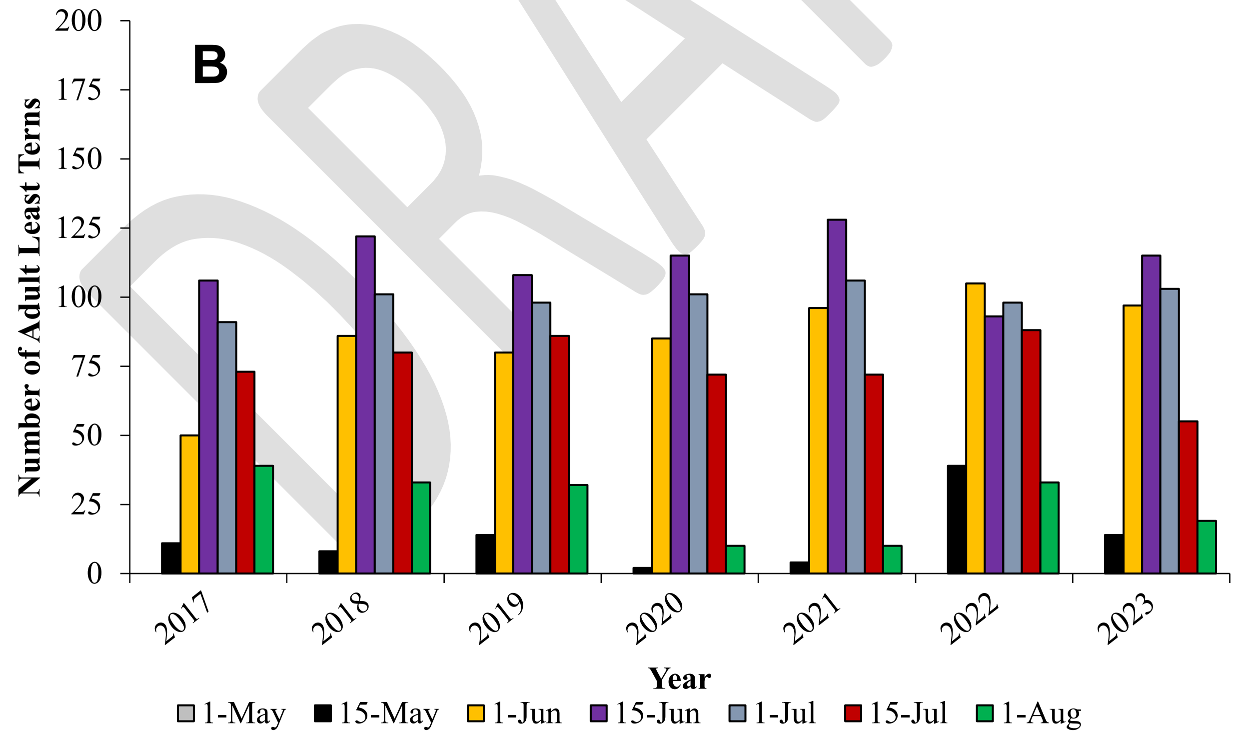


Figure 19. Number of adult least terns observed during seven semi-monthly surveys of off-channel sand and water (OCSW) sites along the Platte River between Lexington and Chapman, Nebraska, 2010–2023, for the periods of (a) 2010–2016, and (b) 2017–2023. Numbers of adults include observations of both non-breeding and breeding least terns.

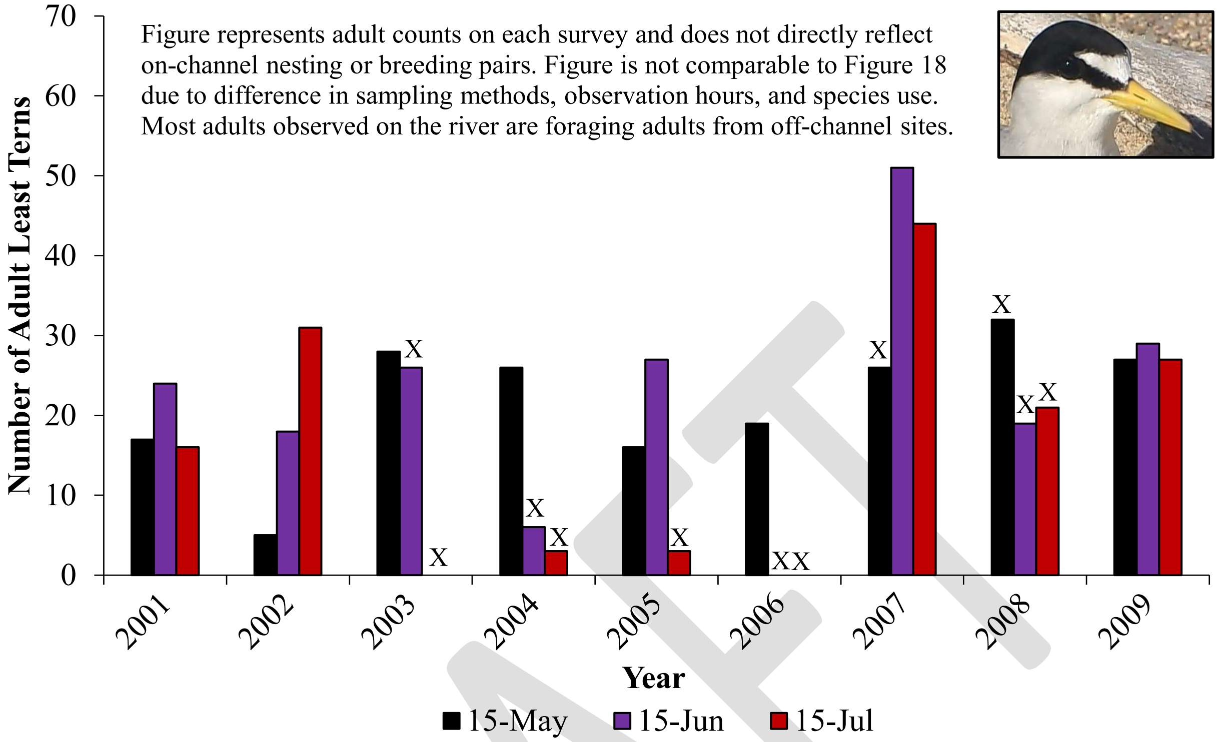


Figure 20. Number of adult least terns observed during three semi-monthly surveys of the Platte River between Lexington and Chapman, Nebraska, 2001–2009. Numbers of adults include observations of both non-breeding and breeding least terns. Sampling periods for which at least one section of the river was not completed due to lack of flow or high flow in the channel, or other restrictions are denoted with an "X". These surveys include: 15 May 2007, 2008; 15 June 2003, 2004, 2006, 2008; and 15 July 2003, 2004, 2005, 2006, 2008.

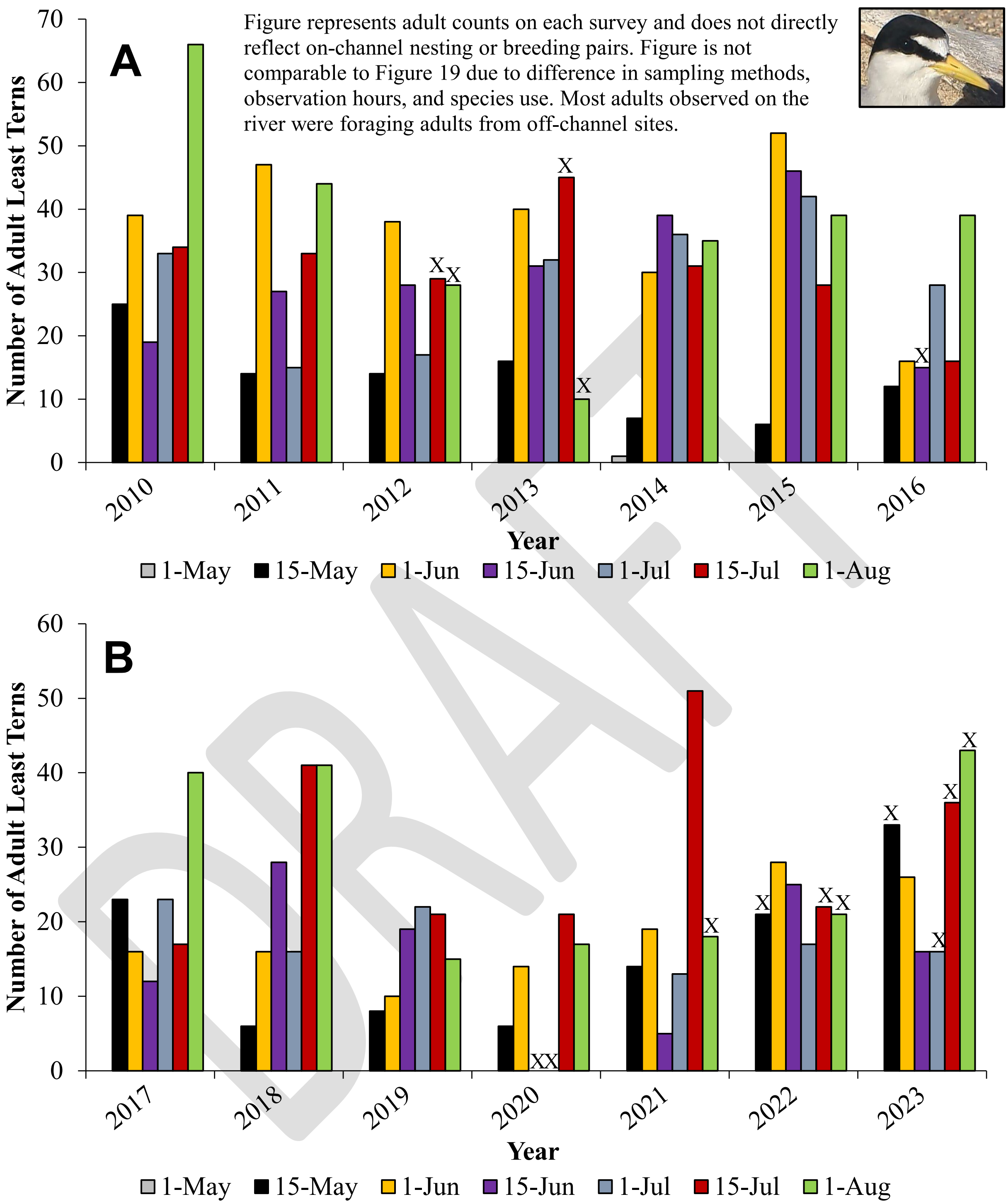


Figure 21. Number of adult least terns observed during s e v e n semi-monthly surveys of the Platte River between Lexington and Chapman, Nebraska, 2010–2023, on (a) 1 May, 15 May, 1 June, and 15 June, and (b) 1 July, 15 July, and 1 August. \Sampling periods for which at least one section of the river was not completed due to lack of flow or high flow in the channel, or other restrictions are denoted with an "X". These surveys include: 15 May 2022, 2023; 15 June 2016, 2020; 1 July 2020, 2023; 15 July 2012, 2013, 2022, 2023; and 1 August 2012, 2013, 2021, 2022, 2023.

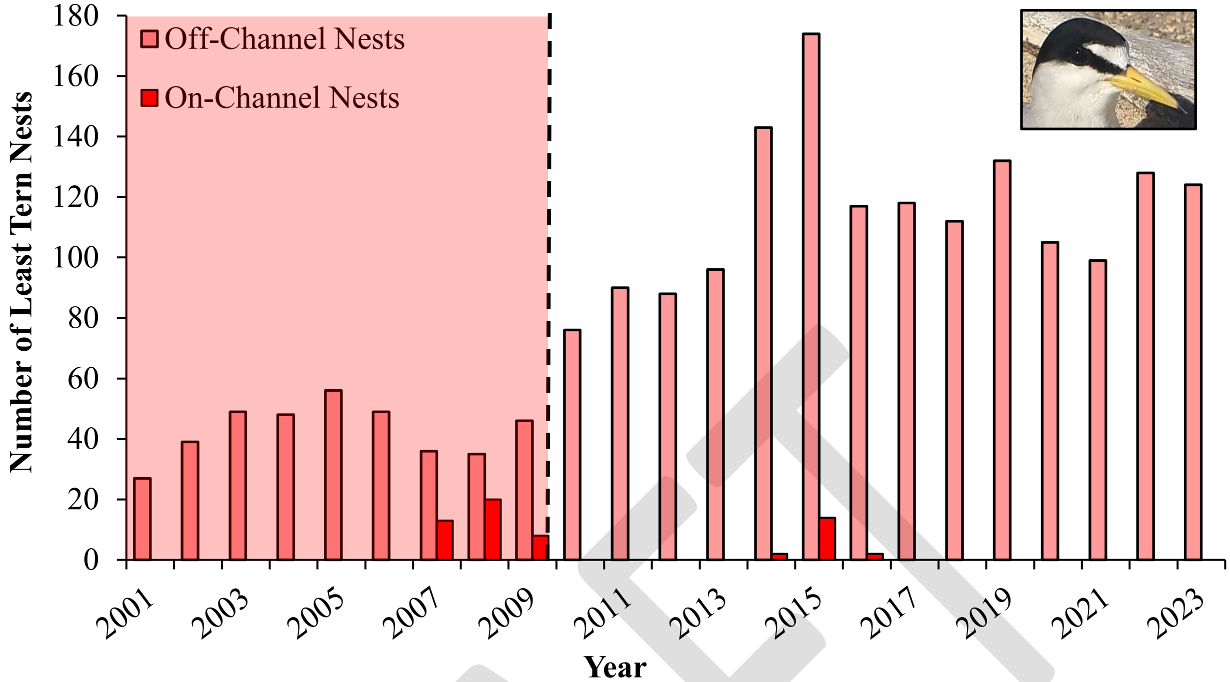


Figure 22. Comparison of numbers of least tern nests found during off-channel (light red bars) and on-channel (dark red bars) surveys within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska, 2001–2023. The black dashed line represents changes in protocol between 2009 and 2010, including an increase in monitoring effort. The shaded area represents years in which nest totals are not comparable to recent totals.

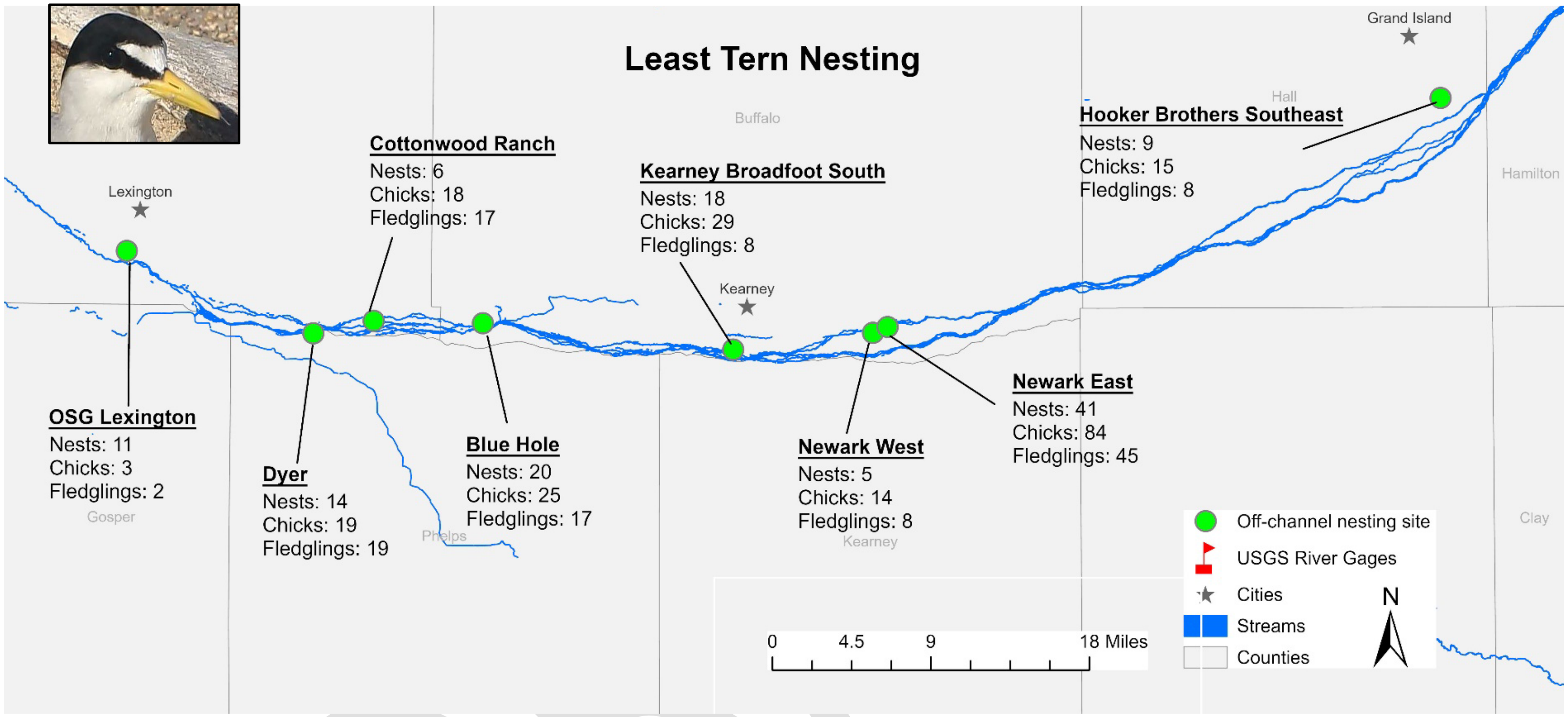


Figure 23. Distribution and numbers of least tern nests, chicks, and fledglings observed within Program associated habitats during 2023 surveys along the Platte River between Lexington and Chapman, Nebraska. Least tern nests and chicks were observed and monitored at eight of 18 off-channel sites during 2023. The location of the Kearney river gage (USGS gage 06770200; USGS 2023) is marked with a red flag.

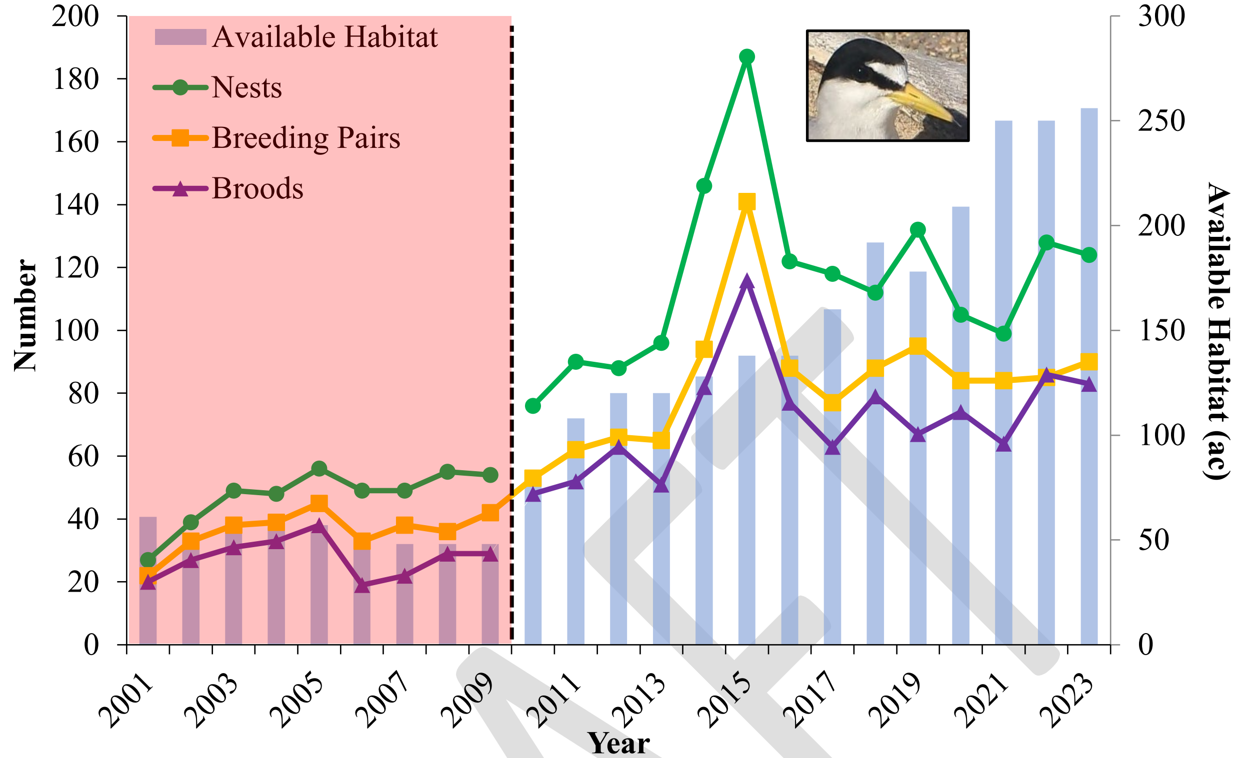


Figure 24. Annual variability in the total numbers of least tern nests (green line), peak breeding pairs (orange line), brood counts (purple line), and total on- and off-channel habitat available (acres; blue bars) observed within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska during 2001–2023. The black dotted line represents changes in protocol that occurred between 2009 and 2010, including an increase in monitoring effort. Data from 2001–2009 (shaded area) may not be comparable to data from 2010–2023. Due to access restrictions that limited monitoring at some sites, available habitat from 2001–2009 only included sites that were used in the reproductive and survival calculations each year.

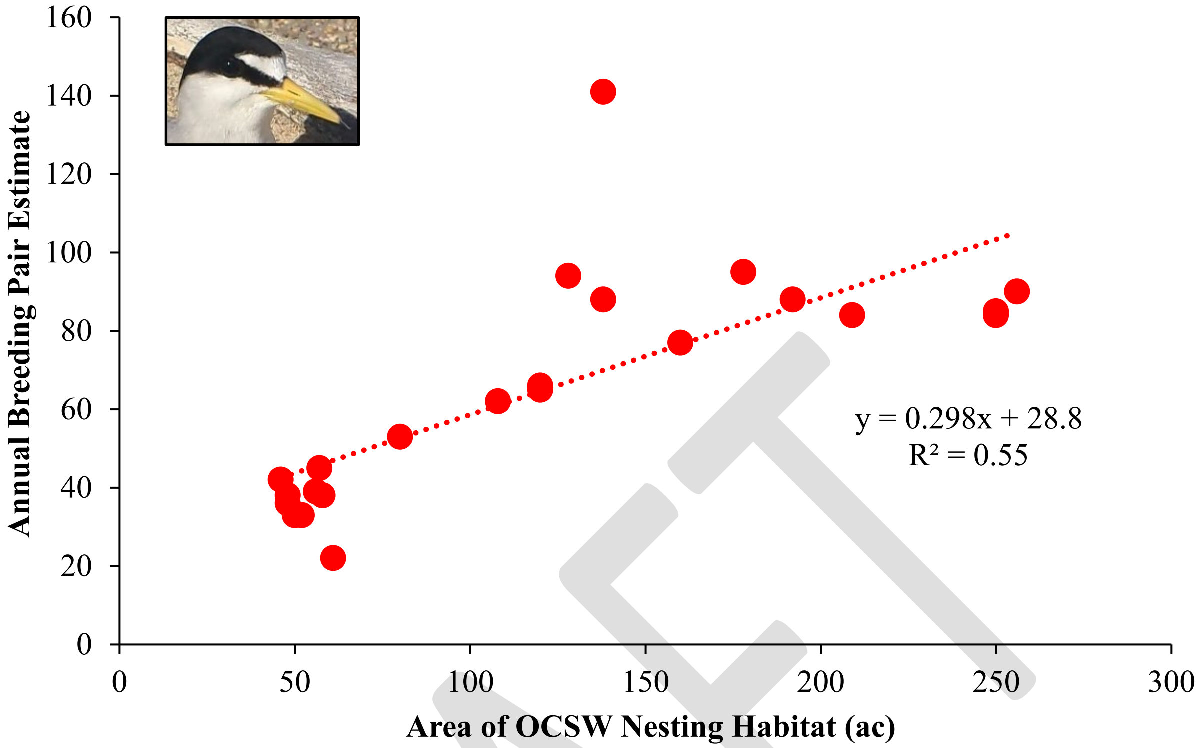


Figure 25. Relationship between the annual estimated number of least tern breeding pairs and availability (acres) of monitored off-channel habitat (OCSW sites) within the Program Associated Habitat Reach between Lexington and Chapman, Nebraska during 2001–2023. For every acre of OCSW habitat increase, an increase of 0.298 least tern breeding pairs occurred (95% CI: 0.176–0.421 breeding pairs) at OCSW sites in the AHR and the results were statistically significant ($P < 0.001$). The linear line of best fit with corresponding equation and R^2 value are depicted. Due to access restrictions that limited monitoring at some sites, available habitat from 2001–2009 only included sites that were used in the reproductive and survival calculations each year.

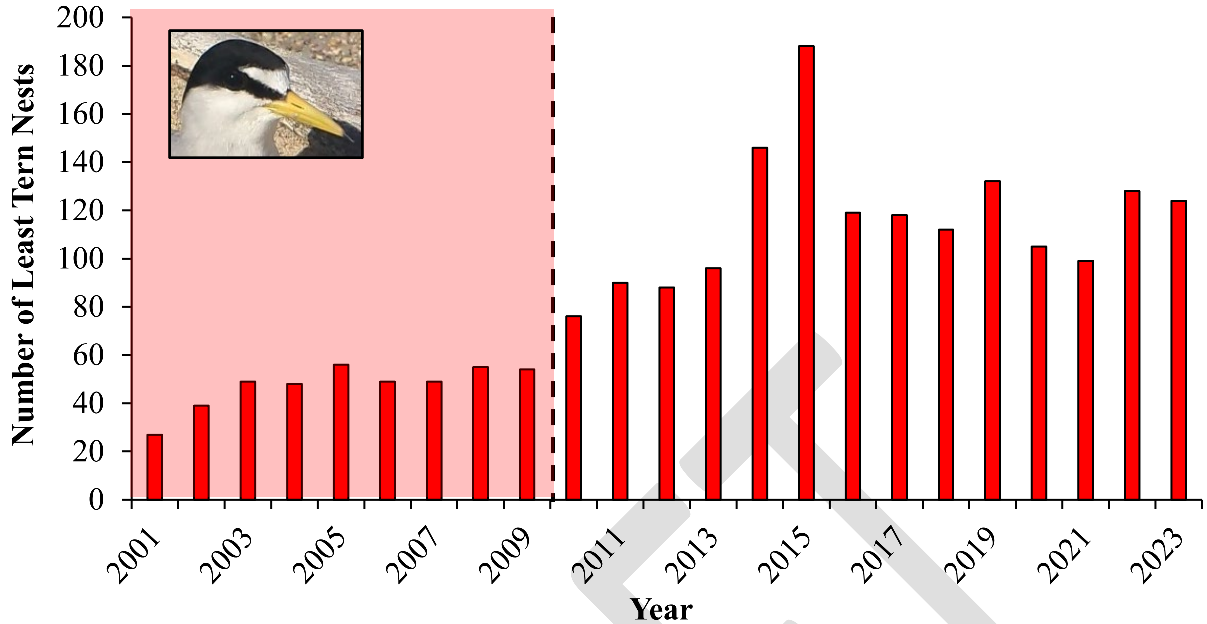


Figure 26. Total number of least tern nests observed during on- and off-channel surveys within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska, 2001–2023. The black dashed line represents changes in protocol between 2009 and 2010, including an increase in monitoring effort. The shaded area represents years in which nest totals are not comparable to recent totals.

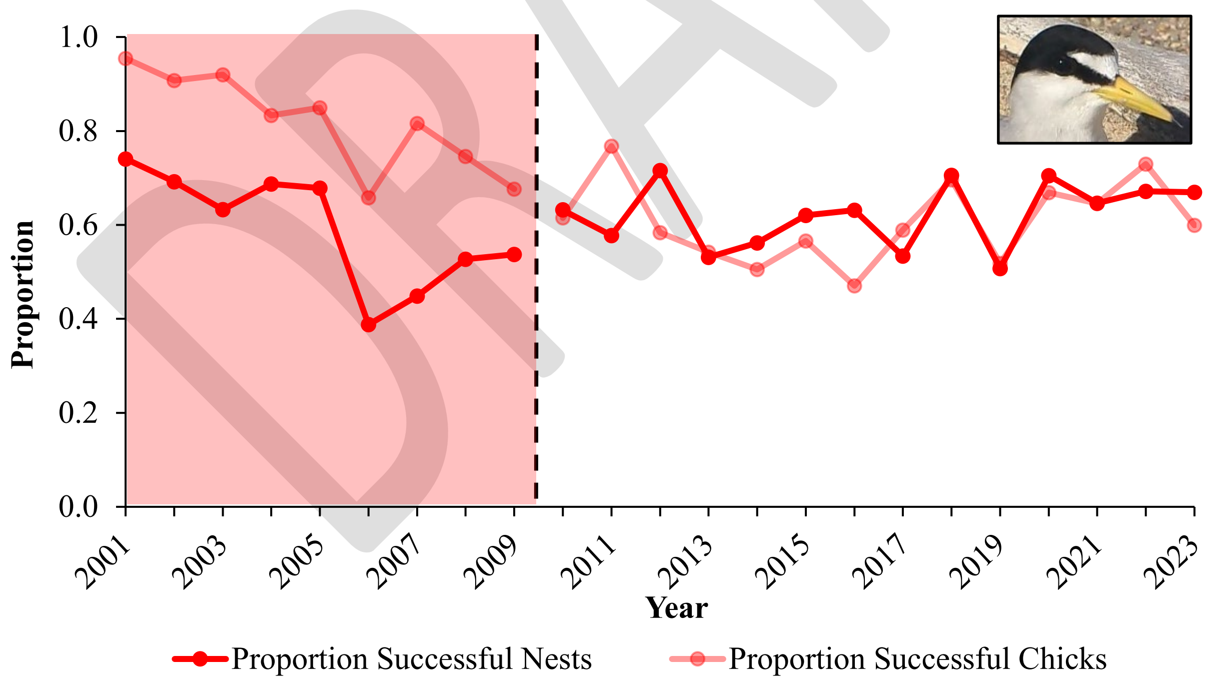


Figure 27. Proportion of successful nests (apparent nest success) and proportion of successful chicks (chicks fledged) for least tern nests monitored during 2001–2023 within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska. The black dotted line represents changes in protocol between 2009 and 2010, including adjusting the fledge age from a 15-day success benchmark to 21 days for least terns. The shaded area represents years in which nest totals are not comparable to recent totals.

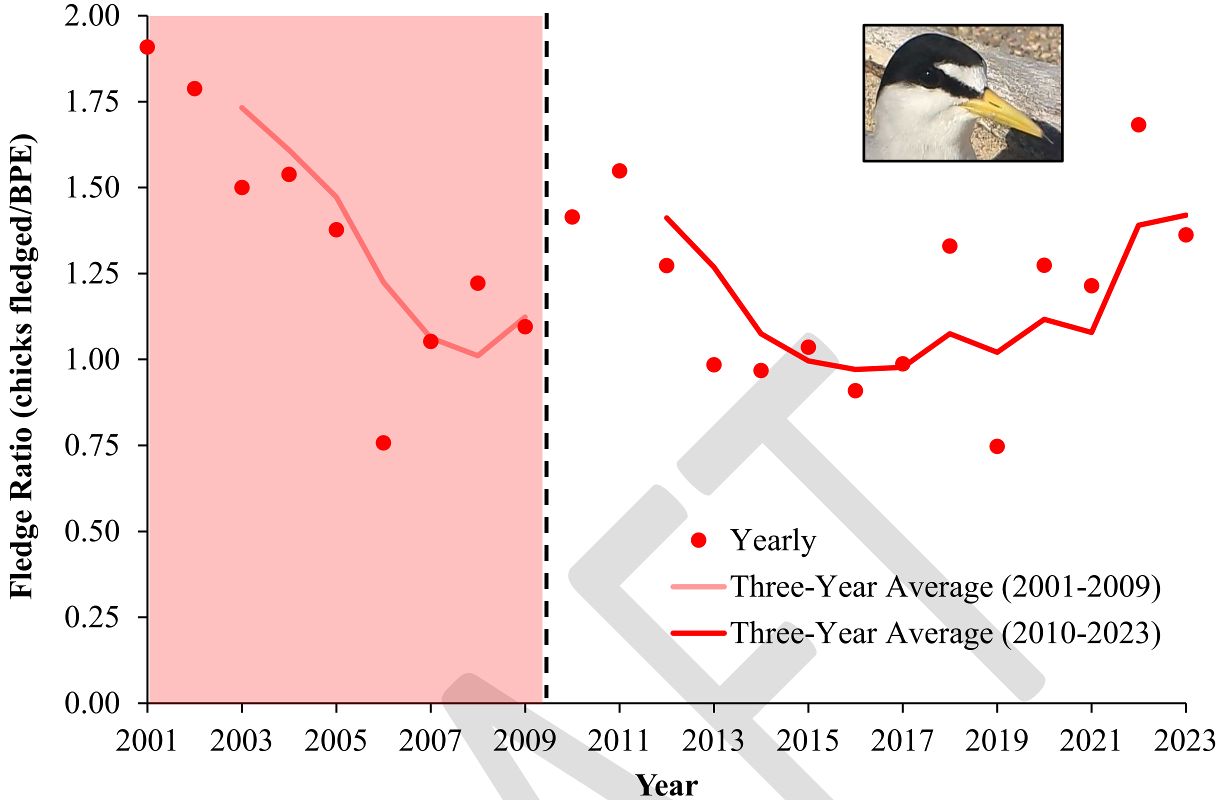


Figure 28. Least tern fledge ratios (chicks fledged/estimated breeding pair [BPE]) on annual (point) and three-year running average (lines) bases during 2001–2009 and 2010–2023 within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska. The black dotted line represents changes in protocol between 2009 and 2010, including the fledge age being increased from 15-days to 21-days for least tern chicks. The shaded area represents years in which fledge ratios are not comparable to recent fledge ratios.

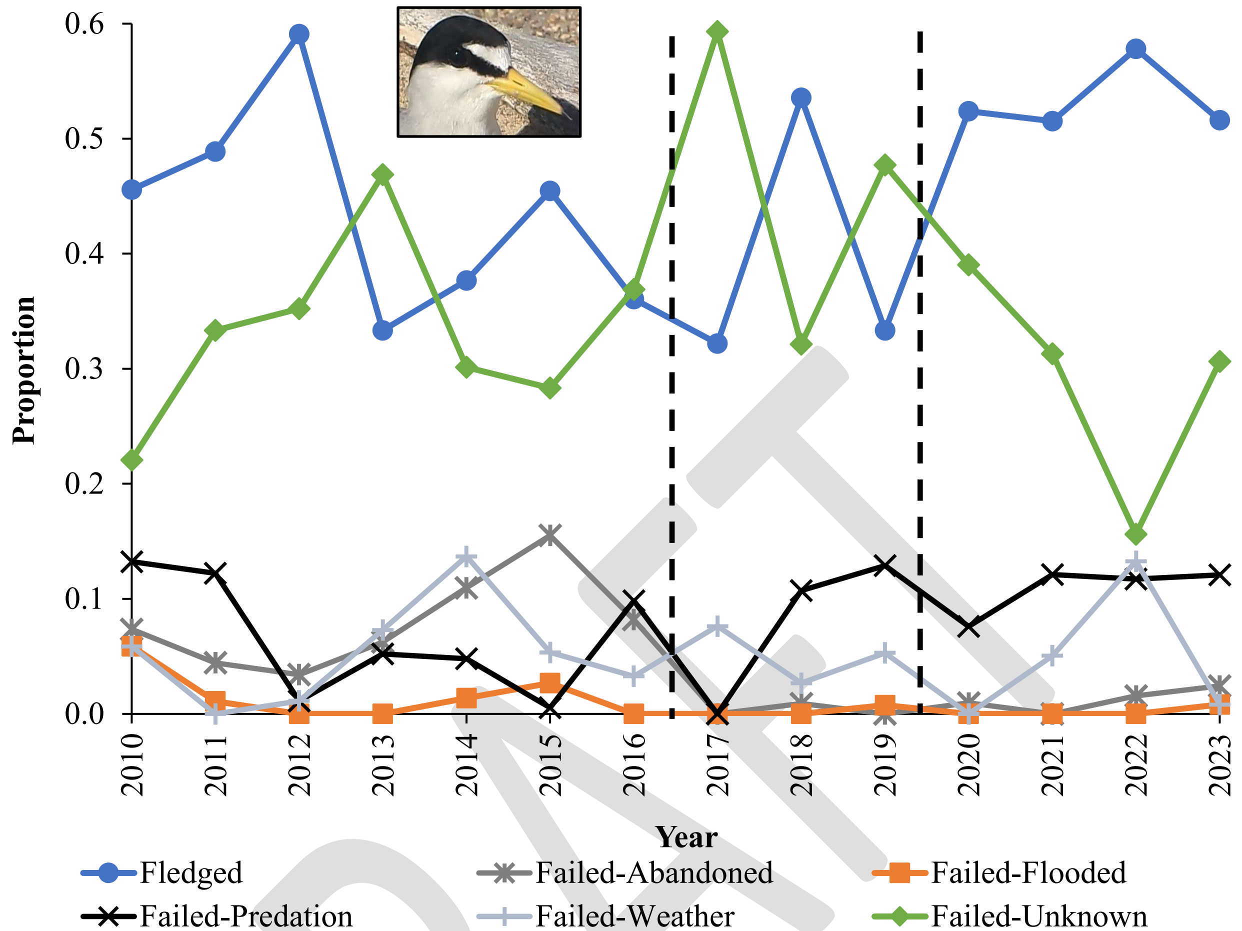


Figure 29. Proportion of least tern nest successes with fledglings and nest failures by year during 2010–2023 across the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska. Each nest success or failure represents a unique reproductive attempt. Assigned causes of nest failures include abandonment, flooding, predation, weather, and failed due to unknown causes. The dotted black lines represent changes in monitoring protocol that occurred between 2016 and 2017, and 2019 and 2020. During 2010–2016, monitoring protocols included twice weekly surveys inside and outside of nesting sites at all sites with nesting and twice monthly river surveys. During 2017–2019, monitoring included twice weekly surveys outside of nesting sites at all sites with nesting, use of incidental evidence to fate nests, and twice monthly river surveys. During 2020–2023, monitoring included twice weekly surveys outside of nesting sites at all sites with nesting, camera monitoring at a sample of nests, nest sites, and shorelines to fate nests, use of incidental evidence to fate nests, additional predator management, and twice monthly river surveys.

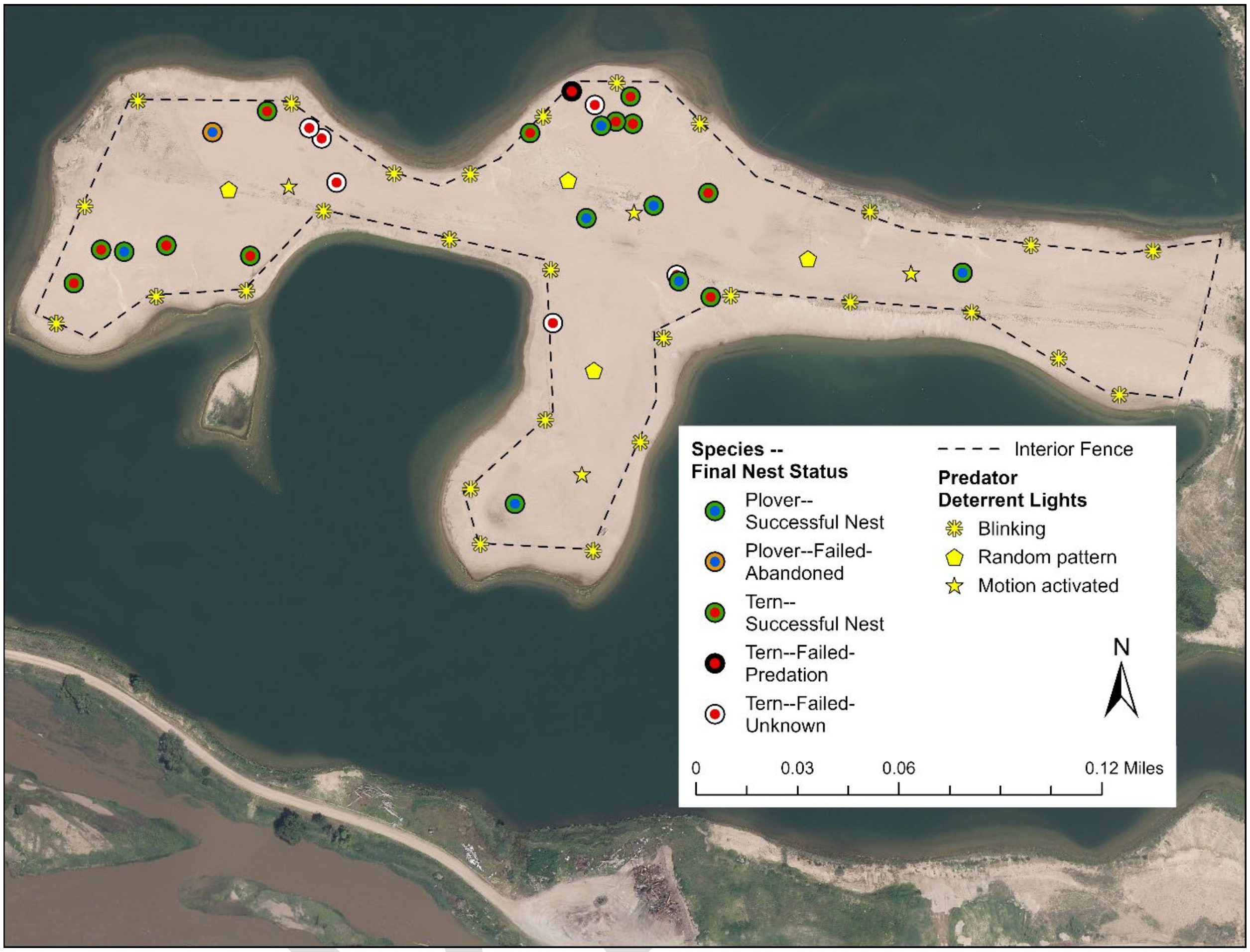


Figure 30. Piping plover (Plover, blue inner circle) and least tern (Tern, red inner circle) nest locations and corresponding final nest status at the Kearney Broadfoot South off-channel sand and water site during May through August 2023. Also depicted are predator management efforts including: an interior predator exclusion fence (black dashed line) placed along the shoreline; random pattern lights (yellow pentagons) and motion activated lights (yellow stars) deployed in sets and evenly distributed; and blinking walking lights (yellow asterisks) mounted to the fenceline to give the illusion of movement. The final nest status denotes whether the nest was successful and at least one chick hatched, or the nest failed during the incubation stage. Final nest status for successful nests is denoted by a blue circle with green outer ring for plovers and red circle with green outer ring for terns. Final nest status for failed nests is denoted by differences in the colored outer rings surrounding the blue or red circles. Nests that failed due to abandonment are denoted with an orange outer ring; nests that failed due to predation are denoted with a black outer ring; and nests the failed due to unknown causes are denoted with a white outer ring.

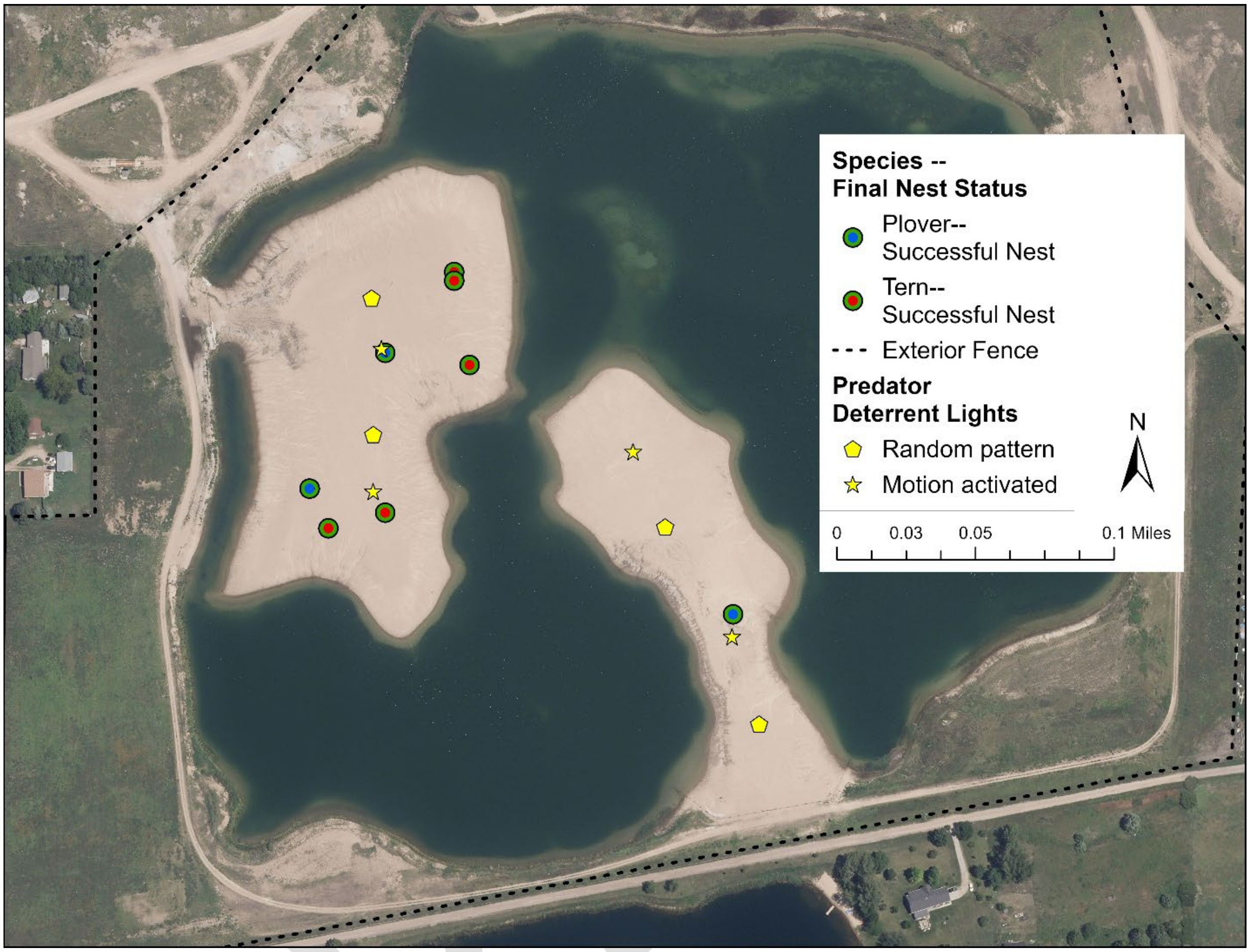


Figure 31. Piping plover (Plover, blue circle) and least tern (Tern, red circle) nest locations and corresponding final nest status at the Newark West off-channel sand and water site during May through August 2023. Also depicted are predator management efforts including: an exterior fence (black dashed line) placed around the site; and random pattern lights (yellow pentagons) and motion activated lights (yellow stars) deployed in sets and evenly distributed. The final nest status denotes whether the nest was successful and at least one chick hatched, or the nest failed during the incubation stage. Final nest status for successful nests is denoted by a blue circle with green outer ring for plovers and red circle with green outer ring for terns.

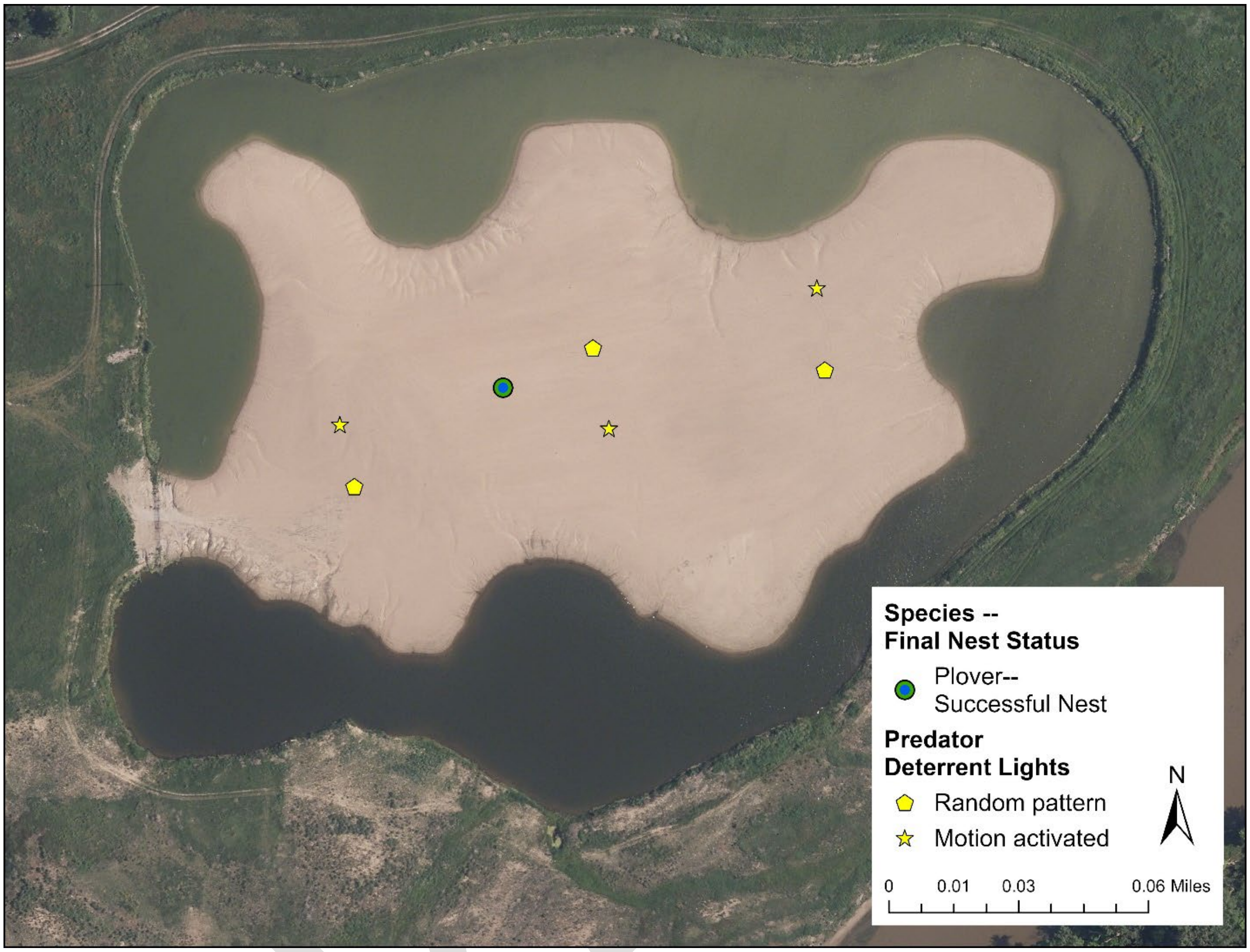


Figure 32. Piping plover nest locations (blue circle) and corresponding final nest status at the Leaman off-channel sand and water site during May through August 2023. Also depicted are predator management efforts including random pattern lights (yellow pentagons) and motion activated lights (yellow stars) deployed in sets and evenly distributed. The final nest status denotes whether the nest was successful and at least one chick hatched, or the nest failed during the incubation stage. Final nest status for successful nests is denoted by a blue circle with green outer ring for plovers.

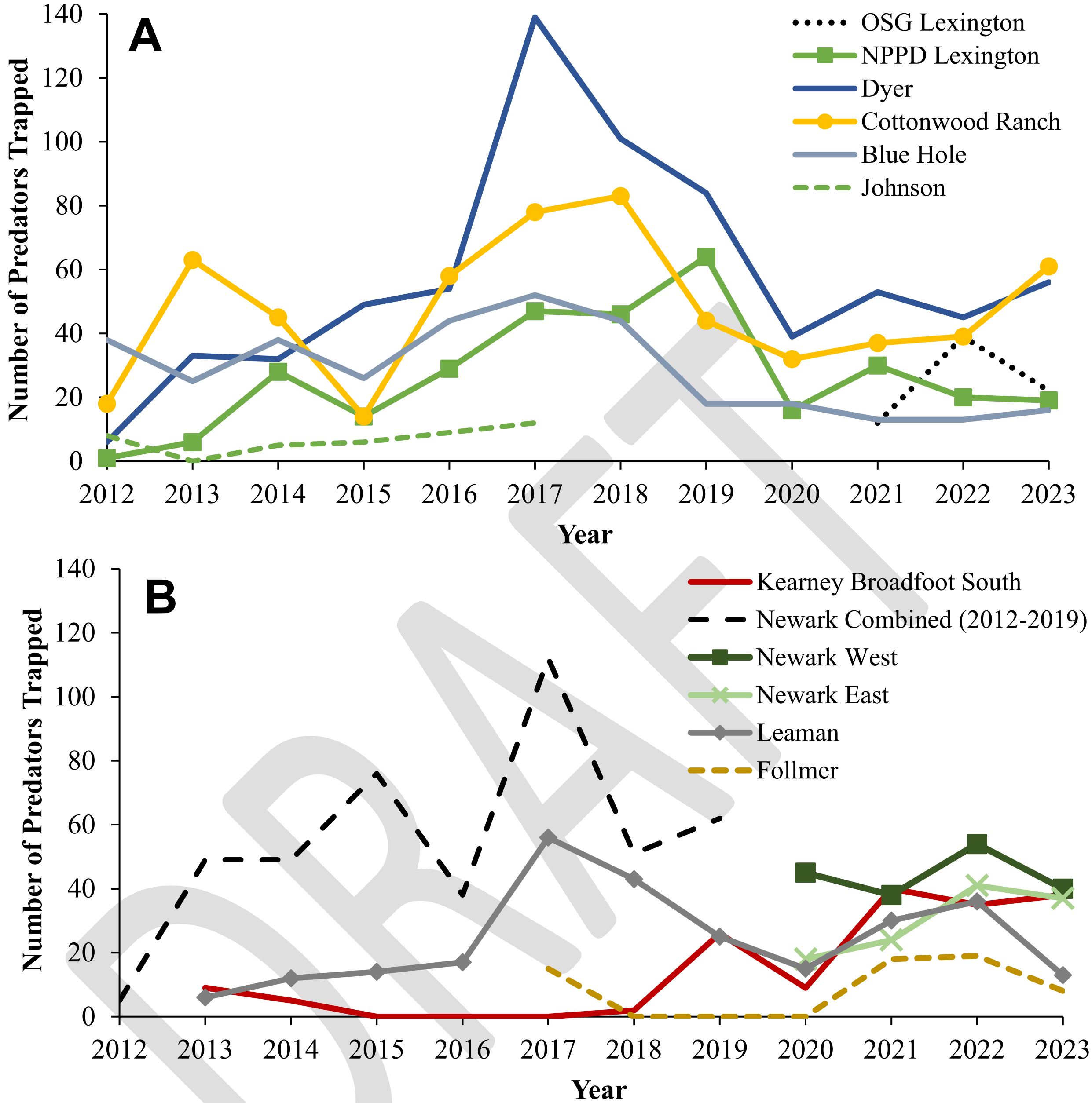


Figure 33. Annual variability in the total number of terrestrial predators trapped at Program-managed off-channel sand and water (OCSW) piping plover and least tern nesting sites and Nebraska Public Power District nesting sites during 2012–2023 between (A) Lexington and Kearney, and (B) Kearney and Alda, Nebraska. Predator trapping occurred during March through August of most years and trapping efforts increased substantially in 2017 at off-channel sites. Trapping did not occur at Kearney Broadfoot South during 2012. Captures only occurred at Follmer in 2017 and during 2021–2023 despite annual trapping efforts during 2017–2023. Predators trapped at Newark West and Newark East were previously reported as a total for both sites and are labeled here as Newarks Combined (2012–2019) until 2020 when Newark East was reported separately from Newark West.

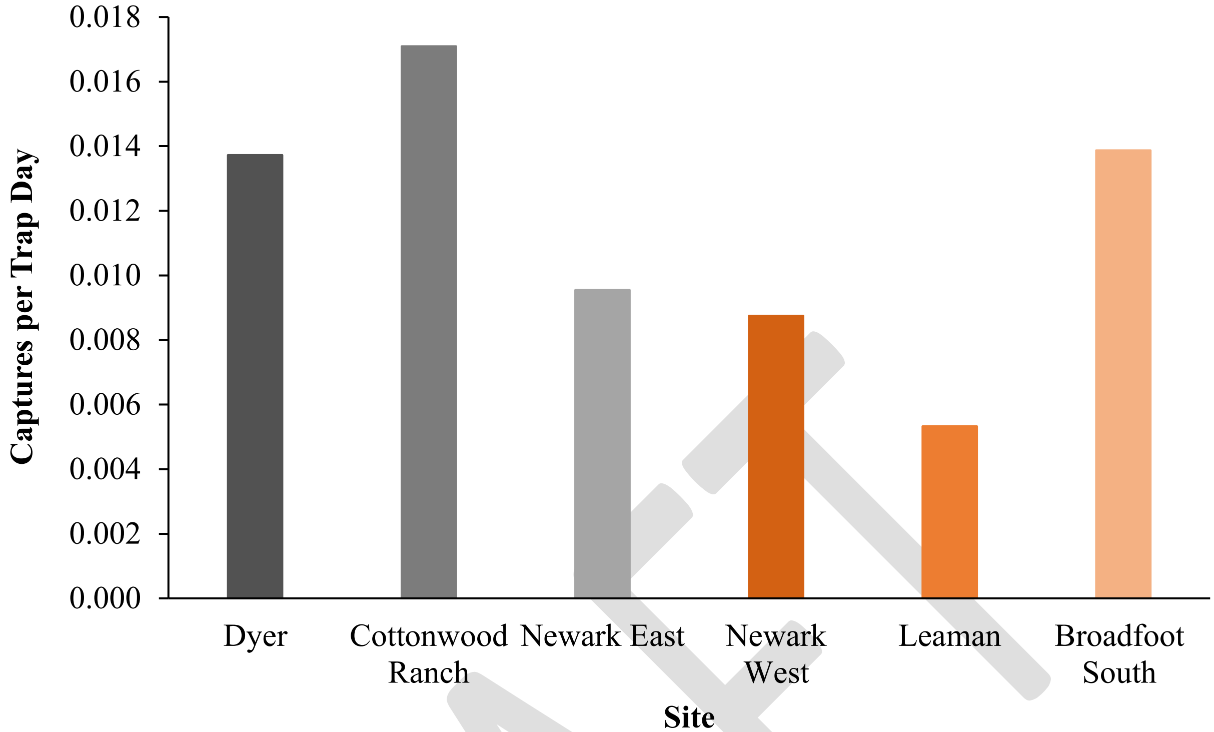


Figure 34. Captures of potential terrestrial predator species per trap day at six off-channel sand and water piping plover and least tern nesting sites adjacent to the central Platte River, Nebraska during March through August 2023. Captures per trap day was calculated by dividing the total number of potential terrestrial predator species captured in traps by the total number of trap days at each site. The total number of trap days at each site was calculated based on the number of traps deployed at each site and the number of days each trap was active for trapping. Sites had basic predator management (gray bars) or additional predator management (orange bars). Sites with basic predator management were Dyer, Cottonwood Ranch, and Newark East. Sites with additional predator management were Newark West, Leaman, and Kearney Broadfoot South.

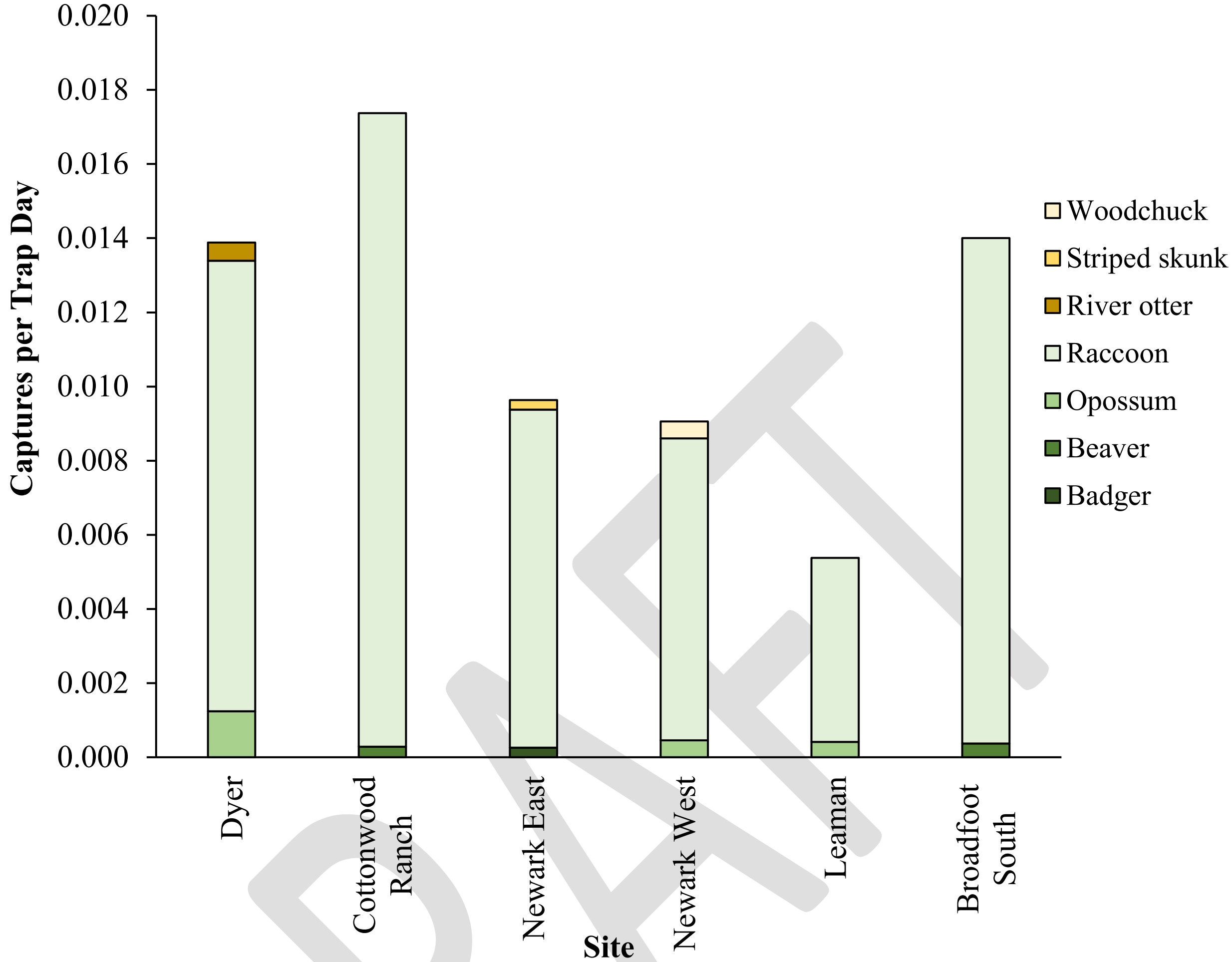


Figure 35. Captures of potential mammalian predator species per trap day by species at six off-channel sand and water piping plover and least tern nesting sites adjacent to the central Platte River, Nebraska during March through August 2023. Captures per trap day for each species was calculated by dividing the total number of each species captured in traps at each site by the total number of trap days at each site. The total number of trap days at each site was calculated based on the number of traps deployed at each site and the number of days each trap was active for trapping. Sites had basic predator management (Dyer; Cottonwood Ranch; Newark East) or additional predator management (Newark West; Leaman; Kearney Broadfoot South).

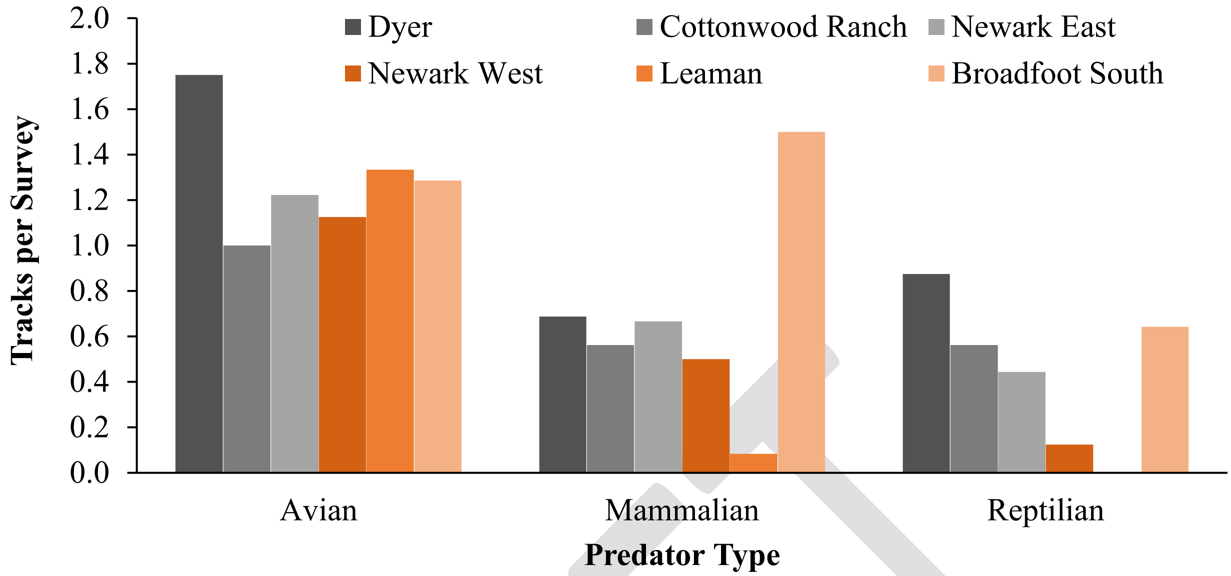


Figure 36. Potential avian, mammalian, and reptilian predators registered per track survey at six off-channel sand and water piping plover and least tern nesting sites adjacent to the central Platte River, Nebraska. Sites had basic predator management (gray bars) or additional predator management (orange bars). Tracks of potential predator species were identified using weekly track surveys at each site. Number of tracks per survey was calculated using the number of unique potential predator tracks at a site divided by the number of total weekly track surveys for that site. Sites with basic predator management were Dyer, Cottonwood Ranch, and Newark East. Sites with additional predator management were Newark West, Leaman, and Kearney Broadfoot South.

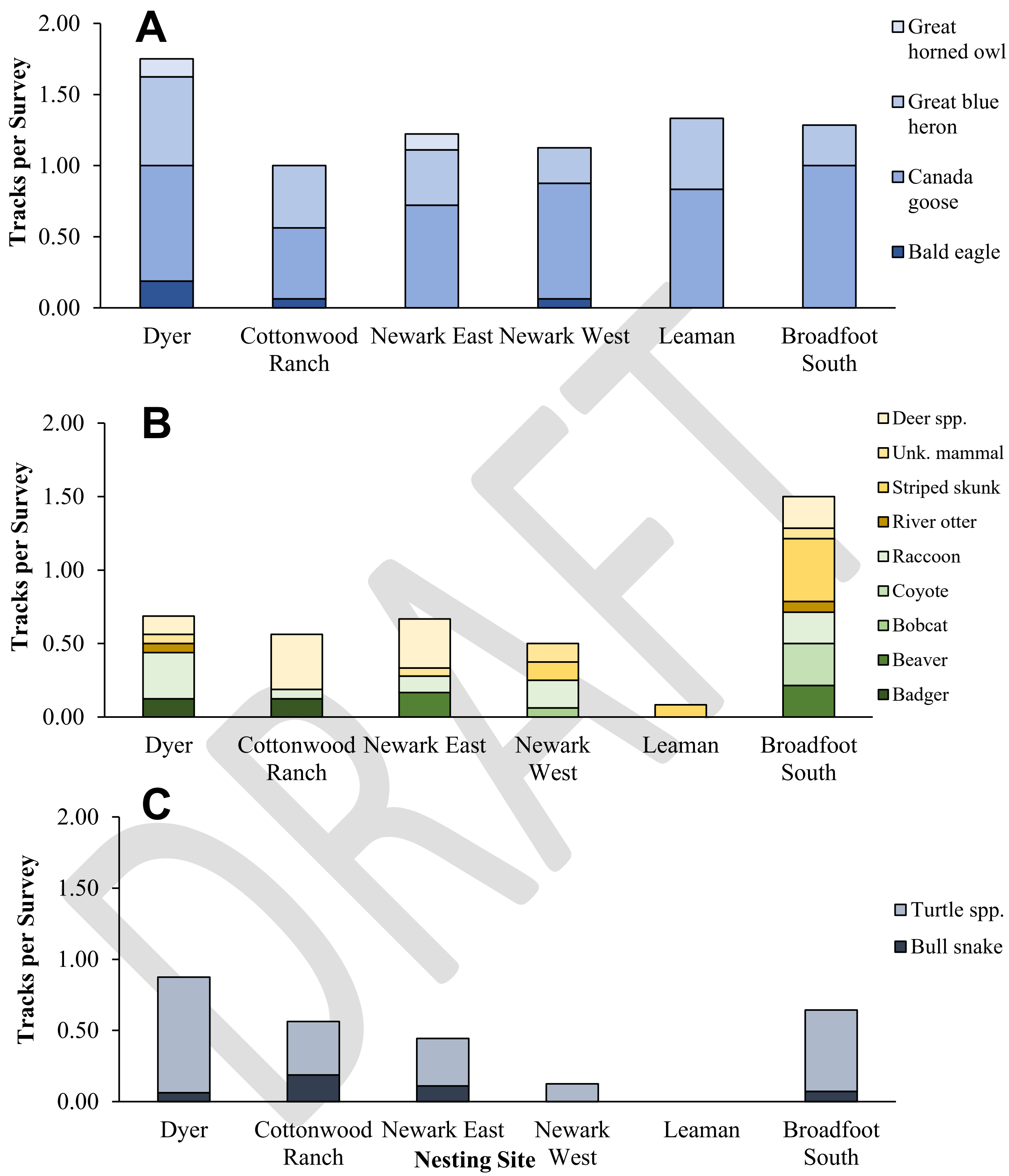


Figure 37. Potential (A) avian, (B) mammalian, and (C) reptilian predator species registered per track survey at six off-channel sand and water piping plover and least tern nesting sites adjacent to the central Platte River, Nebraska. Tracks of potential predator species were identified using weekly track surveys at each site. Number of tracks per species per survey was calculated using the number of unique potential predator tracks by species at a site divided by the number of total weekly track surveys for that site. Sites with basic predator management were Dyer, Cottonwood Ranch, and Newark East. Sites with additional predator management were Newark West, Leaman, and Kearney Broadfoot South.

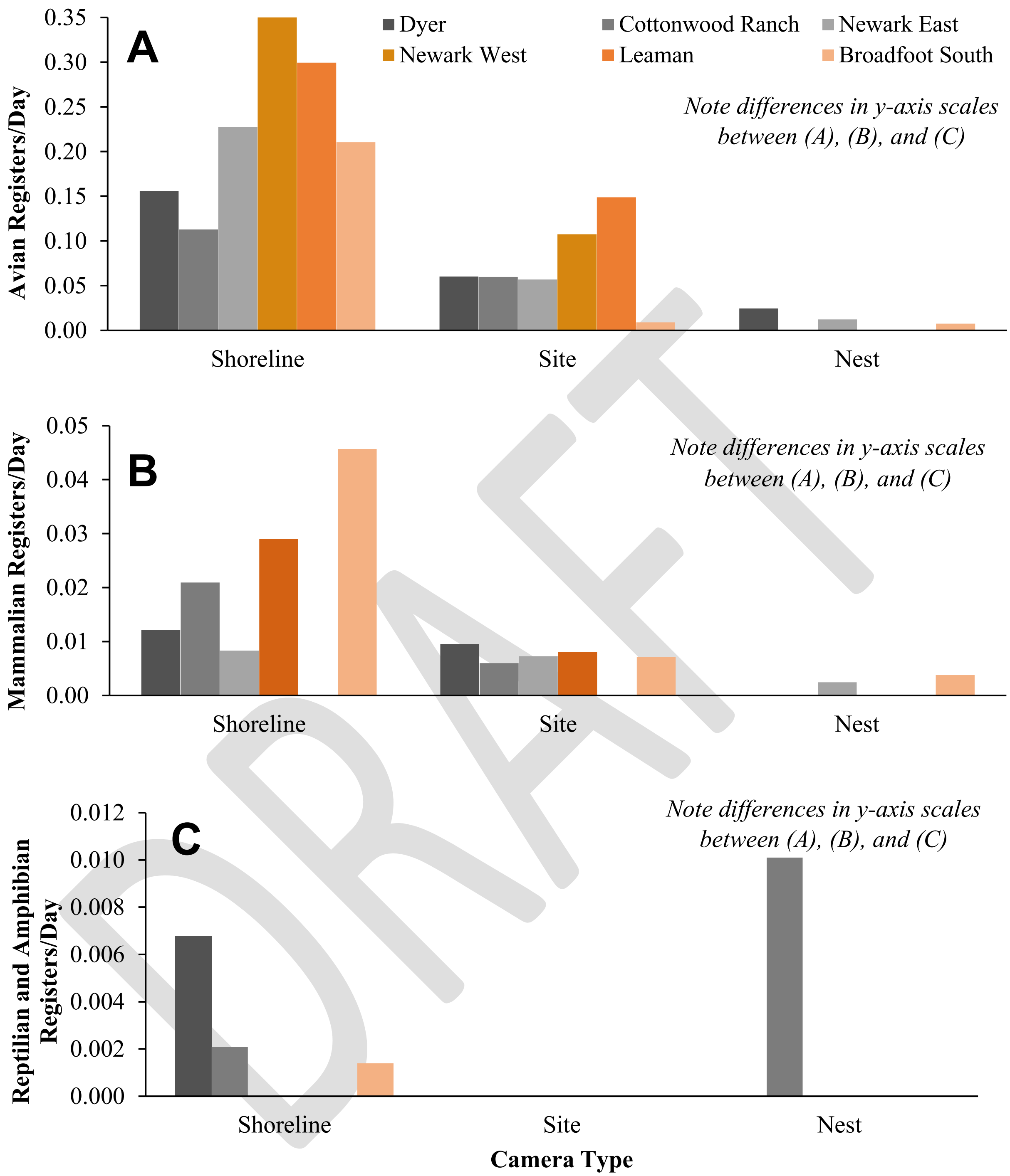


Figure 38. Registers of potential (A) avian, (B) mammalian, and (C) reptilian and amphibian predators captured by shoreline, site, and nest monitoring cameras per day at six off-channel piping plover and least tern nesting sites adjacent to the central Platte River, Nebraska. Sites had basic (gray bars) or additional predator management (orange bars). ***Note the differences in scale of the y-axis among (A), (B), and (C).*** The number of unique potential predator registers observed at a site via the indicated monitoring method was divided by the total number of camera days dedicated to the indicated monitoring effort at that site. Nest-level registers include predation events. Number of predation events/camera day is in Table 31. Please note: nest-level data for the plover nest at the Dippel on-channel site is not provided in this figure (see Tables 31 and 32 for information nest-level registers at this nest).

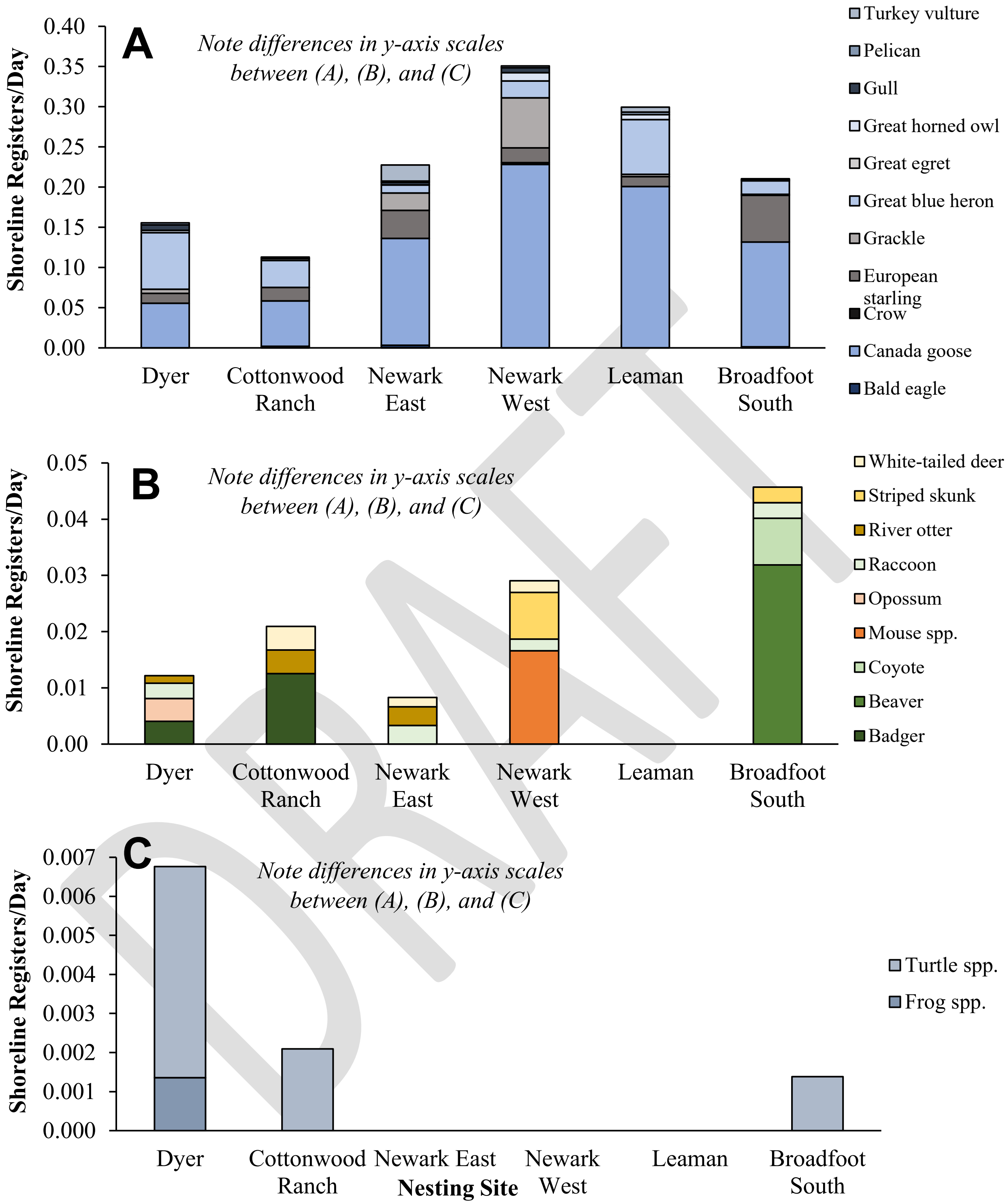


Figure 39. Potential (A) avian, (B) mammalian, and (C) reptilian and amphibian predator species registered by shoreline cameras at six off-channel sand and water piping plover and least tern nesting sites adjacent to the central Platte River, Nebraska. ***Note the differences in scale of the y-axis among (A), (B), and (C).*** The number of unique potential predator registers observed at a site using shoreline cameras was divided by the total number of camera days dedicated to the shoreline camera monitoring effort at that site. Sites with basic predator management were Dyer, Cottonwood Ranch, and Newark East. Sites with additional predator management were Newark West, Leaman, and Kearney Broadfoot South.

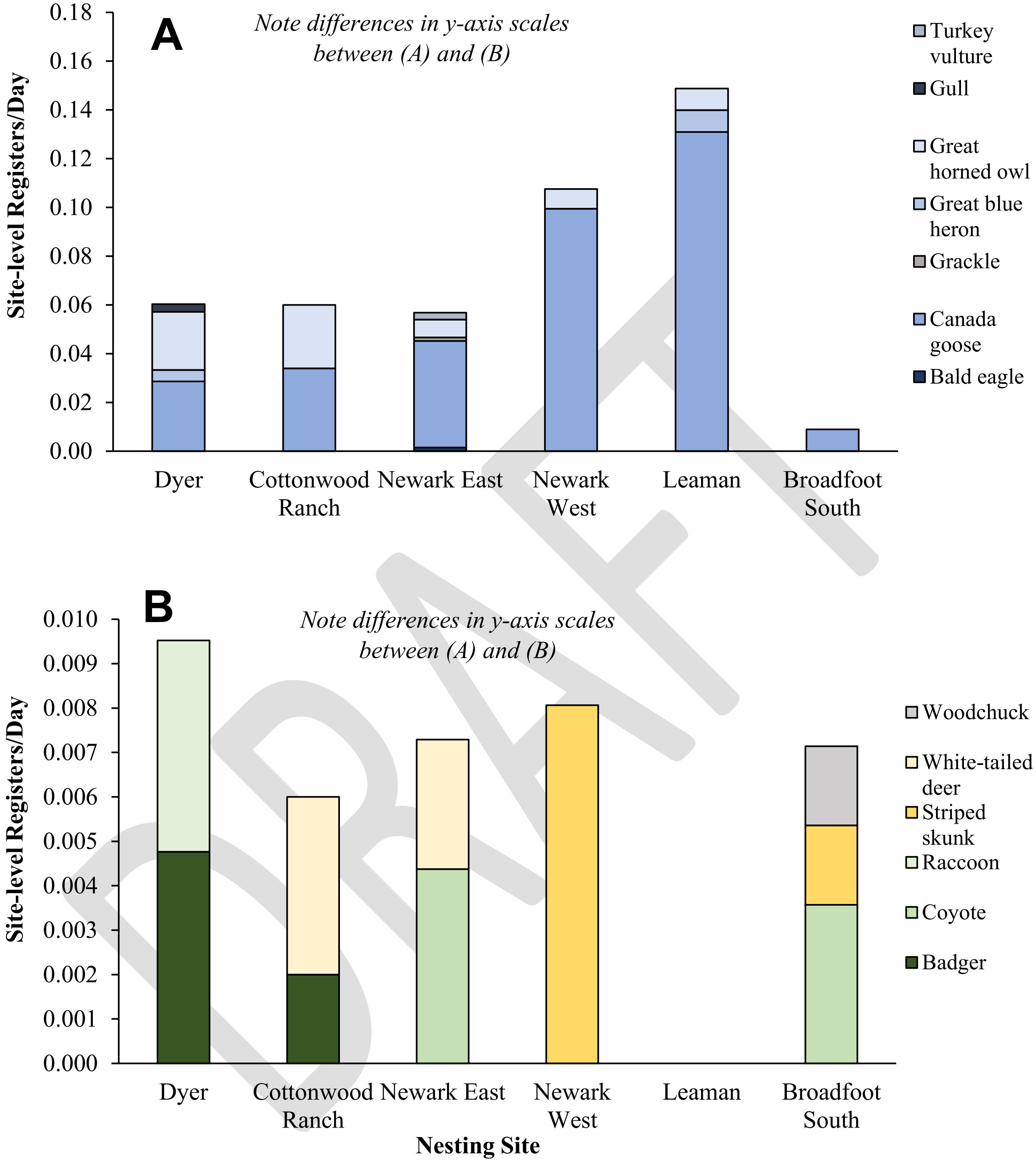


Figure 40. Potential (A) avian, and (B) mammalian predator species registered by site-level cameras at six off-channel sand and water piping plover and least tern nesting sites adjacent to the central Platte River, Nebraska. ***Note the differences in scale of the y-axis between (A) and (B).*** No reptilian or amphibian predator species were recorded on site-level cameras at the six sites. The number of unique potential predator registers observed at a site using site-level cameras was divided by the total number of camera days dedicated to the site-level camera monitoring effort at that site. Sites with basic predator management were Dyer, Cottonwood Ranch, and Newark East. Sites with additional predator management were Newark West, Leaman, and Kearney Broadfoot South.

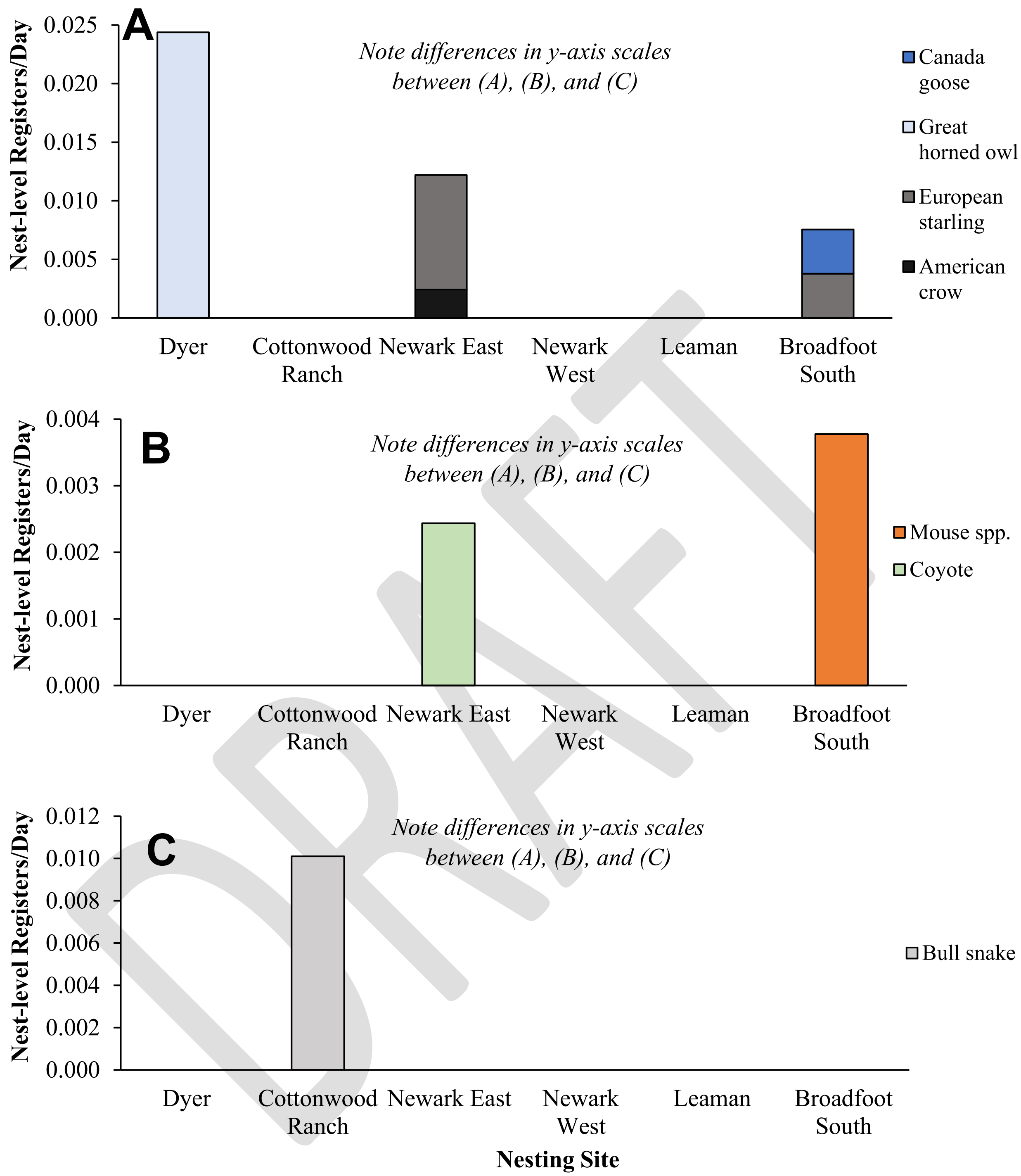


Figure 41. Potential (A) avian, (B) mammalian, and (C) reptilian predator species registered by nest-level cameras at six off-channel sand and water piping plover and least tern nesting sites adjacent to the central Platte River, Nebraska. ***Note the differences in scale of the y-axis between (A), (B), and (C).*** The number of unique potential predator registers observed at a site using nest-level cameras was divided by the total number of camera days dedicated to the nest-level camera monitoring effort at that site. Nest-level registers include predation events. Number of predation events per camera day is provided in Table 31. Sites with basic predator management were Dyer, Cottonwood Ranch, and Newark East. Sites with additional predator management were Newark West, Leaman, and Kearney Broadfoot South. Note: nest-level data for the plover nest at the Dippel on-channel site is not provided in this figure (see Tables 31 and 32).

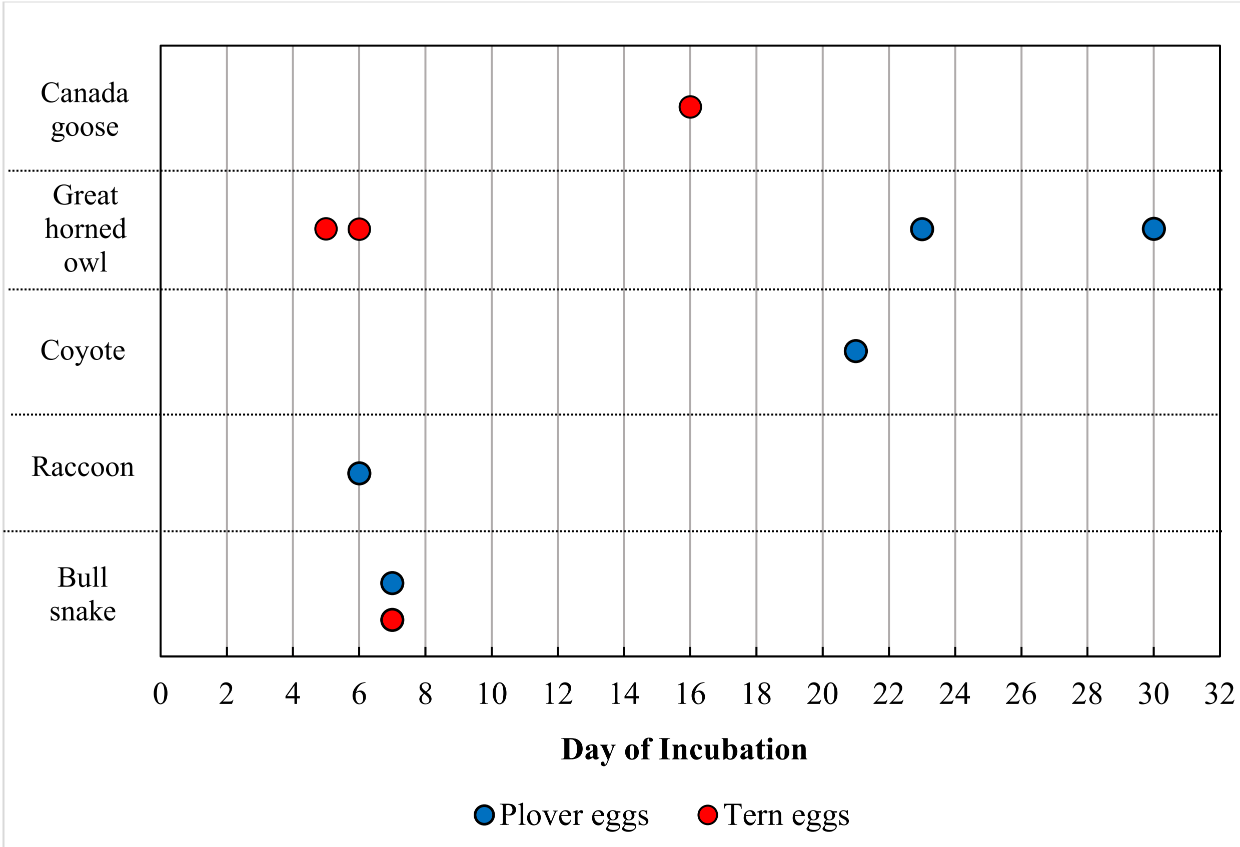


Figure 42. Incubation timeline indicating the day predation occurred on a total of five piping plover nests (blue circles) and four least tern nests (red circles) by a Canada goose, great horned owls, a coyote, a raccoon, and a bull snake during 2023. Nests were located at Cottonwood Ranch (one nest), Dyer (four nests), Kearney Broadfoot South (one nest), and Newark East (two nests) off-channel sand and water nesting sites located adjacent to the central Platte River, Nebraska. One plover nest was also located at the Dippel on-channel site. Data from all nest monitoring sources (i.e., outside/inside observers; nest, site, and shoreline camera data; and track surveys) were used to determine nest fates. All nests contained eggs; no nests had newly hatched chicks present when predation occurred. Note: the plover nest depredated on day 30 had only one egg remaining as one adult and three chicks that had already hatched left the nest before predation occurred. Tern nest ID O-DS-09-23 was not monitored by a camera and is not depicted in the figure, although it was assumed it depredated by a great horned owl near the end of the incubation period.

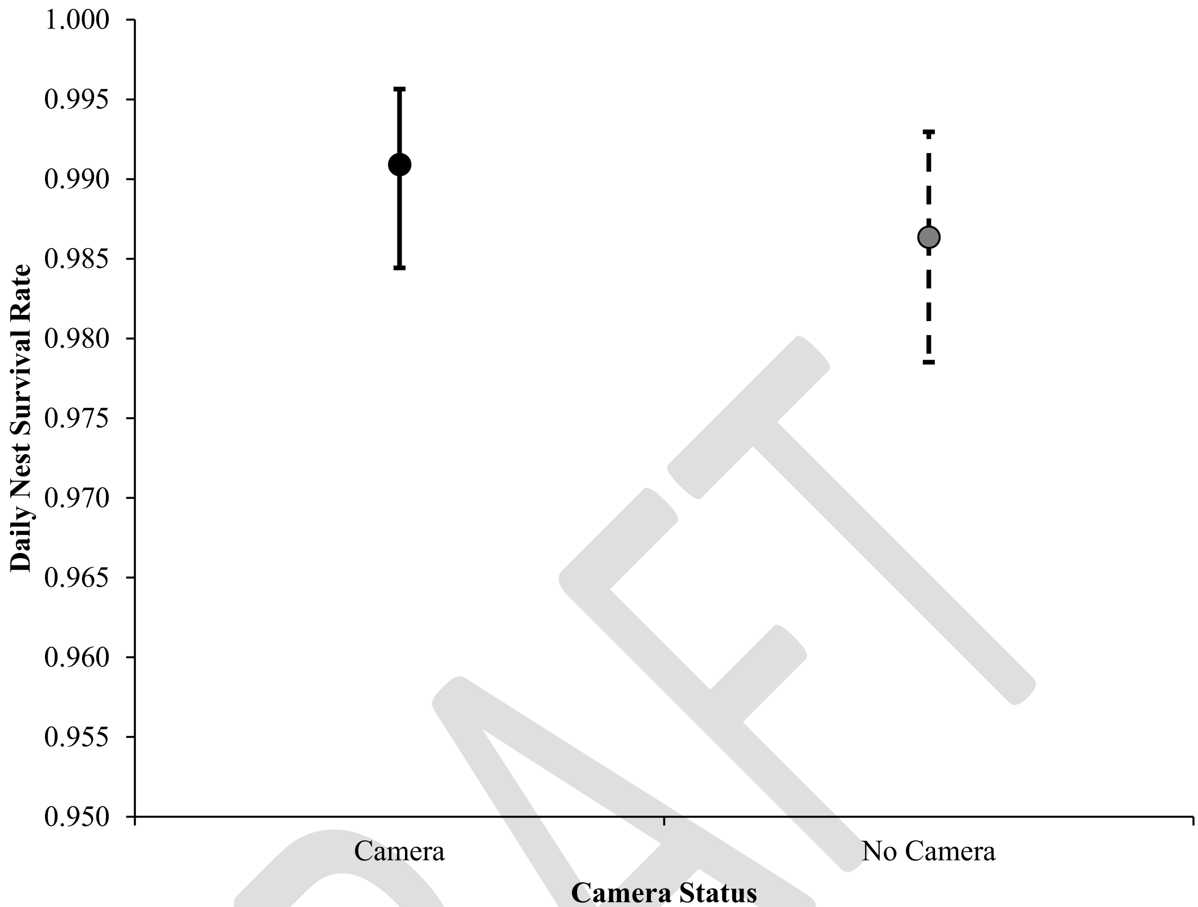


Figure 43. Estimated average daily survival rates of plover and tern nests with a nest camera present (Camera; black circle) or absent (No Camera; gray circle) at six off-channel nesting sites and one on-channel nesting site during 2023. The 95% confidence intervals are depicted around each estimate (solid line for camera; dashed line for no camera). There was no significant difference in daily nest survival rates at nests with and without cameras during 2023.

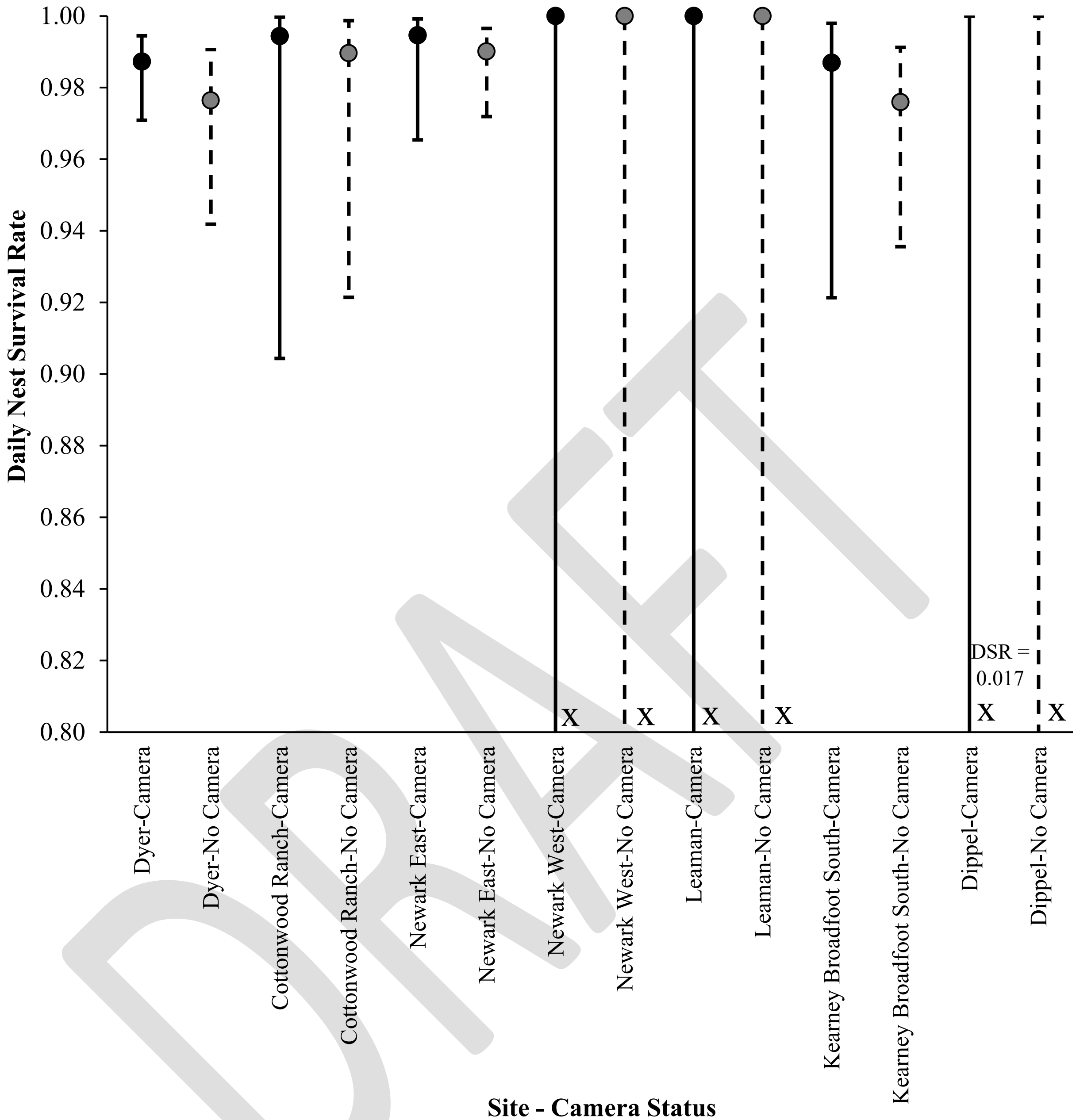


Figure 44. Average daily survival rates of plover and tern nests by site with (black circle) and without (gray circle) a nest camera present during 2023. EDO biologists deployed nest-level cameras at six off-channel nesting sites and one on-channel nesting site (Dippel) during 2023. The 95% confidence intervals are depicted around each estimate (solid line for camera; dashed line for no camera). There was no significant difference in daily nest survival rates at nests with and without cameras for plovers or terns at four sites during 2023. Leaman and Dippel each had only one nest, making it not possible to statistically evaluate differences between nests with and without cameras. The four nests at Newark West all were successful and it was not possible to evaluate differences between nests with and without cameras. The "X" denotes the confidence interval extends from 0 to 1. The Dippel nest failed and had a daily nest survival rate with a camera of 0.017, which is not depicted on the figure given the range of the y-axis.

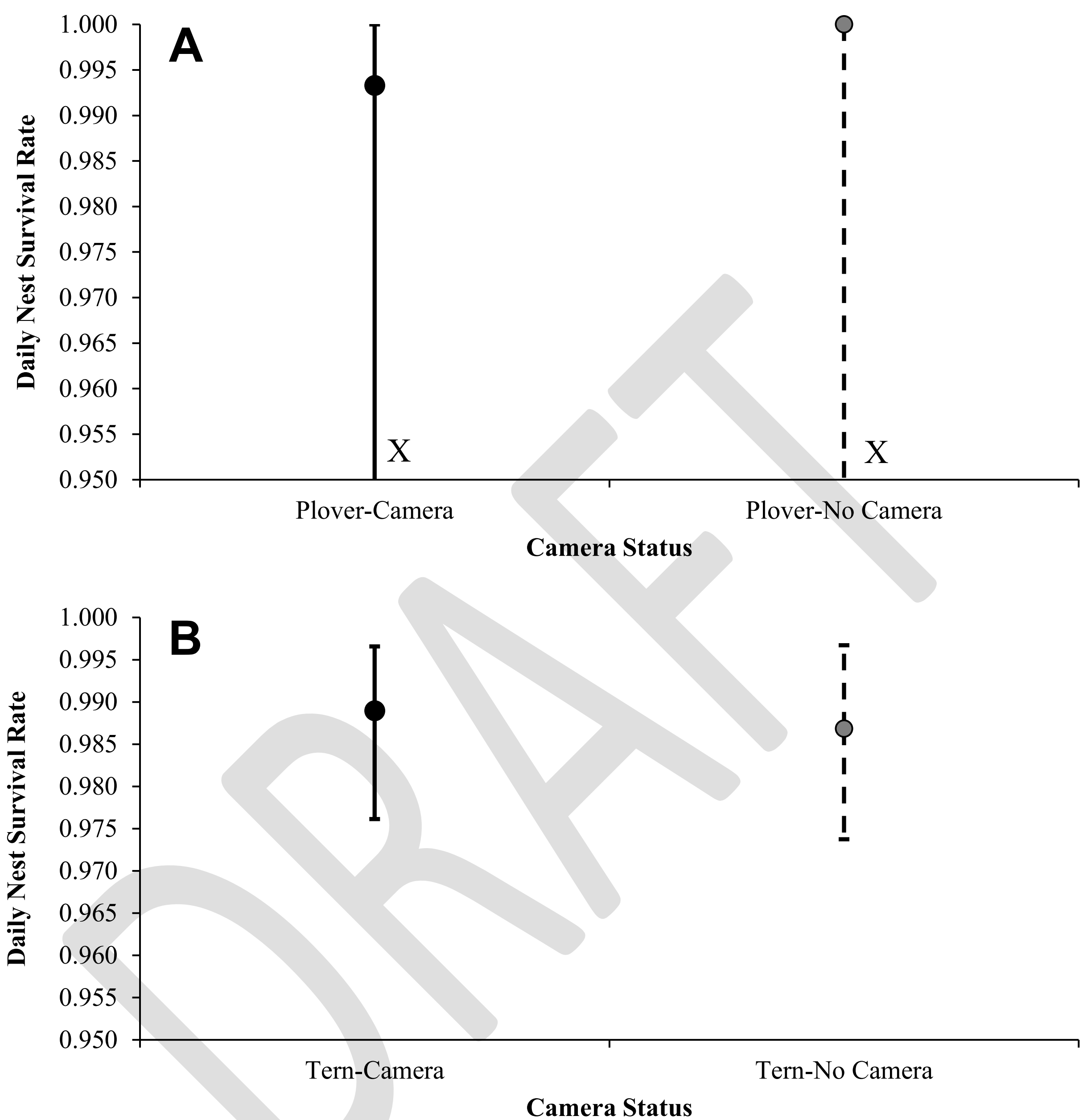


Figure 45. Average daily survival rates of (a) plover nests, and (b) tern nests with (black circle) and without (gray circle) a nest camera present at six off-channel nesting sites and one on-channel nesting site during 2023. The 95% confidence intervals are depicted around each estimate (solid line for camera; dashed line for no camera). There was no significant difference in daily nest survival rates at nests with and without cameras for terns during 2023. Only one plover nest did not have a camera, making it not possible to statistically evaluate differences between nests with and without cameras. The "X" denotes the confidence interval extends from 0 to 1.

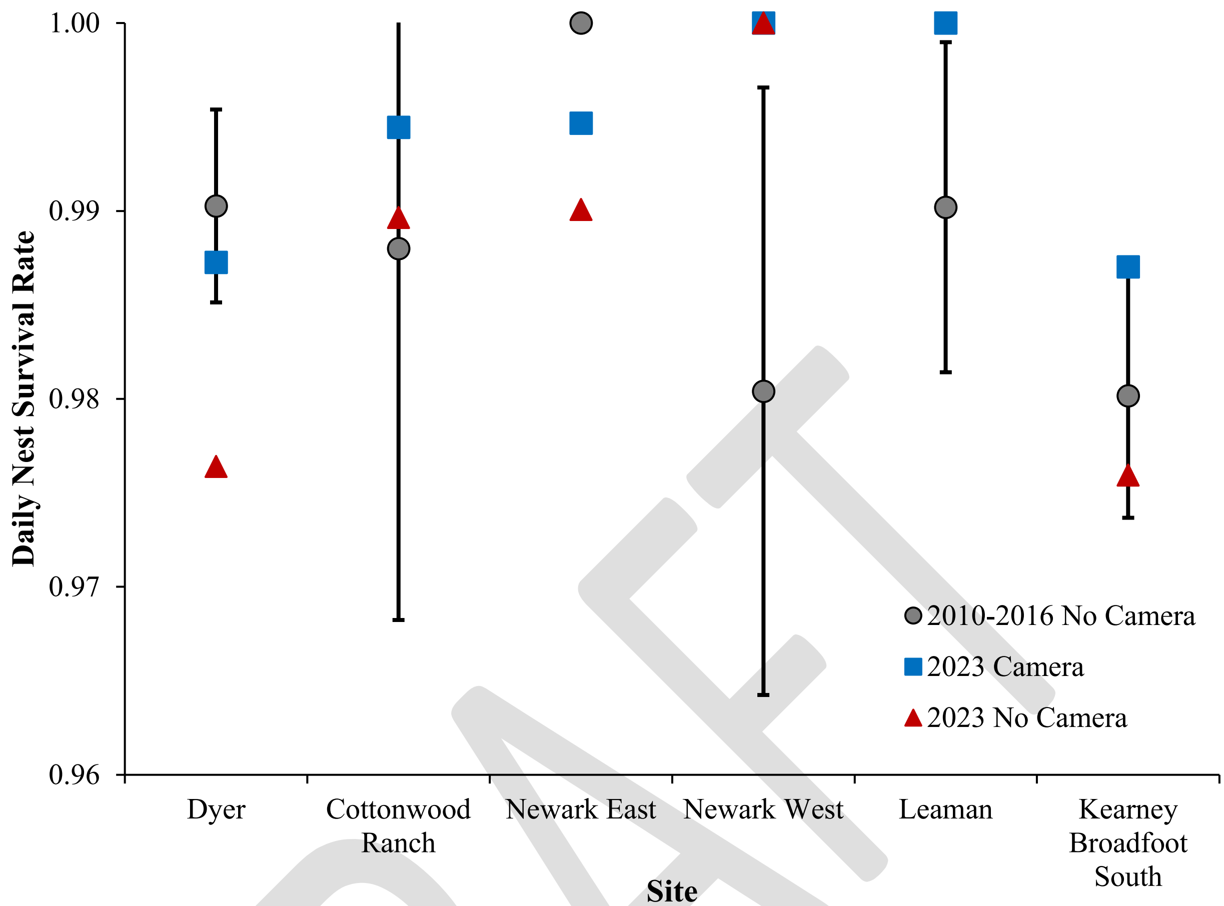


Figure 46. Combined average daily nest survival rates (DSR) of plover and tern nests with a camera present (blue square) or absent (red triangle) at six off-channel nesting sites during 2023. The mean nest DSR for each site during 2010–2016 prior to nest camera deployment is depicted with a gray circle along with 95% confidence intervals (CIs; solid line). One outlying data point (DSR = 0 for 2016) from Cottonwood Ranch was removed from the 2010–2016 calculation of the site mean DSR over the period. The sample size for Newark East during 2010–2016 was one plover nest and one tern nest that were both successful, resulting in no meaningful 95% CIs. There was only one nest at Leaman during 2023 that was successful and at which a camera was deployed, resulting in no data from "No Camera" nests.

APPENDIX.

Table A1. Research relevant to the Program's objectives and to our understanding of piping plover ecology.

Publication Year	Study Topic	Citation	Document Title	Study Years	Summary	Primary Findings
2023	Use of predator exclosures at plover nests	Peters SH, Engley L, Rezansoff A, Prescott DRC, Jones PF. 2023. Conservation Science and Practice 5(4):e12909. https://doi.org/10.1111/csp2.12909	The effectiveness and cost efficiency of different predator exclosure designs to increase piping plover (*Charadrius melodus*) nest success and fledging rate in Alberta, Canada.	1998–2010	The authors compared daily nest survival, nest productivity, and cost using three types of nest exclosures (large, medium, small) and no exclosures.	The authors used data from 1998–2010 from 820 plover nests in Alberta, Canada. During 1998–2001 when large, medium, and small nest exclosures were used, there was no significant difference in daily nest survival rate between nestse with and without an exclosure. During 2002–2010 when only small exclosures were used, nests with exclosures had significantly higher daily nest survival rates than those without exclosures. Nests with small exclosures hatched more chicks and produced more fledglings than those without exclosures. When considering only successful nests, there was no difference in number of fledglings between nests with and without exclosures, indicating no added benefit of exclosures beyond protecting the nest. The authors found that cost per chick was lowest using small exclosures that were cylindrical and measured 40-cm x 60-cm.
2023	Use of predator exclosures at plover nests	Stantial ML, Cohen JB, Darrah AJ, Masio B. 2023. Ornithological Applications 2023:duad047, https://doi.org/10.1093/ornithapp/duad047	Predator exclosures increase nest success but reduce adult survival and increase dispersal distance of piping plovers, indicating exclosures should be used with caution.	2011–2018	Authors evaluated the impact of predator exclosures around plover nests on plover demography using a seven-year dataset from the New Jersey plover population.	Predator exclosures around plover nests increased nest success by 62% over a 34-day period. Exclosed nests were 4.7 times more likely to be abandoned, likely due to adult mortality. Abandoned nests were associated with lower adult survival. The authors found that after the male of a breeding pair had died and the nest was abandoned, the surviving female dispersed 10 times farther than birds whose first nest attempts were lost to other causes (e.g., flooding). This emigration effectively resulted in the loss of a local breeding pair. The authors used an online population projection model (PiperEx) to demonstrate exclosures were not expected to improve plover population growth rates in New Jersey and encouraged managers to consider whether exclosures are worth protecting eggs from predators with the trade-offs of reduced adult survival and increased emigration rates.

2023	Report to provide scientific information to inform future recovery planning	U.S. Fish and Wildlife Service. 2023. U.S. Fish and Wildlife Service Missouri River Recovery Office. 20 June 2023.	Biological Report for the northern Great Plains piping plover population (*Charadrius melodus circumcinctus*).	NA	Literature review and summary of updated information regarding northern Great Plains plover life history, breeding, habitat use, dispersal, and connectivity.	This USFWS literature review provided a summary of plover life history; current status of the northern Great Plains population in relation to habitat use and environmental conditions for breeding and brood rearing; and factors influencing species viability and future conditions needed to maintain sufficient resiliency, redundancy, and representation on the breeding range for a projected 50-year period.
2023	Population Viability Analysis of northern Great Plains piping plover population	Swift RJ, Anteau MJ, Ellis KS, MacDonald GJ, Ring MM, Sherfy MH, Toy DL. 2023. Frontiers in Bird Science 2:1157682. https://doi.org/10.3389/fbirs.2023.1157682	Estimating population viability of the northern Great Plains piping plover population considering updated population structure, climate change, and intensive management	2006–2022	Updated a population viability model constructed by McGowan et al. (2014) using new data on plover vital rates and connectivity, potential management actions, and stochastic climate variability to predict the extinction probability of the northern Great Plains piping plover population over 50 years.	Using new information on metapopulation dispersal rates and connectivity, the authors predicted the risk of plover extinction to be between 0.088 and 0.373 over 50 years based on a 2006 population estimate. This represented an increase over the 0.033 probability of extinction predicted by the McGowan et al. (2014) model. However, in only one of eight scenarios did the median of the estimated plover population from 1,000 simulations decrease relative to the 2006 estimate. Reduction in adult survival due to a simulated effect of nest caging increased extinction probability to 0.267–0.373 and decreased the median of the estimated population size over time. In contrast, simulated increases in fecundity due to nest caging reduced extinction probability to 0.088–0.103 only if there was no negative effect on adult survival. Increasing variance around fecundity estimates to represent climate stochasticity had little effect on predicted population viability.

2023	Species distribution modeling of plover breeding density	[Ellis KS, Anteau MJ, MacDonald GJ, Swift RJ, Ring MM, Toy DL, Sherfy MH, Post van der Burg M. 2023. Scientific Reports 13:6087. https://doi.org/10.1038/s41598-023-32886-w](https://doi.org/10.1038/s41598-023-32886-w)	Data integration reveals dynamic and systematic patterns of breeding habitat use by a threatened shorebird	2000–2019	Developed spatiotemporal model of piping plover breeding habitat use in Montana, North Dakota, and South Dakota using 20-year eBird dataset and nest monitoring data to examine effects of dynamic and long-tern environmental processes on breeding density	Plover breeding habitat use and density was related to dynamic covariates including percentage of surface water within 90 m, vegetation coverage within 30 m, and percentage of crop and hay pasture surrounding the location. Habitat use was also related to a static layer that quantified distance to permanent lakes as a decreasing exponential function. The authors found that use of the cBird dataset provided more complete spatial coverage than nest monitoring data alone, but eBird data was related to surrounding road density due to site accessibility. The authors developed a predictive species distribution map for breeding plovers across portions of Montana, North Dakota, and South Dakota to inform conservation efforts.
2023	Additional predator management and monitoring via trapping, track surveys, and remote cameras	Platte River Recovery Implementation Program. 2023. Platte River Recovery Implementation Program: 2022 piping plover and interior least tern monitoring and research report, central Platte River, Nebraska.	Platte River Recovery Implementation Program 2022 piping plover and interior least tern monitoring and research report, central Platte River, Nebraska	2022	Documentation of predator presence and losses to predation in 2022.	In 2022, remote camera monitoring helped improve accuracy of monitoring on Program managed sites, reducing the number of unknown fates and providing information to determine the stage of the nest or chicks at the time of loss. The proportion of losses assigned to failed-unknown causes for both plovers and terns decreased in 2022, with a corresponding increase in the proportion of nests and broods fated as failed-predation. Out of the total 28 nests (15 plover and 13 tern) that failed due to predation in 2022 across the AHR spanning both Program and non-Program sites, 19 occurred at camera-monitored nests on Program sites. Badgers accounted for eight of the 19 (42%) individual predated nests and great horned owls accounted for seven of the 19 (37%) predated nests. A striped skunk was responsible for two (11%) predated nests and a Virginia opossum and bull snake each predated one (5%) nest. Mammalian predators were responsible for 58%, avian predators were responsible for 37%, and reptilian predators were responsible for 5% of the 19 losses of individual nests to predation for which camera monitoring provided this information.

2023	Camera monitoring of nests	Call MN, Wilke AL, Poulton Z, Boettcher R, Karpanty SM, Kwon E, Lipford A, Gardner ED, Anderson L, Fraser JD, Catlin DH, Wails CN. 2023. Waterbirds 45:312-327. https://doi.org/10.1675/063.045.0310	Comparing in-person versus camera monitoring of shorebird reproductive success	2019	Tested effectiveness of in-person compared to camera-based monitoring to quantify productivity of plover nests in Virginia.	To be summarized later
2022	Additional predator management and monitoring via trapping, track surveys, and remote cameras	Platte River Recovery Implementation Program. 2022. Platte River Recovery Implementation Program: 2021 piping plover and interior least tern monitoring and research report, central Platte River, Nebraska.	Platte River Recovery Implementation Program 2021 piping plover and interior least tern monitoring and research report, central Platte River, Nebraska ATTN: PREDATOR MANAGEMEN T AND MONITORING	2021	Documentation of predator presence and losses to predation in 2021.	In 2021, remote camera monitoring helped improve accuracy of monitoring on Program managed sites, reduce the number of unknown fates, as well as determine the stage of the nest or chicks at the time of loss. Out of the total 28 predation events across the AHR, Program and non-Program sites, 17 occurred at camera-monitored nests on Program sites. For the 2021 season, avian predation accounted for all but two of the predation events at nests with camera monitoring. There were 14 predation events by great horned owls, one by an American Crow, and one by a badger. There was also one tern nest predated but not registered on the nest camera. Most of these camera documented events occurred further along in incubation, resulting in the loss of a greater investment, and reducing the probability of successful renesting.

2022	Population dynamics	Swift RJ, Anteau MJ, Ellis KS, Ring MM, Sherfy MH, Toy DL, Koons DN. 2022. https://doi.org/10.1002/ecs2.4190	Implications of habitat-driven survival and dispersal on recruitment in a spatially structured piping plover population	2014–2017	The authors estimated hatch-year survival to adulthood and natal dispersal rates between Missouri River and Alkali Wetlands breeding groups. They examined the role of habitat availability in natal dispersal and recruitment.	Hatch-year survival to adulthood was slightly higher for individuals hatched on the Missouri than on the Alkali Wetlands but declined over time. Those hatched on the Alkali Wetlands were more likely to disperse to breed on the Missouri than vice versa. The Missouri River showed higher natal fidelity, thus higher recruitment; but declining breeding group abundance was responsible for a declining trend in the number of recruits to the Missouri over time. Unbalanced, high natal dispersal rates withing the Northern Great Plains indicate high connectivity among regions driven by fluctuating availability of habitat.
2022	Annual piping plover and least tern synthesis reports	Available on Program Online Library: https://platteriverprogram.org/program-library. Keywords: least tern, piping plover, technical reports	PRRIP tern and plover monitoring reports (2008–2022)	2008–2022	These reports provide a synthesis of the respective annual monitoring and research efforts for piping plovers and least terns along the Program's Associated Habitat Reach on the central Platte River, and the reproductive data collected.	There was a general positive species response to Program management, as well as habitat creation, restoration, and maintenance along the AHR.
2022	Tern and Plover Conservation Partnership Annual Reports	Tern and Plover Conservation Partnership https://ternandplover.unl.edu/annual-reports	Interior least tern and piping plover annual report for the lower Platte River, Nebraska	2008–2022	These reports provide a synthesis of the respective annual monitoring and research efforts for piping plovers and least terns along the Missouri River and the reproductive data collected.	These reports provide a synthesis of the respective annual monitoring and research efforts for piping plovers and least terns along the Missouri River and the reproductive data collected.

2022	MRRP Annual Reports	Missouri River Recovery Program https://www.nwo.usace.army.mil/mrrp/Library/	MRRP ESA adaptive management compliance report	2001–2022	These reports provide a synthesis of the respective annual monitoring and research efforts for piping plovers and least terns along the Missouri River and the reproductive data collected.	These reports provide a synthesis of the respective annual monitoring and research efforts for piping plovers and least terns along the Missouri River and the reproductive data collected.
2021	Spatially explicit population dynamics	Swift RJ, Anteau MJ, Ellis KS, Ring MM, Sherfy MH, Toy DL, Koons DN. 2021. U.S. Geological Survey Open-File Report 2020-1152. https://doi.org/10.3133/ofr20201152	Spatial variation in population dynamics of northern Great Plains piping plovers.	2014–2019	Studied sources of variation in survival, dispersal probabilities, and dispersal distances for hatch-year and adult piping plover in the northern Great Plains.	To be summarized later

2021	Additional predator management and monitoring via trapping, track surveys, and remote cameras	Mohlman KL. 2021. Platte River Recovery Implementation Program: 2020 interior least tern and piping plover monitoring and research report, central Platte River, Nebraska.	Platte River Recovery Implementation Program 2020 interior least tern and piping plover monitoring and research report, central Platte River, Nebraska	2020	Documentation of predator presence at the nest level in 2020.	In 2020 there were three documented predation events by great horned owls consuming eggs at nests; two occurred at Leaman East and one at Newark East.
2021	Predator monitoring via remote cameras	Keldsen KJ. 2021. Chap 2: Evaluation of predator exclusion techniques on mammalian predator access to interior least tern and piping plover off-channel nesting sites along the central Platte River in Nebraska, USA. Masters thesis, University of Nebraska at Kearney, ProQuest Dissertations Publishing 28645869.	Efficacy of predator exclusion methods and ID of nest predators for interior least terns and piping plovers at off-channel nesting sites along the central Platte River, Nebraska, USA- Chapter 2	2017–2018	The objectives of this study were to determine whether the predator panel wing system (PPW) deters potential mammalian predators from accessing off-channel nesting peninsulas and to identify mammalian species that approached or breached the PPW. We also determined the probability of a breach occurring at the PPW and daily probability of predator activity.	Approaches were much higher than breaches (i.e., 145 approaches and 15 breaches). The PPW was effective 90.6% of the time.

2021	Predator monitoring via remote camera	Keldsen KJ. 2021. Chap 3: Using remote cameras to investigate the assemblage of avian and mammalian predators at interior least tern and piping plover off-channel nesting sites along the central Platte River, Nebraska, USA. Masters thesis, University of Nebraska at Kearney, ProQuest Dissertations Publishing 28645869.	Efficacy of predator exclusion methods and ID of nest predators for interior least terns and piping plovers at off-channel nesting sites along the central Platte River, Nebraska, USA-Chapter 3	2017–2019	This study documented the number of potential predator registers (PPR) at nesting peninsulas using camera-traps, determined the most frequent PPR, and identified potential relationships between PPR and landcover classifications.	Mammalian registers were less abundant than avian registers at off-channel nesting sites. Great horned owl was the most frequent avian species registered and coyote was the most frequent mammalian species registered. Developed landcover was positively correlated with presence of raccoons and skunks and tall vegetation was negatively correlated with presence of raccoons and skunks.
2021	Habitat selection	Robinson S, Bellman H, Walker K, Catlin D, Karpanty K, Ritter S, Fraser J. 2021. Ecosphere 12(12):e03870. https://doi.org/10.1002/ecs2.3870	Adult piping plover habitat selection varies by behavior	2016–2018	Plovers were monitored on Fire Island and Westhampton Island, New York, during 2016-2018 to record locations of adult birds. Used resource selection functions to determine whether breeding status or instantaneous behavior class best explained relationships with landscape characteristics.	Plovers displaying parental behavior (incubating, brooding, and accompanying chicks) selected locations closer to bay intertidal habitats and with proportionally more dry sand in the surrounding landscape. Non-parental plovers avoided areas with more dry sand and did not select for or against bay intertidal habitats. Birds exhibiting both types of behaviors avoided development and higher elevation areas throughout the landscape, but non-parental plovers avoided them more than parental plovers.

2021	Population dynamics	Swift RJ, Anteau MJ, Ellis KS, Ring MM, Sherfy MH, Toy DL. 2021. Movement Ecology 9:59. https//doi.org/10.1186/s40462-021-00293-3	Dispersal distance is driven by habitat availability and reproductive success in northern Great Plains piping plovers	2014–2019	Examined sources of variation for natal dispersal and interannual breeding for piping plovers in the northern Great Plains between 2014-2016.	Natal dispersal was on average longer than adult breeding movements. Individuals moved shorter distances when hatched, previously nested, or settled on river habitats. Hatch-year individuals moved shorter distances when there was more habitat available on their natal site than the year prior. Adults also moved shorter distances when more habitat was available at the settling site and when in closer proximity to other nesting areas.
2021	Effectiveness of predator management	Anteau MJ, Swift RJ, Sherfy MH, Koons DN, Ellis KS, Shaffer TL, Toy DL, Ring MM. 2021. Journal of Wildlife Management 86:e22139. https://doi.org/10.1002/jwmg.22139	Experimental evaluation of predator exclosures on nest, chick, and adult survival of piping plovers	2014–2016	Evaluated the survival of nests, chicks and adults at wetlands across the Northern Great Plain with and without nest exclosures.	Exclosed nests at treatment wetlands had greater cumulative survival than unexclosed nests at treatment or control wetlands. Survival to fledging was highest for chicks hatched from exclosed nests, and similar between chicks hatched from unexclosed nests at treatment and control wetlands. Adults associated with exclosed nests and unexclosed nests at treatment wetlands had greater survival than those associated with unexclosed nests at control wetlands. The positive influence of exclosures on nest survival was not offset by a reduction in chick or adult survival, indicating that exclosures are a viable tool for piping plover conservation.
2021	Plover chick habitat selection	Robinson SG, Walker KM, Bellman HA, Gibson D, Catlin DH, Karpanty SM, Ritter SJ, Fraser JD. 2021. Journal of Wildlife Management 87: e22325. https://doi.org/10.1002/jwmg.22325	Piping plover chick ecology following landscape-level disturbance	2013–2019	Piping plovers on Fire and West Hampton Island, New York, were studied from 2013-2019 following hurricane Sandy which created abundant nesting habitat on these barrier islands in 2012. The study examined the effects of landscape features on habitat selection, behavior, and survival of plover broods.	Plover broods selected flatter sites with less dense vegetation than available at random. Chick foraging rates were highest in moist substrates and were lower in areas of higher nesting plover density. Chick survival was greater for broods that hatched earlier in the season and increased as chicks aged. Natural landscape disturbance was important for creating non-vegetated, open sand habitat for both nesting and plover foraging.

2021	Foraging movements and colony attendance during breeding season of least terns	Sherfy MH, Ring MM, Stucker JH, Anteau MJ, Shaffer TL, Sovada MA. 2021. Waterbirds 44(1): 38-54. https://doi.org/10.1675.063.044.0104	Foraging movements and colony attendance of least terns (*Sternula antillarum*) on the central Platte River, Nebraska, USA	2009–2010	Documented least tern foraging movements and colony attendance during the breeding season on the central Platte River through the use of VHF transmitters and a network of datalogging receivers.	During daylight hours terns typically remained within 8 km of nesting areas, but up to 17.5 km away at night. Moving distances were longer post-fledging. Colony attendance was higher during incubation and lower post fledge. Frequency and success of foraging were lowest on sandpit sites, intermediate on riverine sites, and highest at the Kearney Diversion Dam.
2021	Piping plover survival and migratory connectivity	Ellis KS, Anteau MJ, Cuthbert FJ, Gratto-Trevor CL, Jorgensen JG, Newstead DJ, Powell LA, Ring MM, Sherfy MH, Swift RJ, Toy DL, Koons DN. 2021. Biological Conservation 264: 1-11. https://doi.org/10.1016/j.biocon.2021.109371	Impacts of extreme environmental disturbances on piping plover survival are partially moderated by migratory connectivity	2002–2019	This study evaluates survival at nonbreeding areas due to extreme environmental disturbances and estimates the connectivity between breeding vs. non-breeding areas using data from piping plover individuals from 2002-2019.	Hurricanes and algal blooms are negatively associated with nonbreeding season survival, though no negative association was detected for oil spills in this study. There was low migratory connectivity observed across nonbreeding areas for individuals from separate breeding areas. Survival among breeding states averaged 0.91, with the highest average belonging to the Great Lakes population. Mortality for the non-breeding season was consistently higher. The non-breeding states had an estimated survival of 0.81. A small degree of temporal synchrony in survival was found for the Northern and Southern Great Plains among the breeding states, and between Texas and the Eastern Gulf for the non-breeding states.
2021	Habitat availability	Jorgensen JG, Brenner SJ, Greenwalt LR, Vrtiska, MP. 2021. Ecosphere 12(4): e03474. https://doi.org/10.1002/ecs2.3471	Decline of novel ecosystems used by endangered species: the case of piping plovers, least terns, and aggregate mines	1993–2020	Evaluated how the number, size, and spatial distribution of different site types hosting different numbers of nesting plovers and terns along the Platte, Loup, and Elkhorn Rivers have changed over time and how current trends in the number of different site types will affect future habitat and bird abundance.	Overall area and total number of sites declined between 1993-2020. Traditional mines are being replaced by modern mines, which host lower numbers of nests of both species. Traditional mines are projected to decline in the future, reducing overall nesting habitat. Piping plovers and terns are expected to continue to nest within the study area, but numbers are expected to be smaller compared to what has been observed in the past.

2020	Renesting in piping plovers	Swift RJ, Anteau MJ, Ring MM, Toy DL, Sherfy MH. 2020. The Condor: Ornithological Applications 122:1–18. https://doi.org/10.1093/condor/duz066	Low renesting propensity and reproductive success make renesting unproductive for the threatened piping plover (*Charadrius melodus*)	2014–2016	Studied renesting propensity, renesting intervals, and renest reproductive success in the northern Great Plains.	To be summarized later
2020	Population model for nest exclosure use	Darrah AJ, Cohen JB, Castelli PM. 2020. Wildlife Society Bulletin 1-13. https://doi.org/10.1002/wsb.1115	A decision support tool to guide the use of nest exclosures for piping plover conservation	2013–2018	Developed a decision support tool (PiperEx) that uses site-specific nest-fate data to inform a stochastic population project model to predict plover population growth rate at the site level with and without exclosure use	To be summarized later
2020	Nest cameras	Hunt KL, Gibson D, Friedrich MJ, Huber CJ, Fraser JD, Karpanty SM, Catlin DH. 2020. Ibis 162:1–12. https://doi.org/10.1111/ibi.12726	Using nest captures and video cameras to estimate survival and abundance of breeding piping plovers *Charadrius melodus*	2005–2017	Used video cameras at plover nests to resight previously banded individuals	To be summarized later

2020	Turtle trapping and exclosures	Mohlman KL. 2021. Platte River Recovery Implementation Program: 2020 interior least tern and piping plover monitoring and research report, central Platte River, Nebraska.	Platte River Recovery Implementation Program 2020 interior least tern and piping plover monitoring and research report, central Platte River, Nebraska ATTN: TURTLE FENCE and TURTLE TRAPPING WITH MARK AND RECAPTURE	2020	Two types of predator exclusion fencing, wood slat and woven wire, were tested as a means of reducing turtle nesting on piping plover and least tern nesting sites. Effectiveness and possible tern and plover interactions and avoidance were monitored. A mark and recapture study for softshell turtles was also implemented to test the ability to capture softshell turtles and obtain information about softshell turtle populations and their utilization of tern and plover nesting sites.	No avoidance of either fence type in nesting or foraging by terns or plovers was recorded. Incidental evidence of successful turtle exclusion was observed, but a larger data set would be needed to determine efficacy. Hoop traps were established as an effective method of capturing softshell turtles and softshell nesting on tern and plover sites was observed. This research is on hold as the Program evaluates the benefits of pursuing this research to further the understanding of turtle populations and their movement, the Program's ability to manage turtle presence on nesting sites, and the benefits this management effort would provide to terns and plovers.
2020	Shorebird productivity monitoring protocols	Farrell PD, Baasch, DM. 2020. Waterbirds 43(2): 123-133. https://doi.org/10.1675/063.043.0201	Reducing effort when monitoring shorebird productivity	2013–2016	This study is a comparison of the accuracy of two monitoring protocols; one from inside nesting colonies, and one from outside the nesting colonies.	Both inside and outside monitoring result in reasonable estimates of abundance and productivity for both least terns and piping plovers. Outside monitoring of least terns resulted in higher fledge counts and lower breeding pair estimates, increasing reported fledge ratios. No consistent over or underestimates were found upon implementation of outside monitoring of piping plovers due to annual variability. Outside monitoring reduces effort, cost, and potential disturbance

2020	Population dynamics of piping plovers	Swift RJ, Anteau M, Ellis K, Ring M, Sherfy M, Toy D, Koons D. 2020. U.S. Geological Survey Open-File Report 2020–1152, 211 p.	Spatial variation in population dynamics of northern Great Plains piping plovers	2009–2020	The purpose of this study was to determine movement and connectivity within and among the various populations of piping plovers in the Great Plains and factors that affect their success and survival. This study looked at survival, dispersal, renesting, and reproductive success of the birds.	River and alkali wetlands seem to be higher quality habitat for plovers than reservoirs, but river habitat had higher survival, reproductive output, and fidelity probabilities than alkali wetlands. Dispersal, both natal and adult, was highly affected by habitat availability and reproductive success, as well as affected by population density. Renesting propensity and renest success were low. The data indicates that there is high connectivity between the U.S. Alkali Wetlands and the norther river units of the Missouri river.
2020	Heterospecific breeding association	Swift RJ, Anteau MJ, Roche EA, Sherfy MH Toy DL, Ring MM. 2020. Oikos 129: 1504-1520. https://doi.org/10.1111/oik.07256	Asymmetric benefits of heterospecific breeding association vary with habitat, conspecific abundance and breeding strategy	2007–2016	Tested how piping plover and interior least tern associations during breeding influence nest and chick survival.	Studied nest and chick survival for piping plover and interior least tern on Lake Sakakawea, Garrison River Reach, and the Gavins Point Reach between 2007-2016. Plover nest and chick survival improved with the presence and abundance of terns, but terns only benefited from plover presence for certain study areas and breeding stages. Associations between these two species are mutualistic, but asymmetric, moderated by habitat, abundance on conspecifics and breeding stage. Nesting requirements of both species should be considered when managing habitat for target species.

2019	Nest fate classification	Andres AK, Shaffer TL, Sherfy MJ, Hofer CM, Dovichin CM, Ellis-Felege SN. 2019. Ibis 161:286-300. https://doi.org/10.1111/ibi.12629	Accuracy of nest fate classification and predator identification from evidence at nests of least terns and piping plovers	2013–2015	Evaluated nest fate misclassification rate and studied factors resulting in misclassification of least tern and piping plover nests	To be summarized later
2019	Predator monitoring via remote cameras	Mohlman KL. 2020. Platte River Recovery Implementation Program: 2019 interior least tern and piping plover monitoring and research report, central Platte River, Nebraska.	Platte River Recovery Implementation Program 2020 interior least tern and piping plover monitoring and research report, central Platte River, Nebraska	2019	Pilot year to test methods for documentation of predator presence at the nest level in 2019.	In 2019 there was one documented predation event at Broadfoot-South Kearney by a red fox consuming eggs at a nest in 2019.

2018	Population dynamics	Saunders SP, Cuthberg FJ, Zipkin EF. 2018. Journal of Applied Ecology 55:1380–1392. https://doi.org/10.1111/1365-2664.13080	Evaluating population viability and efficacy of conservation management using integrated population models	1993–2016	Authors developed a coupled integrated population model and Bayesian population viability analysis to assess impact of demographic rates on past population dynamics and predict population viability 10 years into the future for the Great Lakes piping plover population	To be summarized later
2018	Piping plover and least tern nest and brood survival	Farrell PD, Baasch DM, Farnsworth JM, Smith CS. 2018. Avian Conservation and Ecology 13(1): 1. https://doi.org/10.5751/ACE-01133-130101	Interior least tern and piping plover nest and brood survival at managed, off-channel sites along the central Platte River, Nebraska, USA 2001–2015	2001–2015	This study assessed the influence of several biotic and abiotic variables on the survival of least tern and piping plover nests and broods to inform Program management.	Productivity of least terns and piping plovers was reduced during both the nesting and brood rearing stage primarily by climactic factors rather than factors the Program can manage. At that point, we concluded that habitat management activities implemented at off-channel sites to date were sufficient for maintaining high levels of productivity for least terns and piping plovers along the central Platte River.
2017	Nest-site selection by piping plovers and least terns	Baasch DM, Farrell PD, Farnsworth JM, Smith CS. 2017. Journal of Field Ornithology 88(3): 236-249. https://doi.org/10.1111/jofo.12206	Nest-site selection by interior least terns and piping plovers at managed, off-channel sites along the Central Platte River in Nebraska, USA	2001–2015	This study investigated habitat measurements that may influence nest site selection, nest placement, and productivity in an effort to gather information needed to design OCSW sites in a way to encourage tern and plover nesting and improve productivity.	Plovers preferred not to nest near each other, their probability of use for nesting was maximized when distance to was ~50 m, and an effective site design for them would be linear to maximize area of nesting habitat near the water. Least terns are colonial nesters, their nesting probability increased as distance to water was maximized, and an efficient design for them would be circular to maximize the area for nesting habitat away from the shoreline. Both species' probability of use was maximized when nearest predator perches were ≥150 m and elevation above water was ≥3 m. An efficient site design for both species would be lobate, incorporating centralized nesting habitat for least terns and increased access to foraging areas for nesting and brood-rearing piping plovers.

2016	Meta-population viability and habitat change	Catlin DH, Zeigler SL, Bomberger Brown M, Dinan LR, Fraser JD, Hunt KL, Jorgensen JG. 2016. Movement Ecology 2016 4:6 https://doi.org/10.1186/s40462-016-0072-y	Metapopulation viability of an endangered shorebird depends on dispersal and human-created habitats: piping plovers (*Charadrius melodus*) and prairie rivers	2008–2013	Studied effect of high flow events on plover metapopulation dynamics on lower Platte and Missouri Rivers	To be summarized later
2016	Population dynamics	Roche EA, Shaffer TL, Dovichin CM, Sherfy MH, Anteau MJ, Wilternuth MT. 2016. Condor 118:558–570. https://doi.org/10.1650/CONDOR-15-195.1	Synchrony of piping plover breeding populations in the U.S. Northern Great Plains	1993–2011	Authors assessed population synchrony, population stability, and factors influencing these metrics for plovers on the Northern Great Plains	To be summarized later

2016	Demographics and movements of piping plovers and least terns	Roche EA, Sherfy MH, Ring MM, Shaffer TL, Anteau MJ, and Stucker JH, 2016. U.S. Geological Survey Open-File Report 2016–1061, 27 p.	Demographics and movements of least terns and piping plovers in the central Platte River valley, Nebraska.	2009–2014	Summarized data from banding and resighting of piping plovers and least terns along the central Platte River to evaluate reproductive success, colonization, adult survival and recruitment, dispersal, and renesting.	There was no relationship between site age and plover chick and nest survival, but this was most likely due to the low sample size. Least tern nest and chick survival was correlated with the age of the site. Least tern nest survival at older sites was associated with higher nest survival and lower chick survival. Site age correlated with increased use for both species. Between species, least terns were more likely to use sites with newly available habitat than plovers, and within a species, young and inexperienced plovers were more likely to use newly created habitat compared to older adults. No natal site fidelity was observed in plovers, but instances of birds returning to the same general area were recorded. Adult plovers did have high breeding site fidelity year to year. Dispersal for piping plovers was dependent on habitat availability and reproductive success; when these were high, site fidelity was high. Dispersal distance for plovers was affected by age, as typically juveniles dispersed farther. Low natal site fidelity was observed in terns and breeding adult dispersal year to year was highly variable. No renesting was observed by terns, and there were few instances of renesting for plovers. Of these few attempts, about half were after losses that occurred in the brood stage Most plover renesting attempts were on the same site as the first failure and had a high success rate. Renesting initiation after initial loss had high variability, 7.5 days ± 7.3.
2015	Double brooding in plovers	Hunt KL, Dinan LR, Friedrich MJ, Bomberger Brown M, Jorgensen JG, Catlin DH, Fraser JD. 2015. Waterbirds 38:321–434. https://digitalcommons.unl.edu/natrespapers/641?utm_source=digitalcommons.unl.edu%2Fnatrespapers%2F641&utm_medium=PDF&utm_campaign=PDFCoverPages	Density dependent double brooding in piping plovers (*Charadrius melodus*) in the northern Great Plains, USA	2005–2013	Studied instances of plovers raising two broods per season on the Missouri River and lower Platte River	To be summarized later

2015	Breeding population estimators	Baasch DM, Hefley TJ, Cahis SD. 2015. Ecology and Evolution 5(18): 4197-4209. https://doi.org/10.1002/ece3.1680	A comparison of breeding population estimators using nest and brood monitoring data	2001–2014	This study details the method developed by the Program to estimate the number of breeding pairs using counts of nests and broods where multiple surveys were made throughout a single breeding season; it also compares the results of this method with other commonly used estimation methods.	When using data from multiple nest and brood surveys, this method results in reasonably precise estimates of the number of breeding pairs. Each method has its own biases, and either over- or underestimates based on data and frequency collected.
2014	Population viability analysis models	McGowan CP, Catlin DH, Shaffer TL, Gratto-Trevor CL, Aron C. 2014. Biological Conservation 177:220-220. https://doi.org/10.1016/j.biocon.2014.06.018	Establishing endangered species recovery criteria using predictive simulation modeling	NA	Used a population viability analysis model to simulate extinction probability of piping plovers in the Great Plains	To be summarized later
2012	Predator exclosures at nests	Beaulieu G. The implications of predator management for an endangered shorebird; do nest exclosures affect the behaviour of piping plovers and their predators? 2012. M.S. Thesis, Dalhousie University, Halifax, Nova Scotia.	The implications of predator management for an endangered shorebird; do nest exclosures affect the behaviour of piping plovers and their predators?	2010–2011	Examined effects of nest exclosures on incubating plovers and their predators using behavioral observations, video observations, and an artificial nest experiment.	To be summarized later

2012	Foraging ecology of piping plovers and least terns	Sherfy MH, Anteau MJ, Shaffer TL, Sovada MA, Stucker JH. 2012. U.S. Geological Survey Open-File Report 2012–1059, 50 p.	Foraging ecology of least terns and piping plovers nesting on central Platte River sandpits and sandbars	2009–2010	This study looked at movement acquired via telemetry, behavior data, foraging habitat data, and productivity results in order to evaluate the use of foraging habitats by least terns and piping plovers.	When foraging, terns were more likely to be located outside their nesting area, while plovers were more likely to be within the nesting area. Terns rely more heavily on the nearby central Platte River and are more mobile. Plovers forage more often along sandpit shorelines while in the nesting or brooding stages.
2011	Population viability analysis models	McGowan CP, Runge MC, Larson MA. 2011. Biological Conservation 144:1400-1408. https://doi.org/10.1016/j.biocon.2011.01.005	Incorporating parametric uncertainty into population viability analysis models	NA	Developed a method for adding uncertainty in parameter estimates into population models and used data from the Northern Great Plains piping population to demonstrate its utility	To be summarized later

2011	Predator trapping	Catlin DH, Felio JH, Fraser JD. 2011. Journal of Wildlife Management 75:458-462. https://doi.org/10.1002/jwmg.56	Effect of great-horned owl trapping on chick survival in piping plovers	2008–2009	Examined effect of removing great-horned owls from plover hatchling survival on Missouri River sandbars	To be summarized later
2010	Predator exclosures at nests	Barber C, Nowak, A, Tulk K, Thomas L. 2010. Avian Conservation and Ecology 5:6. http://www.ace-eco.org/vol5/iss2/art6/	Predator exclosures enhance reproductive success but increase adult mortality of piping plovers (*Charadrius melodus*)	1984–2006	Examined reproductive success and adult mortality for plover nests with and without predator exclosures at Prince Edward Island National Park, Canada	To be summarized later

2009	Population dynamics	Catlin DH. 2009. Ph.D. Dissertation, Virginia Polytechnic Institute, Blacksburg, Virginia.	Population dynamics of piping plovers (*Charadrius melodus*) on the Missouri River	2004–2007	Monitored 623 nests on 16 sandbar complexes to evaluate plover habitat selection, nest success, and adult and juvenile survival.	To be summarized later
2007	Annual piping plover and least tern synthesis reports	Available on Program Online Library: https://platteriverprogram.org/program-library. Keywords: least tern, piping plover, technical reports	Tern and plover monitoring protocol implementation reports (2001-2007)	2001–2007	These reports provide a synthesis of the respective annual monitoring and research efforts for piping plovers and least terns along the Program's Associated Habitat Reach on the central Platte River, and the reproductive data collected.	Though no on-channel nesting was observed from 2001-2006, birds were consistently present on OCSW sites. From 2001-2007, most of the nesting occurred on sites managed by NPPD. Blue Hole typically had the highest nest success for both species.

2003	Nest predator exclosures	Murphy RK, Michaud IMG, Prescott DRC, Ivan JS, Anderson BJ, French-Pombier ML. 2003. Waterbirds 26:150–155. https://doi.org/10.1675/1524-4695(2003)026[0150:POAPPA]2.0.CO;2	Predation on adult piping plovers at predator exclosure cages	1993–2002	Compared adult plover mortality at nests surrounded by predator exclosures to those without exclosures.	To be summarized later
2002	Nest fates	Williams GE, Wood PA. 2002. Auk 119:1126–1132. https://doi.org/10.1093/auk/119.4.1126	Are traditional methods of determining nest predators and nest fates reliable? An experiment with wood thrushes (*Hylocichla mustelina*) using miniature video cameras	1998–2000		To be summarized later

2002	Species recovery	Lutey JM. 2002. Final Report Prepared for U.S. Fish and Wildlife Service	Species recovery objectives for four target species in the central and lower Platte River (whooping crane, interior least tern, piping plover, pallid sturgeon)	NA	Author provided a literature review and a summary of recovery objectives for four threatened or endangered species along the Platte River	To be summarized later
2000	Population viability	Plissner JH, Haig SM. 2000. Biological Conservation 92:163–173.https://doi.org/10.1016/S0006-3207(99)00050-6	Viability of piping plover *Charadrius melodus* metapopulations	NA	Authors used metapopulation viability analysis to examine viability and recovery objectives for plovers for the Atlantic Coast, Great Plains, and Great Lakes populations.	To be summarized later
1993	Population dynamics	Ryan MR, Root BG, Mayer PM. 1993. Conservation Biology 7:581–585. https://doi.org/10.1046/j.1523-1739.1993.07030581.x	Status of piping plovers in the Great Plains of North America: a demographic simulation model	NA	Authors developed a stochastic population growth model using empirical demographic data for plovers in the northern Great Plains	To be summarized later