Platte River
Recovery Implementation Program

2022 Piping Plover and Interior Least Tern Monitoring and Research Report, Central Platte River, Nebraska

Prepared for: Governance Committee
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PREFACE

This is a report of the Platte River Recovery Implementation Program's (Program or PRRIP) monitoring and research efforts for piping plover (plover) and interior least tern (tern) during 2022. The report was prepared to inform Program partners, licensing agencies, and the general 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.

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TABLE OF ABBREVIATIONS

AHR	Associated habitat reach
cfs	Cubic feet per second
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
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	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

To evaluate progress toward the Platte River Recovery Implementation Program ("Program" or "PRRIP") management objective of improving productivity of threatened piping plover (*Charadrius melodus*) and interior least tern (*Sternula antillarum*) on the central Platte River, the Executive Director's Office (EDO) conducted monitoring of piping plover and interior least tern, hereafter plover and tern, respectively, along PRRIP's Associated Habitat Reach (AHR) on the central Platte River between Lexington and Chapman, Nebraska. Monitoring took place from 02 May to 31 August 2022. Surveys were conducted twice a month at off-channel sand and water sites (OCSW) and along the river, and twice a week at sites with active nests and broods.

Along with traditional monitoring, research in 2022 focused on implementing additional predator management actions and remote camera monitoring to address two Big Questions during the Program's First Increment Extension: 1) How much of an effect does predation have on piping plover productivity? and 2) How effective is Program management at mitigating losses of plover productivity due to predation? These questions were identified as priority uncertainties in response to the dip in fledge ratios observed in 2018 and 2019 for plovers, and the dip in 2019 for terns, as well as the decrease over time in proportion of successful chicks for plovers. Reducing predation was identified as an important objective for improving plover and tern reproductive success at OCSW sites.

Existing predator management deployed across all PRRIP managed sites included predator trapping and removal, tree removal within ≥150 m radius of the nesting area, avian spike installation on all potential non-removable perches, a ≥100 ft water moat that surrounds nesting peninsulas, and electrified predator exclusion fences deployed across the entrances to each peninsula. In 2021 and 2022, we deployed additional predator management in the form of predator exclusion fencing completely surrounding nesting peninsulas and predator deterrent lights at three Program managed sites, Kearney Broadfoot South, Newark West, and Leaman, in an effort to reduce predator presence moving inward across barriers to reach nesting plovers and terns.

To evaluate potential predator presence on nesting sites, the impacts of predation on productivity, and the effectiveness of the additional management, our traditional monitoring protocol was supplemented with additional monitoring implemented at the six Program managed OCSW sites in 2021 and 2022. Additional monitoring included utilization of USDA/APHIS trapping data, weekly track surveys along nesting peninsula shorelines, and utilization of cellular video and trail camera monitoring along shorelines, on the interior of the nesting site, and at individual nests.

For the 2022 season, the number of breeding pairs observed peaked at 38 pairs for plovers and 85 pairs for terns, resulting in a fledge ratio of 1.37 fledges per breeding pair for plovers and a fledge ratio of 1.68 for terns. The Program has observed an overall positive species' response in reproductive output to habitat creation, rehabilitation, and management from 2001-2022. Increases have been seen in breeding pair estimates, brood counts, and fledgling counts. Breeding pair estimates increased significantly with the addition of OCSW habitat. When examining years with comparable monitoring protocols (2010-2022), nest success has remained relatively stable for both species. In 2021, we reported a gradual decrease in chick success for plovers from 2010-2021; however, with the increase in proportion of success to 0.52 in 2022 the long-term picture for plover

chick success may be stabilizing. Tern chick success has remained in a stable range from 2010-2022.

The 2022 fledge ratio for plovers was higher this year than last (1.37 in 2022 vs. 0.97 in 2021), showing improvement from the lows observed in 2018 and 2019 (0.62 in 2018 and 0.67 in 2019). Plover daily nest and brood survival estimates for the entire reach have remained stable over time, but there has been significant variation across sites. This season, Blue Hole and Dyer had both high reproductive investment (i.e., number of nests) and high fledge ratios for plovers. In addition, the Program's newest site, OSG Lexington, hatched three plover nests this year with a fledge ratio of 1.33. Kearney Broadfoot South, a site that has historically had high initial investment, but poor nest and brood survival and documented losses to predation leading to low fledge ratios, performed better this year with a fledge ratio of 1.14. NPPD Lexington and Newark West had high investment but fledged no plover chicks in 2022.

Fledge ratios for terns have usually remained within a relatively stable range, though they also experienced a low in 2019 (0.75). More recent fledge ratios show considerable improvement over the 2019 low. Fledge ratios were higher in 2022 (1.68) than in 2021 (1.21) and 2020 (1.27). Tern nest and brood survival across the AHR has also been stable over time, but has been variable among sites. For terns, the Program's newest site, OSG Lexington, had the highest tern fledge ratio (2.38), but Cottonwood Ranch (2.13) and Blue Hole (2.17) also had high fledge ratios in 2022. Kearney Broadfoot South had a tern fledge ratio of 1.58, which was much higher than the 0.40 fledge ratio observed in 2021. Dyer, the Program's most successful site for terns in 2021, had one of the lowest fledge ratio for terns (0.83) observed across all sites in 2022. Only two tern nests were observed at NPPD Lexington this year and when coupled with poor nest survival the site had no tern fledges this year. Though terns nested on Leaman this year, they had poor nest survival and lost all nests to weather early in the season. Remote camera monitoring conducted on Program monitored sites, Dyer and Newark West, indicated that predation was responsible for nest loss leading to low fledge ratios.

Prior to implementation of additional camera monitoring in 2021, nest and brood loss during 2010-2020 was most often attributed to unknown causes (fated as failed-unknown), as there was a lack of sufficient evidence to fate those nests and broods. In 2021 and 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 during 2020-2022, with a corresponding increase in the proportion of nests and broods fated as failed-predation. The highest proportion of nest and brood losses for plovers were categorized as failed-predation this year due to the additional information provided by remote cameras to fate nests. The highest proportion of loss for terns in 2022 were categorized as failed-unknown because our camera monitoring effort was focused on plovers, resulting in less information available for fating tern nests.

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. Badger (*Meles meles*) at Dyer and great horned owl (*Bubo virginianus*) at Dyer and

Newark West were the predator species responsible for the most predation events in 2022. Badgers accounted for eight of the 19 (42%) individual predated nests and great horned owls accounted for seven of the 19 (37%) individual predated nests. Striped skunk (*Mephitis mephitis*) at Newark West was responsible for two (11%) predated nests and a Virginia opossum (*Didelphis virginiana*) at Newark East and bullsnake (*Pituophis catenifer sayi*) at Newark West 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.

Three lines of evidence are being gathered to evaluate the effectiveness of additional predator management: 1) predator presence on nesting peninsulas and, more specifically, at the nest; 2) losses to predation; and 3) productivity of plovers and terns. Potential avian, mammalian, and reptilian predators were present across all levels of monitoring. For potential avian predators, the number of registers/camera day decreased moving from shorelines to the interior of the nesting peninsula (site-level), and further decreased at the nest-level for both status quo (i.e., no additional predator management) and additional management sites. For mammalian predators, this pattern was not consistently observed within or across sites. Current predator management does not address access to nesting sites by snakes, and bullsnakes were registered across all levels this year, including the predation of one nest.

When looking specifically at nest events (nest presence and nest predation) normalized for camera effort, nest events occurred more frequently at status quo sites than at sites that received additional management. Specifically, 63% of the 27 unique nest events (registers with and without predation) documented in 2022 occurred at status quo sites compared to 37% at additional management sites. The result was the same for both avian and mammalian predator presence at the nest. At a finer scale, looking only at the 15 documented nest predation events, eight (53%) occurred at status quo sites and seven (47%) occurred at sites with additional management, resulting in 11 (58%) individual nests predated at status quo sites versus eight (42%) nests at sites with additional management. Though differences are small, this may be an indication that additional predator management and deterrents deployed on additional management sites may be effective at reducing potential avian and mammalian presence at the nest level and reducing the number of nests lost to predation over time.

If additional predator management is effective at reducing the number of losses to predation, we should be able to see improvements in productivity at sites where additional management has been implemented. This was not the case for either plovers or terns for 2022. Though Kearney Broadfoot South did well this year with a fledge ratio of 1.14 fledges/breeding pair for plovers and 1.58 fledges/breeding pair for terns, losses of all nests to weather at Leaman this year and the loss of nine nests and one brood to predation at Newark West (in addition to the loss of three nests and one brood to other causes) resulted in zero plover fledges and only five tern fledges for a fledge ratio of 0.83 for terns at Newark West in 2022. Thus, additional management sites (0.38 plover and 0.80 tern fledges/breeding pair) did not have higher fledge ratios overall than status quo sites (1.57 plover and 1.27 tern fledges/breeding pair) in 2022.

Average plover fledge ratio at Kearney Broadfoot South has increased from 0.43 plover fledges/breeding pair (range 0 – 1.0) from 2010-2020 to 0.70 fledges/breeding pair (range 0.25 – 1.14) in 2021-2022 when additional predator management was implemented. For terns, the fledge ratio at this site has increased from an average of 0.90 fledges/breeding pair (range 0.33 – 1.5) from 2010-2020 to 0.98 fledges/ breeding pair (range 0.38 – 1.58) in 2021-2022. There was no documented nest predation (no failed-predated nests) at Kearney Broadfoot South in 2022. Newark West lost a total of nine nests to predation this year and fledge ratios have not improved over pre-implementation averages. Leaman has not fledged any plover or tern chicks since 2016. Predation by great horned owl resulted in no fledglings at Leaman in 2021 and weather events destroyed all nests at Leaman in 2022. Therefore, no information on potential predators or predation at the nest was provided by Leaman in 2022.

The Program plans to continue implementation of additional management and monitoring of results to further quantify the impact of predation and evaluate the effectiveness of our management techniques. Information gathered will be used to modify management actions and reduce losses to predation at OCSW sites along the AHR.

INTRODUCTION

The Platte River Recovery Implementation Program (PRRIP or Program) is responsible for implementing certain aspects of the threatened piping plover (*Charadrius melodus*; hereafter plover) and the recently delisted interior least tern (*Sternula antillarum*; hereafter tern) recovery plan.

The northern Great Plains population of plovers was listed as threatened on 10 January, 1986. The tern was listed as endangered on 27 June, 1985; however, on 12 February, 2021, the US Fish and Wildlife Service (USFWS) removed the tern from the federal list of Endangered Species (ESA). The tern remains protected under the Migratory Bird Treaty Act and the Nebraska Non-game and Endangered Species Conservation Act. The Program will abide by prohibitions regarding take of the tern provided by these Acts and will continue to manage for tern consistent with ongoing plover management. In line with the First Increment Extension Science Plan, implementation of habitat management, plover and tern monitoring, and the active learning derived from these activities to address the management objectives specified below will be focused on the plover as its status remains as federally threatened. Though not required for ESA compliance, the Program's Governance Committee (GC) directed Executive Director's Office (EDO) staff in 2021 to continue to monitor the species following the same monitoring protocol for terns as it did prior to the federal delisting. Moving forward, the Governance Committee may direct monitoring of tern to continue in a manner consistent with any Service post-delisting monitoring plan for the species (PRRIP 2021a)

MANAGEMENT OBJECTIVES AND INDICATORS

The Program manages land and water to attain specific management objectives for plovers. The management objective for plover as defined in the First Increment Adaptive Management Plan

(AMP) (PRRIP 2021b) is to improve production of plover and tern along the central Platte River through:

a) Increasing the number of fledged plover and tern chicks by:

i) Increasing breeding pairs (indicator is nesting pairs)

ii) Increasing fledge ratios (indicator is chicks successfully produced per unit adult, nest, or pair) and reducing chick mortality from causes such as flooding, predation, weather, and inadequate forage.

b) Reducing adult mortality by:

i) Reducing predation (indicator is nesting pairs)

Additionally, Attachment 1 of the Extension Science Plan (PRRIP 2022a) specifies the following check in activities which are habitat and plover monitoring activities to provide additional information relevant to the previous/existing conclusions on the First Increment Big Questions (PRRIP 2020) for consideration by the Program's Governance Committee. These activities include:

a) Monitoring of on-channel nesting on natural sandbar habitat following peak flow events.

b) Monitoring of plover breeding pairs and fledges in relation to habitat availability.

c) Monitoring of nesting locations to detect an increase in on-channel nesting with a corresponding decrease in off-channel nesting.

d) Monitoring to detect emaciated adults/chicks and/or a drop in productivity (fledging) that is not attributable to weather or predation.

BIG QUESTIONS AND LEARNING OBJECTIVES

The following set of "Big Questions" identify key areas of plover related uncertainty to be addressed by Program science during the First Increment Extension. Information gathered will be used to assess the need for additional predator management, develop novel and targeted strategies for mitigating losses due to predation, evaluate the effectiveness of these strategies, and quantify potential costs and benefits of implementation. Extension Big Questions (EBQ) and management learning objectives specific to plovers include:

- **EBQ #8**- How much of an effect does predation have on plover productivity?
    1) Quantify the impact of predation on plover productivity.
    2) Identify predator species responsible for losses.
    3) Determine whether losses are incurred at the nest or during brood rearing.
    4) Utilize population viability models to predict what effect decreases in fledge ratios due to predation may mean in terms of future plover breeding pairs on the central Platte River.

- **EBQ #9**- How effective is Program management at mitigating losses of plover productivity due to predation?
    1) Evaluate effectiveness of trapping, fencing, and/or predator deterrent lighting at reducing nest/brood failure due to predation.
    2) Develop predator management alternatives based upon learning through remote camera/video monitoring.
    3) Evaluate the necessity for additional predator management based upon plover response to predation over time.

Monitoring protocols were developed and implemented to obtain data for the above key indicators and to provide the data necessary to gather information on learning objectives, evaluate learning related to plover Big Questions, and ultimately assess progress toward meeting the management objective. The data summarized in this report were collected in accordance with the PRRIP 2017 Central Platte River Tern and Plover Monitoring and Research Protocol (2017). Implementation includes: 1) monitoring plover and tern use and productivity on riverine mid-channel sandbars and created or rehabilitated off-channel sand and water (OCSW) nesting sites; 2) identifying and documenting factors that are believed to influence nest site selection and nest and brood success along the central Platte River between Lexington and Chapman, Nebraska; and 3) monitoring potential predators to gather information on the predator community present on and around nesting sites, acquire more data on predation events and their impact on plover productivity, and assess effectiveness of Program management to mitigate the impacts of predation.

Program management of plover and tern habitat, plover and tern activity and reproductive success, and additional research aimed at improving productivity and adult survival are summarized in this report for 2022. Monitoring and research during 2022 were a collaborative effort between Program EDO staff and Nebraska Public Power District (NPPD).

Previous data and analyses are included in annual reports produced by West Incorporated (2001−2007) and Program EDO staff (2008−2022) and are available in the Program's online Public Library (https://platteriverprogram.org/program-library). Long-term monitoring and research are used to evaluate progress toward the management objective and to support adaptive management decisions related to our target species. 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.

STUDY AREA AND HABITAT USE

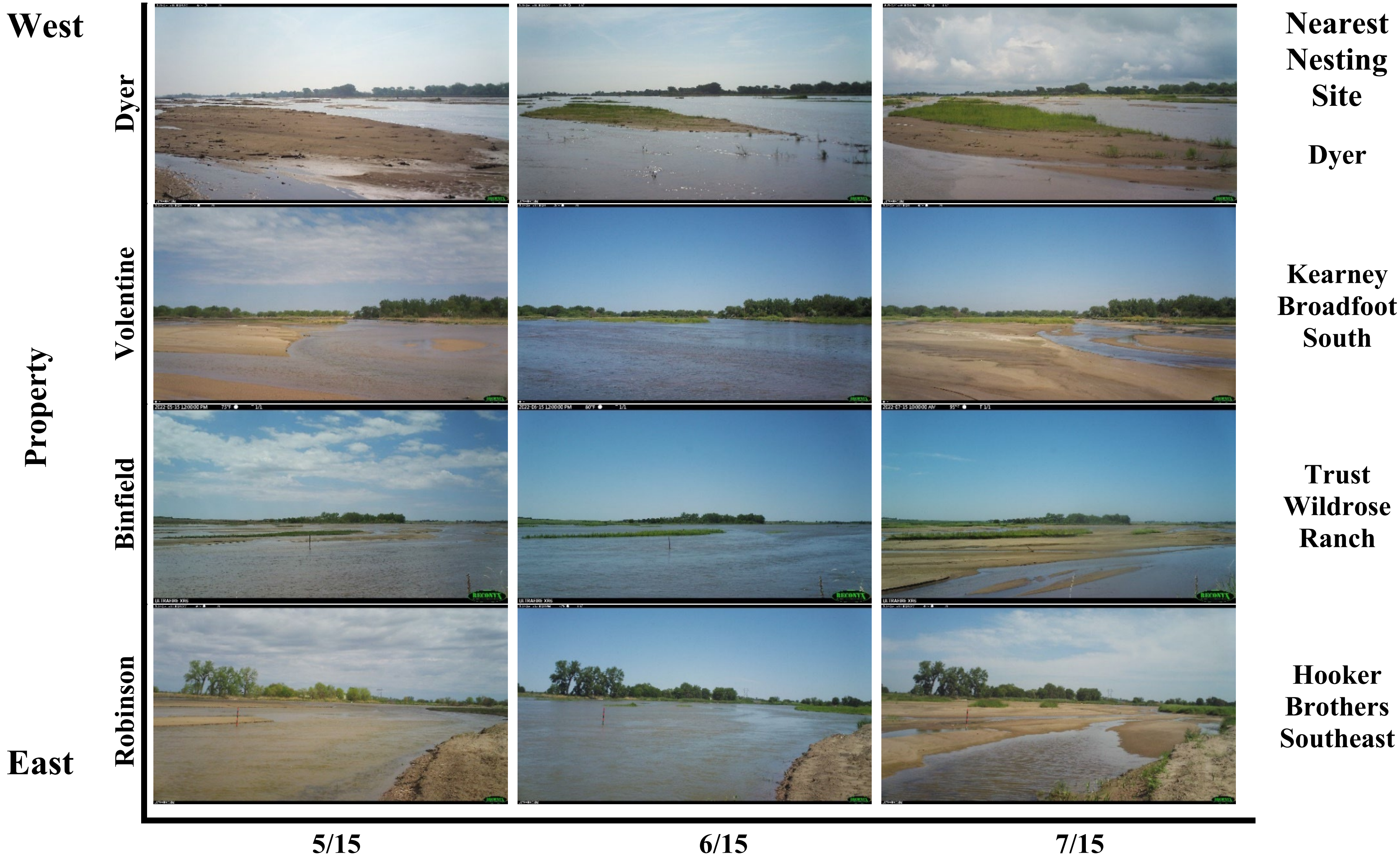
Our study area encompassed the PRRIP's Associated Habitat Reach (AHR) segment of the central Platte River between Lexington and Chapman, Nebraska (~90 river miles, Figure 1) as well as OCSW sites within 3.5 miles of the river in this reach. River or on-channel habitat includes naturally formed or constructed midstream sandbars used for nesting and open river channel used for foraging. OCSW habitat includes spoil piles of sparsely- or non-vegetated sand at sand and gravel mines and constructed nesting sites. Plovers typically 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). Juveniles forage along OCSW waterline until fledging when they are often observed foraging on the river channel. Terns typically nest on OCSW habitat or constructed on-channel islands and forage at both the sand and water site and on the river channel, though they rely more heavily 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 later are often observed on the river channel.

2022 RIVER CONDITIONS

The number of low-elevation sandbars present within the PRRIP AHR of the central Platte River is 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.

Other than during the Environmental Account (EA) flow release implemented by the Program from 1 – 30 June to suppress germination of in-channel woody vegetation, daily flows at the Kearney gage (USGS gage 06770200, USGS 2022) in 2022 were generally lower across the nesting season than the median daily flows from 2001-2021 (Figure 2). Discharge was lower than the 20-year median at the start of the season, in May, when plover nests are typically being initiated. Flows increased with the June germination suppression flow release to peak at 1,840 cubic feet per second (cfs) on 7 and 8 June. Peak flows coincided with the period of peak nesting for plovers at OCSW sites as detailed later in the results (though no nesting has been observed on the river since 2016 for either plovers or terns). Use of the river by adult terns also peaked while flows were high during this release as detailed in the results. Low flows at the onset of July (without the additional EA water) coincided with peak river use by plover adults and peak nesting for terns at OCSW sites across the AHR (see results). Peaks in daily flow that were less than the early June peak, but still above the 20-year median occurred on 7 July during the nesting season and again on 28 July when many birds had already fledged and migrated to the river or moved out of the area. During the high flows in June and later peaks most in-channel sandbars and potential nesting habitat were inundated and saturated due to their low elevation, and as such did not meet the Program's in-channel nesting habitat requirements (Figure 3; PRRIP 2015). The sandbars that did stay exposed became covered in short dense vegetation, again making them unsuitable as nesting habitat. Examples of the river conditions at semi-monthly river surveys on 15 May, 15 June, and 15 July demonstrate river flow before, during, and after the June flow release in relation to sandbar habitat and vegetation growth (see pictures below).

The lowest flow this gage experienced during the nesting season (1 May – 1 August) of 2022 was 22.8 cfs on 24 July (Figure 2). Flows were reduced even further to a minimum of 2.17 cfs on 30 August as fledging came to an end and birds left the reach. Throughout the season some stretches of the main channel that are typically monitored during river surveys were completely dry. As a



Vegetation monitoring photos demonstrating changes in on-channel habitat availability through time across the AHR (west to east) before, during, and following June flow release. Properties (left) and nearest OCSW nesting site (right) corresponding with the location of each photo series are on the y-axes.

result, river surveys on 15 May, 15 July, and 1 August were incomplete, with some stretches inaccessible by boat. Where accessibility was not a problem, spot counts were performed from the bank and/or middle of the mostly dry river channel.

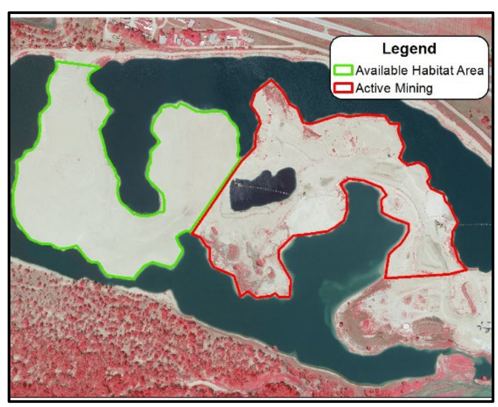
MANAGEMENT

Management actions designed to increase nesting habitat (bare sand) and productivity of plovers and terns were taken at on- and off-channel sites during fall 2021 and spring 2022. Management activities were site specific and included: mechanical actions to improve nesting conditions and remove vegetative cover (reducing washouts along shorelines, disking, tree removal, and nest furniture distribution); 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).

SUMMARY OF HABITAT AVAILABILITY, 2007−2022

OFF-CHANNEL MECHANICAL HABITAT CREATION AND MAINTENANCE

Approximately 48 acres of managed off-channel nesting habitat were present in the AHR at the beginning of the 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 approximately 250 acres during the period of 2009−2022 as the Program constructed and/or restored acres of habitat. Habitat availability across the AHR remained the same in 2022 with gains at a few sites attributable to the creation of new bare sand habitat from active mining balanced by losses at other sites due to erosion at shorelines or vegetation encroachment. Program managed sites lost a total of five acres of bare sand habitat in 2022 (see site specific details below), with four of those acres lost at Non-Access Islands Kearney Broadfoot South due to vegetation growth along unmanaged shorelines. Mining activities are still underway at this site as well as at Follmer and Newark East but are expected to make only small contributions to available habitat moving forward. There was also some give and take in acres of bare sand available at non-Program managed OCSW sites, with a gain of five acres over all sites from 2021 to 2022 (see below for details). Most notable was the gain of 12 acres at Hooker Brothers Southeast. T&F Lakeside was added this year to the list of OCSW sites monitored for nesting, contributing two acres of potential nesting habitat. Larger gains in Program managed OCSW habitat moving forward are expected to come from the OSG Lexington OCSW site as the eastern portion of that site is mined and rehabilitated for tern and plover nesting in 2025. The Program plans to acquire or construct a minimum of 60 acres of off-channel habitat prior to the end of the First Increment Extension in 2032.



OSG Lexington from June 2022 demonstrating west portion rehabilitated as nesting habitat (in green) and east portion (in red) expected to be rehabilitated in 2025.

OCSW Sites

Thirteen of the 18 off-channel sites monitored during 2022 were actively managed to increase plover and tern reproduction. Program owned and/or managed sites are denoted with a superscript “P” (^{P}) and managed sites are identified by a superscript “M” (^{M}). Sites that were constructed specifically for plover and tern nesting are denoted by a superscript “C” (^{C}), and former sand and gravel mines (both formerly active and currently active) that were rehabilitated into or designated as possible nesting habitat are denoted by a superscript “G” (^{G}). Numbers correspond to map locations on Figure 5.

^{PMG}1 OSG Lexington – A contact herbicide was applied to kill existing vegetation in the fall of 2021 and a pre-emergent herbicide was applied during spring 2022. A permanent 4-ft-high woven wire predator fence was installed in spring 2021 across the north entrance to the nesting area. This fence has offset electric wires to prevent terrestrial predators from climbing and an electrified top wire to prevent avian predators from perching. Mechanical improvements included construction of low berms outside the predator fence on the northern entrance to the nesting peninsula to divert water runoff and prevent washouts underneath the predator fencing. Additionally, a temporary 4-ft-high electrified predator fence was also installed 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. Predator trapping also occurred during the 2022 nesting season.

^{MG}2 NPPD Lexington – A pre-emergent herbicide was applied during spring 2022, the woven-wire predator fences with offset electric wires along the west side of the nesting areas were maintained, and predator trapping occurred during the 2022 nesting season. No sand and gravel mining occurred during 2022.

^{PMG}3 Dyer – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2021. A pre-emergent herbicide was applied during spring 2022. Permanent 4-ft-high woven wire predator fences, with offset electric wires and an electrified top wire, were maintained across the south ends of each peninsula. Predator trapping also occurred during the 2022 nesting season. Current imagery shows a total of 20 acres of bare sand habitat suitable for nesting or foraging across the two nesting peninsulas at this site. This is a reduction of one acre from the 21 acres in 2021 due to washouts and shoreline erosion making some areas unsuitable for foraging. No sand and gravel mining occurred.

^{PMC}4 Cottonwood Ranch – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2021, a pre-emergent herbicide was applied spring 2022, and predator trapping occurred during 2022. A permanent 4-ft-high woven wire predator fence with offset electric wires and top wire was maintained at the entrance to the nesting peninsula in 2022. No sand and gravel mining occurred.

^{G}5 T&F Lakeside – Not managed. Sand and gravel mining occurred during 2022 adding two acres of potential bare sand nesting habitat.

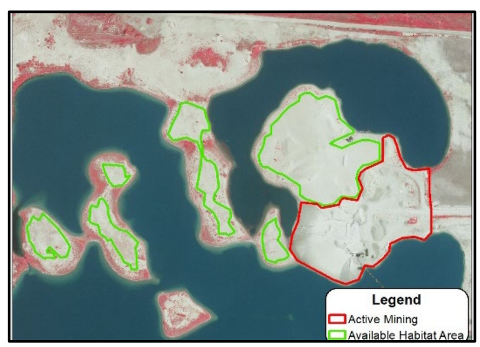
[MG]*6 Blue Hole* – A pre-emergent herbicide was applied during spring 2022. There was no predator fence, but predator trapping was conducted during 2022. Sand and gravel mining did not occur during 2022; however, the area west of this OCSW site is a high traffic area for loading and unloading equipment. This site lost two acres of habitat from 2021 to 2022 due to bank erosion on the south side of the site.

[MG]*7 Johnson* – A pre-emergent herbicide was applied during spring 2022. The woven-wire predator fence along the west side of the nesting area was maintained but not energized in 2022. No predator trapping was implemented at this site. No sand and gravel mining occurred during 2022.

[G] ***8 Ed Broadfoot and Sons*** – Not managed. Despite sand and gravel mining occurring during 2022, the amount of bare sand habitat available for nesting at this site was reduced by one acre from 2021-2022 to total eight acres in 2022.

[PMG]***9 Kearney Broadfoot South*** **–** A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2021 and a pre-emergent herbicide was applied to the nesting area during spring 2022. A permanent interior 4-ft-high woven wire fence with an electrified top wire present to prevent avian perching was maintained along the interior shoreline of the entire nesting peninsula as well as closing off the east end of the peninsula from its only land entrance (interior predator fencing). Mechanical improvements were made prior to the 2022 nesting season to fill the existing washouts under the interior predator fence and to redirect water runoff from the nesting site to reduce future washouts. Predator trapping along the exterior shorelines of the site occurred during 2022. Predator deterrent lights were again installed on the site for the 2022 nesting season as a part of our additional predator management study. Sand and gravel mining took place north of the main peninsula during 2022.

[PMG]***10 Non-Access Islands Kearney Broadfoot South*** – Due to active mining, the area of this site varies from year to year. There were six acres of unmanaged, suboptimal habitat available on these islands for plover or tern nesting and foraging this season, down from 10 acres in 2021. The six acres 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.



Habitat availability (in green) and active mining (in red) at Non-Access Islands Kearney Broadfoot South, July 2022.

[PMG]***11 Newark West*** – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2021. A pre-emergent herbicide was applied during spring 2022. Permanent 4-ft-high woven wire predator fences with offset electric wires and a top wire were maintained across the ends of each peninsula. In addition, the entire perimeter of the exterior of this site, outside of the surrounding water barrier, is enclosed with a permanent 4-ft-high woven wire fence with an offset electric wire (exterior predator fencing). Predator trapping inside the perimeter fence, but outside the nesting peninsula, occurred during 2022. Predator deterrent lights were also installed on the nesting site during spring 2022 as part of our additional predator management. Current imagery shows a total of 13 acres of habitat across two peninsulas at Newark West, a reduction from 14 acres in 2021 due to washouts and shoreline erosion making some areas unsuitable for foraging. No sand and gravel mining occurred during 2022.

[PMG]***12 Newark East*** – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2021. A pre-emergent herbicide was applied during spring 2022. The permanent 4-ft-high woven wire predator fence with offset electric wires and electrified top wire was maintained across the west peninsula and a temporary 4-ft-high electrified predator fence was installed across the east peninsula. Predator trapping was implemented in 2022. Sand and gravel mining occurred east of the nesting areas. There were 24 acres available for plover and tern nesting and foraging in 2022, which was an increase of one acre from 2021.

[PMC]***13 Leaman*** – A contact herbicide was applied to kill existing vegetation along the waterline during fall 2021. A pre-emergent herbicide was applied to the nesting area during spring 2022. A permanent 4-ft-high woven wire predator fence with an electrified top wire and offset electric wires closes off the nesting peninsula from its only land connection. Additionally, there is a 4-ft-high woven wire fence that is not electrified separating the northern boundary of the site from the property to the north, but this fence does not completely enclose the site. Predator trapping occurred during 2022. Predator deterrent lights were installed on the nesting site during spring 2022 as part of our additional predator management. No sand and gravel mining occurred.

[MG]***14 Trust Wildrose East*** – The nesting area was disked in the fall of 2021. No herbicide was applied in the fall of 2021 or in the spring of 2022. No sand and gravel mining occurred.

[PMG]***15 Follmer*** – A contact herbicide was applied to kill existing vegetation along the waterline during fall 2021. A pre-emergent herbicide was applied to the nesting area during spring of 2022. No fencing has been put up at this site given no documented use by plovers or terns to date. Predator trapping did occur during 2022. Sand and gravel mining occurred between the two existing managed peninsulas in 2022 but did not contribute any additional habitat this year due to high levels of activity and shifting terrain. Additional habitat may become available as mining continues at this site.

[G]***16 DeWeese*** – Not managed. Sand and gravel mining occurred during 2022. Available bare sand habitat was reduced from 11 acres in 2021 to five acres in 2022.

[G]***17 Hooker Brothers Southeast*** – Not managed. Sand and gravel mining occurred during 2022 adding 12 acres of habitat to this site for a total of 21 acres in 2022.

[G]***18 Hooker Brothers East*** – Not managed. Sand and gravel mining occurred during 2022.

ON-CHANNEL MECHANICAL HABITAT CREATION AND MAINTENANCE

Constructed on-channel habitat availability was variable and somewhat limited during the First Increment of the Program (Figure 3) and no additional on-channel habitat has been added during the First Increment Extension. Approximately 24 acres of constructed habitat were present in the AHR in 2007 as the result of efforts by other conservation organizations (Figure 3). That habitat was subsequently lost over the course of several years due to erosion during natural 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 the fall of 2012 and was also able to create on-channel habitat at the Cottonwood Ranch and Plum Creek complexes as part of sediment augmentation activities to provide 55 acres of on-channel habitat during the 2013 nesting season (Figure 3). Much of that habitat was lost during a natural high flow event in the fall of 2013. On-channel island construction began at the Shoemaker Island complex following the fall 2013 event. A high flow event in June of 2014 eroded a portion of the habitat constructed in the fall of 2013, but the Program was able to construct a total of 28 acres of on-channel habitat during the fall of 2014 at the Elm Creek and Shoemaker Island complexes to increase on-channel habitat availability for the 2015 nesting season (Figure 3). However, most of it was lost due to erosion during the 2015 and 2016 high flow events. The Program did not construct on-channel habitat after 2014, and without repeated habitat creation and management, no suitable on-channel habitat was available for plover and tern nesting from 2017-2022.

In preparation for the 2022 season, on-channel maintenance on Program managed properties was mainly in the form or herbicide application at targeted sites. Disking has been minimal since 2021 to allow for testing effectiveness of June germination suppression/channel inundation flow releases for reducing in-channel vegetation. Fall 2021 herbicide and spring 2022 pre-emergent herbicide were applied to an in-channel island within the Cottonwood Ranch Complex. Spring 2022 pre-emergent was applied at the Pawnee, Ft. Kearny, and Clark Island complexes. Spring 2022 pre-emergent and 2022 late summer/fall herbicide application was done around the perimeter of islands that were cleared in the Chapman Complex without disking. The moving complex approach (MCA) island in the Chapman Complex was not treated with pre-emergent prior to the 2022 season but was treated with herbicide in late summer/early fall in preparation for next year. This management has created appropriate foraging habitat for at least a portion of the season, but no nesting habitat that met Program requirements was created or maintained.

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 in the central Platte River from Lexington to Chapman, Nebraska. The standardized protocol was implemented by CNPPID, CPNRD, NPPD, and USFWS-GI 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). The data presented for 2022 were collected following the 2017 monitoring protocol.

The current report includes a synthesis of data collected from 2001-2022 to provide a look at plover and tern reproductive success over time and as management has evolved. Unless otherwise noted, data presented in tables and figures for 2001-2009 has been synthesized from previous reports. Changes in monitoring protocols over time that affect the comparability of results presented in tables and figures have been noted as they apply. Most changes occurred in 2010 and included:

- Brood survival rates changed from a 15-day success interval for both species, to a fledging age of 21 days for terns and 28 days for plovers, which created a higher benchmark of fledging success.
- River surveys increased from three to seven surveys a season.
- Both inside and outside monitoring was implemented at all off-channel sites from 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

We conducted seven semi-monthly (1 and 15 of May, June, and July; and 1 August) OCSW and river surveys along the AHR. Semi-monthly OCSW surveys were conducted at 18 Program owned or partnered OCSW sites along the reach to document adults, breeding pairs, nests, chicks, and fledglings during 2022 (Figure 5). River surveys were conducted along the central Platte River between Chapman and Lexington, Nebraska.

Semi-monthly OCSW Surveys

We conducted seven semi-monthly surveys from outside the nesting colony at 18 OCSW Program owned or partnered sites (Figure 5) to count individual birds and document plover and tern adults, breeding pairs, nests, chicks, and fledglings. Surveys of OCSW sites were distributed among multiple observers, each responsible for specific sites. As such, surveys were usually conducted on the same date across multiple sites over the entire AHR, or typically within 1-2 days of each other. Semi-monthly surveys were conducted outside the nesting areas on 2, 3, and 6 May; 16, 19, and 23 May; 31 May; 3 and 8 June; 13-15, 17, and 23 June; 30 June; 1 and 7 July; 15, 18, and 21 July; 26 and 29 July; and 1 and 2 August during 2022. Program staff and personnel from NPPD conducted the semi-monthly OCSW surveys during 2022.

Semi-monthly River Surveys

Program staff conducted semi-monthly river surveys between the J-2 Return and the Chapman Bridge. Each of the surveys took 2-3 days to complete. Semi-monthly river surveys were conducted on 3-6 May; 17-18 May; 1-2 June; 15-16 June; 28-29 June; 19-20 July; and 2-3 August during 2022. For all river surveys, we used an airboat to survey channels wider than 75 yards between Lexington and Chapman, NE that could be safely navigated. We documented all observations of plover and tern adults, breeding pairs, nests, chicks, and fledglings. Throughout the season some of the stretches of the main channel that are typically monitored during river surveys were mostly or completely dry. On 15 May survey, the Minden to Gibbon bridge segment was not completed due to a lack of flow. This stretch of river between the Minden and Gibbon bridges on the Rowe property is regularly used by both species for foraging as it is near some of the OCSW habitat, is wide and has fewer trees, and typically has large amounts of exposed sandbars and shallow water that is ideal for foraging. Though inaccessible by airboat, a point count survey was completed in the middle of the main channel at Rowe headquarters. On 15 July, channel segments that were not completed in their entirety due to low flow or channel blockage included the Kearney to Minden, Minden to Gibbon, Alda to HWY 281, and HWY 281 to South Locust bridge. A point count survey was again completed in middle of the main channel at Rowe headquarters. On 1 August survey, 28.2 miles of the main channel including the following river sections were not completed in their entirety due to low flow: Kearney Diversion Dam Reservoir to Odessa (5 miles not surveyed), Odessa to Kearney (9 miles), Kearney to Minden (7 miles), Minden to Gibbon (6 miles), and Hwy 281 to South Locust (1.2 miles). Point count surveys were completed at the Kearney Diversion Dam Reservoir, the north river channel at the Kearney Broadfoot South nesting site, Kearney bridge, and in the middle of the main channel at Rowe Headquarters.

SEMI-WEEKLY NEST AND CHICK MONITORING

In addition to semi-monthly surveys, we monitored all sites with active nests or broods on a semi-weekly basis throughout the nesting season. We determined the amount of nesting habitat available at each site using GIS. There were 18 OCSW sites monitored semi-monthly in 2022 (Figure 5); 10 of these sites had observed nesting by both species and were monitored on a semi-weekly basis. We attempted to observe nests and chicks twice per week until the nest or brood failed, or the chicks fledged. We conducted surveys of adults, nests, chicks, and fledglings from outside the nesting area. Program staff, technicians, and NPPD personnel monitored nesting sites during 2022.

Outside Monitoring

Surveys outside of the nesting area were performed for at least 30 minutes during each site visit 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). Observations were conducted from multiple vantage points to allow observation of as much of the site as possible. Nests and chicks were often located by observing adult birds. We 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 chicks or fledglings were observed, we estimated the date of hatching or fledging based on current and previous nest and chick observations. Counts reported are calculated across all sites along the AHR unless it is stated that the number site-specific. Adult counts represent the total across all the sites, including those without nesting, of the largest count of adults observed at each site on any one survey. Nests are calculated as the total number of nests observed across all the sites over the nesting season. Brood count is the total number of successful nests (at least one chick hatched) across all sites along the AHR. Chick and fledgling counts are the total of the highest number of chicks or fledglings in the appropriate age categories that are associated with each unique nest.

BREEDING PAIR ESTIMATION

We derived plover and tern breeding pair estimates (BPE) according to the methods described by Baasch et al. (2015). Briefly, we estimated plover and tern breeding pairs 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 2010−2022); 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 2010−2022); 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. We included summaries of the total number of adults, breeding pairs, nests, chicks, and fledglings observed during OCSW and river surveys to provide seven snapshots of the numbers observed during the 2022 nesting seasons. All counts of adults, breeding pairs, nests, chicks, and fledglings reported during semi-monthly surveys represent minimums present as they rely on direct observation.

The Program typically reports breeding pairs at their peak, when numbers of breeding pairs observed during a single observation period within the entire Program AHR first peaked (e.g., Tables 1-2 and 13-14). Thus, peak breeding pair estimates are associated with a specific peak date. A site peak is reported in Tables 3 and 15 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. On- vs. off-channel peaks are reported in Tables 4-5 and 16-17. These represent breeding pairs observed on dates when numbers peaked on- and off-channel respectively. All peak breeding pairs utilize the rules for calculated breeding pairs (BPE) as described above. 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).

SURVIVAL RATES

We calculated daily and incubation-period nest survival rates using the RMark package (Laake 2013) in Program R (R Core Team 2021) through RStudio (Posit Team 2022). We included nests located on OCSW sites that were monitored during 2022 by Program staff and personnel from NPPD to determine survival rates. In past years, when on-channel nesting was observed, these nests were also included. Nest success was defined 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 used the package RMark in RStudio to determine daily and brooding-period survival rates for broods of chicks. 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). Similar to 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.

RESULTS

PIPING PLOVER

2022 Seasonal Summary

We have observed an overall positive response in plovers to Program habitat creation, rehabilitation, and management across the AHR when comparing data across 2001-2022 (Tables 1-2). However, reproductive success varied across sites in 2022 (Table 3), which corresponded with previous years of monitoring. We documented the following in 2022 (Tables 2-3):

Plover adult and eggs.

- Throughout the AHR, 250 acres of off-channel habitat were available.
- Nesting occurred at 10 of the 18 OCSW sites.
- Estimated plover breeding pairs peaked at 38, leading to a fledge ratio of 1.37 fledges/BPE.
- Fledge ratios were higher in 2022 than the 0.97 fledges/BPE documented in 2021.
- Blue Hole had both good investment (i.e., number of nests) and high nest success in 2022 with the highest fledge ratio among sites.
- Dyer was also productive for plovers in 2022, with high investment in nests and an above average fledge ratio.
- NPPD Lexington and Newark West had high investment but did not fledge any chicks in 2022.
- Remote camera monitoring reduced the number of failed fates due to unknown causes, documenting losses of nests due to weather in addition to predation in 2022.

Off- vs. On-Channel Productivity

Semi-Monthly OCSW Surveys- Similar to past years, plover breeding pairs, nests, and chicks were observed on OCSW sites rather than on-channel river locations (Table 4 vs. Table 5). Beginning in 2017, all documented plover reproduction has occurred on OCSW sites. Though monitoring effort changed from three surveys a season in 2001-2009 (Figure 6), to seven surveys a season in 2010-2022 (Figure 7), patterns of peak adult counts remain consistent. In 2022 adult counts for plovers (45 adults) peaked on off-channel sites on the 15 June survey (Table 6, Figure 7). This mid-season off-channel peak is typical when comparing trends to previous years, including the 2001-2009 period (Figures 6-7). OCSW survey breeding pairs also peaked on the 15 June and 1 July surveys on the off-channel sites, with 33 estimated breeding pairs (Table 6). The highest OCSW survey nest count was 1 June for plovers (22). The highest chick count occurred 15 June (36); for fledglings this occurred on 1 July (5).

Semi-Monthly River Surveys - No nests or chicks were observed on-channel during 2022 (Tables 5 and 7). Nesting has not been observed on-channel for plovers since 2016. Adults observed on the river are largely assumed to be foraging adults from nearby OCSW sites due to the lack of nesting behavior and observations made most often at river locations near OCSW sites. Dates when on-channel adult counts peaked from 2001-2022 are not as consistent as on OCSW sites (Figures 8-9). This could be due to presence on the river that is not strictly tied to the timing of nesting behavior, changes in flow, habitat availability, incomplete sample periods, or other factors. For the 2022 surveys, the highest number of adult plovers (10 adults) was observed on the river during the 1 July survey (Table 7, Figure 9). This followed the patterns demonstrated in more recent years of adult counts on the river peaking in mid to late summer (Figure 9). A single plover fledgling was observed on the river during the 15 July survey in 2022. This fledgling was presumed to have come from an OCSW site as no nests or chicks were observed on-channel and it was observed near an OCSW site together with three plover adults.

Although some nesting has occurred on riverine sandbars in the past, OCSW sites have provided the most consistently available nesting habitat for both species (Figures 3 vs. 4). The limited amount of on-channel nesting observed at the beginning of the First Increment declined even further as on-channel habitat was lost during several high flow events. As a result, most of the nesting in the AHR during the First Increment and Extension of the Program has occurred on managed off-channel habitats (Table 4 vs. Table 5, Figure 10).

Semi-Weekly Nest and Brood Monitoring

Plover nesting was observed at 10 of the 18 OCSW sites as a result of semi-monthly monitoring in 2022. Nests and broods at these 10 OCSW sites were then monitored on a semi-weekly basis (Table 3, Figure 11).

<u>Breeding Pairs</u>- During the 2022 season, the number of plover breeding pairs peaked on 7 June at 38 pairs. Plover breeding pairs have been generally increasing since 2001 (Tables 1-2) and have significantly increased with the additions of OCSW sites that were included starting in 2010 (Table 4, Figures 12-13). For every acre of habitat created from 2001-2022, 0.15 more plover breeding pairs (95% CI: 0.11 - 0.20 breeding pairs) were present in the AHR (Figure 13). Over the long term, the Program has observed an overall positive species response in breeding pairs to the creation, rehabilitation, and maintenance of OCSW sites.

<u>Nests</u>- Nest counts, from which breeding pairs are calculated, increased sharply in 2010 with the addition of OCSW habitat and increase in monitoring effort (Figures 12 and 14). A total of 55 plover nests were observed and monitored at 10 of the 18 off-channel sites during 2022 (Tables 2-4, Figures 11-12,14). The first plover nest was observed on 3 May 2022 and the last nest was first observed on 7 July 2022. Plover nests had an apparent nest success of 0.55 (30/55; Table 2). The proportion of successful plover nests (or apparent nest success) varies from year to year but appears to stay within a relatively stable range since the changes in monitoring protocol were implemented and with the inclusion of additional OCSW habitat that began in 2010 (Tables 1-2, Figure 15).

Across the life of the Program average daily nest survival has remained stable in the AHR, with incubation-period survival rates varying more from year to year (Tables 1-2). During 2022, average daily survival rate of plover nests over all monitored sites was 0.9741 (range = 0.9195 –

1; Table 8), but the null model (Akaike Information Criterion adjusted for small sample size, AICc = 171.73; Burnham and Anderson 2002) was a better model to predict daily survival rates than the site-specific model (AICc = 172.45. Average survival rate over the 28-day incubation period over all the monitored sites during 2022 was 0.4798 (range = 0.0953-1; Table 8).

We tested for an effect of ownership (i.e., Program or non-Program) on daily nest survival rates during 2022. Average daily plover nest survival rate at Program owned and/or managed nesting sites was 0.9735 (95% CI: 0.9589 - 0.9831) and 0.9761 (95% CI: 0.9439 - 0.9900) at non-Program sites (Table 9), but the null model (AICc = 171.73) was a better model to predict daily survival rates than the ownership model (AICc = 173.70). Average survival rate over the 28-day incubation period across all Program sites was 0.4717 (95% CI: 0.3084 - 0.6196), compared to 0.5083 (95% CI: 0.1987 - 0.7554) at non-Program sites (Table 9).

Plover brood and egg in nest bowl.

Broods- Brood counts followed the trend of other reproductive parameters and have generally increased from 2001-2022 (Tables 1–2; Figure 12). The first observation of a plover chick occurred on 31 May 2022, and the last nest known to hatch occurred on 23 July 2022. The 30 successful nests in 2022 resulted in 100 chicks and an overall hatch ratio of 1.82 chicks/nest or 2.63 chicks/breeding pair (100 chicks/38 breeding pairs) (Table 2). The proportion of chick success (fledged chicks/total chicks) was 0.52 (52/100) in 2022 (Table 2, Figure 15). When considering long-term trends, care must be used not to compare current numbers using a higher benchmark (fledge age) for chick success and relying upon increased monitoring effort to those numbers observed under a different protocol from before 2010. Between 2010 and 2021 when monitoring protocols and age at fledging were comparable, the proportion chick success seemed to be slowly decreasing for this species in our study area. However, with the increase in proportion of chick success to 0.52 in 2022, the long-term picture may be stabilizing despite a fair amount of interannual variability.

Young piping plover chick.

When comparing daily brood survival rates from the start of the Program to the present, the rate has remained relatively stable across years (Tables 1-2). Across all sites, average daily survival rates during 2022 for plover broods was 0.9915 (range = 0 – 1; Table 10). The site-specific brood survival model had a substantially lower AICc of 48.87 compared to the null model value of 58.97, indicating daily brood survival rates varied by site in 2022 (Table 10).

When testing for the effect of ownership, average daily plover brood survival rate at Program owned and/or managed nesting sites was 0.9945 (95% CI: 0.9830 – 0.9982) and 0.9813 (95% CI: 0.9437 – 0.9940) at non-Program sites (Table 11). Average daily plover brood survival rates did not vary by ownership as the null model (AICc = 58.97) was a more parsimonious model and within two AICc units of the ownership model (AICc = 58.86). Thus, the null model was more appropriate to use to predict daily survival rates.

Average survival rate over the 28-day brooding period over all monitored sites was 0.7865 (range = 0 – 1). Average survival rate over the 28-day brooding period across all Program sites was 0.8561 (95% CI: 0.6184 – 0.9512), compared to 0.5895 (95% CI: 0.1971 – 0.8439) at non-Program sites (Table 11). Brooding-period survival rates have been more variable from year to year than average daily brood survival rates with two of the lowest rates occurring in 2018 and 2019 (Tables 1-2).

Fledges- During the 2022 season, we first observed a plover fledgling on 30 June and the last known plover chick to fledge did so on 9 August. The apparent nest-based fledge rate for plovers was 0.95 (52 fledglings/55 nests) and there was a pair-based fledging rate of 1.37 (52 fledglings/38 breeding pairs) at all sites monitored during 2022 (Table 2). This pair-based fledge ratio represents an approximate 41% increase over the fledge ratio of 0.97 observed in 2021 (Table 2, Figure 16).

Fledge ratios are one of the indicators used by the Program to measure reproductive success of the species. Due to changes in the monitoring protocol, the most comparable time-period for fledge ratios is from 2010 on. During this time, the Program observed a peak in plover fledge ratios from 2010-2014 (Figure 16). This peak coincides with an increase in OCSW habitat along the AHR; though it could be due to multiple factors, including a lack of habitat availability outside the reach where they might have otherwise decided to nest. Plover fledge ratios declined after 2014 and were low during 2018 and 2019, which prompted investigation into possible causes, specifically the impact of predation on plover productivity. Fledge ratios increased in 2020 and have since remained within a higher range. The observed fledge ratio for 2022 is in line with the mean pair-based fledge ratio of 1.31 from 2010 (when the benchmark for fledging was raised to 28 days) through 2021 (Table 2, Figure 16).

Incidental Take Summary and Mortality

The USFWS in its 2006 Biological Opinion (USFWS 2006) and 2018 Supplemental Biological Opinion (USFWS 2018) on the Program 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 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).

On 5 June 2022, incidental take was observed at an inland lake (Table 12). A single nest containing four plover eggs was inundated at Lake Minatare as the lake was filled in preparation for delivery of irrigation water (Table 12). The nest was discovered on 25 May with four eggs documented in the nest on 26 May. When the potential for nest inundation became apparent, discussion between the Bureau of Reclamation, Nebraska Game and Parks Commission, and the USFWS began to identify potential Reasonable and Prudent Measures to take to avoid loss due to nest inundation. The USFWS found that term and condition 1) of the Reasonable and Prudent Measure and Terms and Conditions from the PRRIP's Biological Opinion which addresses plover nesting in Inland Lakes could not be achieved because it was not possible to manage lake content to avoid nest inundation. Reclamation does not directly manage the elevation of Lake Minatare, as it is managed by the PID to supply Reclamation project water to irrigators downstream, mainly through Lowline Canal. Because Lake Minatare will be near the high-water mark, term and condition 2).a. (i.e., moving the nest to a higher elevation) was not deemed a reasonable option because a barren shoreline would not be available for nest relocation and brood rearing. USFWS also discussed the possibility for relocating the eggs to off-site nests with the Nongame Bird Program Manager for the Nebraska Game and Parks Commission. Accomplishing this would be difficult because incubation stage of the relocated eggs would need to be similar to the incubation stage of the host nest. Chick survival would be uncertain if eggs hatched several days apart. Additionally, USFWS felt it was unlikely that successful fledging would occur even with an investment of substantial time and resources to locate suitable host nests and successfully transport, place, and monitor eggs. Because of this, USFWS requested assistance from Reclamation and Nebraska Game and Parks Commission under term and condition 2).d to monitoring the fate of the nest and for Reclamation to report water levels and the duration of rise from detection through inundation at Lake Minatare. The Bureau's report contained the following information:

- Pathfinder Irrigation District started delivery of water to Lake Minatare through the Interstate Canal on 14 May at Whalen Diversion Dam, and water started to arrive at the reservoir on approximately 16 May. Water levels continued to rise at Lake Minatare as PID prepared for the delivery of irrigation water below the reservoir.
- The elevation at Lake Minatare was 4104.41 on 25 May and was at elevation 4108.18 on 5 June.
- The approximate rate of rise of the water level was 0.31 feet/day from 25 May – 5 June.
- The nest, including four plover eggs, was reported as inundated on 5 June 2022.

Between 2007 and 2016, a limited amount of predation has been observed and has not exceed the Service's threshold at any Program owned or managed off-channel sand and water nesting site in any year (USFWS 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 12). The percentages provided in Table 12 for losses of nests 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.

Due to increased focus on remote camera monitoring, we were able to reduce uncertainties on Program managed sites around causes of reproductive failures and mortality of plovers in 2022 (see Predator Management and Monitoring section for more detail). Across the entire AHR, Program and non-Program sites, there was no documented research related mortality in 2022. Two nests (4% of total plover nests) and zero broods were determined to be abandoned. There were three plover nests (5% of total plover nests) and one brood (3% of total plover broods) lost to weather. Failed-predated losses accounted for 15 plover nests (27%) and one plover brood (3%). In 2022, four plover nests (7%) were lost due to unknown causes and were fated as failed-unknown. These losses occur when loss stage is known, but there is not enough evidence to assign a specific fate. Four plover broods (13%) were also assigned a failed-unknown fate. There was one case of an unknown nest/brood (2%) this season. The nest was known to have failed overall; however, it is uncertain whether it had hatched before failing so the failure could not be assigned to either the nest or brood stage. Increased predator monitoring in the form of cameras and track surveys allowed more fating evidence to be collected and the total combined failed-unknown and unknown losses were lower compared to previous years. In addition to mortality of nests and broods, one adult plover mortality was attributed to a hailstorm. Two adult plovers were also observed with broken wings following a hailstorm, likely resulting in eventual mortality though not directly observed through monitoring.

Adult plover (top) mortality caused by a hailstorm at Leaman. Two plover chick (bottom) mortalities caused by unknown reason at Dyer (bottom).

Over the years, attributing losses of nests and broods to a known cause and identifying factors responsible for losses that management could focus on to improve productivity, has been a challenge. From 2010-2020 the largest number of losses each year have been consistently attributed to unknown causes (failed-unknown; Figure 17) due to lack of specific evidence for fating. Even during 2010-2016 when monitoring included gathering information from both inside and outside nesting peninsulas, the majority of losses were fated as failed due to unknown causes. When inside monitoring was discontinued in 2017, it was accompanied by a rise in failed-unknown nest and broods (Figure 17). The second most common reason for nest and brood loss from 2010-2020 was due to predation (failed-predated; Figure 17), a cause which likely also accounts for a portion of our failed-unknown losses during this time-period. Beginning in 2020, remote camera monitoring was deployed to reduce this uncertainty, identify causes, and narrow down the timing of loss. The information gathered has reduced the number of losses attributed to unknown causes and improved certainty around the number of losses due to predation. This information will be used to inform management decisions to reduce losses and improve plover reproductive success along the AHR.

Conclusions

The Program has observed an overall positive response in plover reproductive output to habitat creation, rehabilitation, and management. Increases have been seen in nest counts, breeding pair estimates, brood counts, and fledgling counts. These numbers have been generally increasing since 2001 and experienced a more drastic increase as the Program began constructing and restoring off-channel habitat. Breeding pair estimates have generally increased since 2001 and have seen a significant increase with the addition of OCSW habitat. Nest success has remained within a relatively stable range when looking across data collected under comparable protocols (2010-2022). In this same 2010-2022 period, the proportion of successful chicks has remained relatively stable as well. Changes in protocol in relation to increasing fledge age increased the benchmark of success from 15 days to 28 days for plovers in 2010, so proportions of chick success and fledge ratios before and after 2010 are not comparable. There was a peak in plover fledge ratios from 2010-2014, after which numbers gradually decreased before reaching a minimum in 2018. The fledge ratio remained low in 2019 before increasing in 2020-2022 and returning to a more normal or acceptable range. When examining data from other plover recovery programs, such as the Missouri River Recovery Program, large variation over cycles of a few seasons is not uncommon (USACE 2020, USACE Unpublished). Nonetheless, dips in fledge ratios, combined with decreasing proportions of chick success and a very low brooding-period survival rate in 2018, prompted investigation into possible causes and ways to improve reproductive success.

This year, both Blue Hole and Dyer had high plover reproductive investment in nests and above average fledge ratios (Table 3). In addition, the Program's newest site, OSG Lexington, hatched three plover nests this year with a fledge ratio of 1.33. Kearney Broadfoot South, a site that has historically had high initial investment but poor nest and brood survival and documented losses to predation leading to low fledge ratios, performed better this year with a fledge ratio of 1.14. Sites with high reproductive investment, but low reproductive output were NPPD Lexington (seven nests) and Newark West (eight nests). Neither site fledged any plover chicks in 2022. Comparatively, Newark East (within the same complex of sand and gravel mining but located 0.33 miles just east of Newark West) had seven nests and a fledge ratio of 1.71 for the year. Leaman produced only two plover nests in 2022 and both were lost due to weather. With the additional remote camera monitoring that took place on Program managed sites and the emphasis on plovers, we were able to reduce our number of failed-unknown losses, which was previously our largest category of loss (see Predator Management and Monitoring section for more detail). Camera information helped us fate 12 plover nests lost to predation and 3 plover nests failed due to weather (Table 33). In addition, one nest was documented on camera as being abandoned. We also documented predation at a nest that was eventually fated as successful, hatching at least one chick after the predation event. With the additional evidence collected with cameras and track surveys, most of our losses in 2022 for plovers were fated as failed-predated. Documented losses due to predation this season have reinforced the importance of developing effective management strategies to combat impacts incurred from both avian and terrestrial predators, as well as enforced the importance of improving our monitoring to further reduce our failed-unknown losses by accurately fating them.

LEAST TERN

2022 Seasonal Summary

Terns have also shown an overall positive response to Program habitat creation, rehabilitation, and management along the AHR from 2001-2022 (Tables 13-14). However, reproductive success has varied across years (Tables 13-14) and by site (Table 15). In 2022, we documented the following:

- Throughout the AHR, 250 acres of off-channel habitat were available.
- Nesting occurred at 10 of the 18 OCSW sites.
- The peak AHR breeding pair estimate for terns was 85, leading to a fledge ratio of 1.68 fledges/BPE.
- Fledge ratios observed in 2022 were higher than the fledge ratio of 1.21 fledges/BPE observed in 2021.
- The Program's newest OCSW site, OSG Lexington, had the highest tern reproductive success (fledge ratio based on the AHR peak date), but Cottonwood Ranch and Blue Hole also had high fledge ratios in 2022.
- Contrary to last year when Dyer was the Program's most successful site for terns, in 2022 the fledge ratio seen at Dyer was the lowest of all monitored sites that had productive tern nests. Two sites had tern nesting without a successful nest.
- Remote camera monitoring reduced the number of failed fates due to unknown causes.

Tern adult and chick.

Off- vs. On-Channel Productivity

Semi-monthly OCSW Surveys- Like past years, most tern breeding pairs, nests, and chicks were observed on OCSW sites (Table 16 vs. 17). Adult count peak dates on OCSW sites have remained relatively consistent from 2001-2021, with a mid-season peak (15 June and 1 July) being typical in this area (Figures 18-19). In 2022, adult counts for terns (105 adults) peaked on off-channel sites on the 1 June survey (Table 18, Figure 19). The number of breeding pairs observed at off-channel sites was highest on the 15 July survey, with 85 pairs (Table 18). The highest OCSW survey nest counts were on 15 June for terns (48). The highest chick counts (49) and highest number of fledglings (44) were observed on 15 July for terns (Table 18).

Semi-monthly River Surveys- As with plovers, the date when peak adults were observed on the river has varied more than at OCSW sites (Figures 20-21). After terns arrive in the area, they use nearby river habitat for foraging more consistently throughout the season than plovers (Sherfy et al. 2012) with numbers of adults usually peaking just before or at the same time fledges begin moving to the river. This was not the case for 2022, with the highest number of adult terns (28) observed on the river during the 1 June survey (Table 19, Figure 21). The high use of the river by adult terns in early June coincided with flow releases made by the Program to suppress germination of vegetation in the channel throughout the month of June. A seasonal peak in adult tern use of the river early in June has not been observed since 2015 (Figure 21). No nests or chicks were observed on-channel during 2022. No nesting has been observed on-channel since 2016 (Table 17). As with the plovers, tern fledglings were first observed on the river during the 15 July survey. The highest numbers of tern fledglings (10) were recorded during the 1 August survey (Table 19). All fledglings were presumed to have come from OCSW sites as no nests or chicks were observed on-channel, and the location and timing of these observations were similar to that of OCSW sites (Tables 18 vs. 19).

Nesting has occurred on riverine sandbars in the past, but OCSW sites have provided the most consistently available nesting habitat for both species (Figures 3-4). On-channel habitat is limited and susceptible to erosion or submersion by river flow, so without on-channel nesting islands being actively constructed and managed, its availability has declined, and most nesting has occurred on OCSW sites (Table 16 vs. Table 17, Figure 22).

Semi-Weekly Nest and Brood Monitoring

Terns were observed nesting on 10 of the 18 OCSW sites during semi-monthly monitoring, and these sites with reproductive activity were then monitored on a semi-weekly basis (Table 15, Figure 23).

Tern breeding pair at nest with two eggs and one chick.

Breeding pairs- Tern breeding pair estimates peaked at 85 pairs (Table 14) on 2 July 2022. Though counts demonstrate variability from year to year, tern breeding pairs have been generally increasing since 2001, which marks the start of the Program's available monitoring data set along the AHR (Tables 13-14; Figure 24). The Program began constructing and restoring additional OCSW habitats in 2009, and new habitat began being included and monitored in 2010 (Figure 4). Observed breeding pair estimates increased significantly with the addition of OCSW habitat (Table 16 vs. 17, Figure 25). For every acre of habitat increase, 0.32 more tern breeding pairs (95% CI: 0.18 - 0.45 breeding pairs) were present in the AHR. This is the first of several pieces of evidence indicating that terns respond positively to Program management.

Nests- Nest counts, from which breeding pairs are calculated, have generally increased along the reach since 2001 (Figures 24 and 26), and increased sharply as the Program started adding OCSW habitat and monitoring effort increased. A total of 128 tern nests were observed and monitored at 10 of the 18 off-channel sites during 2022 (Tables 14-16, Figure 23). The first observation of a tern nest was on 16 May 2022 and the last nest was first observed on 15 July 2022. In 2022, at least 1 egg from 67% (86/128) of tern nests hatched (Table 14). The proportion of successful nests, or apparent nest success, was similar to 2021 and remains within a relatively stable range since the Program began adding habitat and increased monitoring efforts (Table 14, Figure 27). All nests were located on off-channel sites and no nesting was observed on-channel during 2022 (Tables 16 vs. 17, Figure 22). Over the course of the First Increment and the Extension, the Program has observed an overall positive species nesting response to the creation, rehabilitation, and maintenance of OCSW sites.

For terns, we documented both an increase in nest counts and a relatively stable apparent nest success as the Program has made additions to habitat and increased monitoring effort (Figures 24 and 27). Across the reach, terns have also experienced stable daily nest survival rates over the life of the Program (Tables 13-14). Average daily survival rate of tern nests in 2022 over all monitored sites was 0.9793 (range = 0.8106 – 0.9956; Table 20). The site-specific average daily nest survival model had a substantially lower AICc of 289.13 compared to the null model value of 316.22, indicating average daily nest survival rates varied by site in 2022.

Average daily survival rate of tern nests at Program owned and/or managed nesting sites was 0.9763 (95% CI: 0.9676 – 0.9827) and 0.9906 (95% CI: 0.9752 – 0.9965) at non-Program sites (Table 21). When the effect of site ownership (i.e., Program or non-Program) on average daily nest survival rates was tested, the ownership nest survival model had an AICc of 314.20 compared an AICc of 316.22 for the null model. Therefore, inclusion of an ownership factor resulted in a better model than the null model without an ownership effect. However, based on AICc values, the site-specific survival model was a better overall model regardless of ownership.

Although average daily nest survival rates for terns have remained relative constant over the Program, the incubation-period survival rates have varied more across years (Tables 13-14) and sites (Table 20). Average survival rate over the 21-day incubation period over all monitored sites during 2022 was 0.6444 (range = 0.0122–0.9118; Table 20). When comparing ownership, the average survival rate over the 21-day incubation period across all Program sites was 0.6042 (95% CI: 0.5006 – 0.6933), compared to 0.8199 (95% CI: 0.5901 – 0.9283) at non-Program sites (Table 21).

Tern chicks and one egg in nest bowl.

Broods- Tern brood counts have also been increasing over time, likely in response to the increase in available habitat, breeding pairs, and nests (Tables 13-14; Figure 24). The 86 nests that we observed to hatch produced 196 chicks, which corresponded to a hatch ratio of 1.53 chicks/nest and 2.31 chicks/breeding pair (196 chicks/85 breeding pairs) during 2022 (Table 14). The first observation of a tern chick occurred on 11 June 2022, and the last nest known to hatch occurred on 4 August 2022. The proportion of successful chicks was 0.73 this year (143 fledged chicks/196 total chicks), higher than the 0.65 proportion observed in 2021. The proportion of successful chicks has also stayed within a relatively stable range, with some yearly variation, since the Program started adding off-channel habitat in 2009 (Figure 27).

Tern brood counts have also responded positively to Program management actions over the course of the First Increment and Extension. We have documented an increase in tern brood counts

(Tables 13-14) and relatively stable proportions of successful nests and chicks across years (Figure 27), which was also reflected in high and relatively constant average daily brood survival rates over time (Table 14). Average daily survival rates for tern broods across all sites during 2022 was 0.9919 (range = 0.9499 - 1; Table 22). The site-specific average daily tern brood survival model had an AICc of 115.07 compared to the null model value of 117.32, indicating inclusion of site in the model was an improvement over the null model with no site effect. When testing Program vs. non-Program ownership, average daily survival rate of tern broods at Program owned and/or managed nesting sites was 0.9920 (95% CI: 0.9847 – 0.9958) and 0.9915 (95% CI: 0.9739 – 0.9973) at non-Program sites (Table 23) and the null model (AICc = 117.32) was a better model to predict daily survival rates than the ownership model (AICc = 119.31).

Brooding-period survival rates for terns were more variable across years than average daily brood survival rates, but they had less variability across years than the brooding-period survival rates for plovers. For example, brooding-period survival rates for terns never reached the very low rates like that for plovers in 2018 and 2019 (Tables 13-14 vs. Tables 1-2). Average 21-day brooding period survival rate for terns over all monitored sites during 2022 was 0.8427 (range = 0.3401 - 1; Table 22). Average survival rate over the 21-day brooding period across all Program sites for terns was 0.8449 (95% CI: 0.7236 – 0.9161), compared to 0.8357 (95% CI: 0.5745 – 0.9439) at non-Program sites (Table 23).

Fledges- We observed the first tern fledgling on 30 June 2022 and the last known tern chick to fledge did so on 25 August 2022. Apparent fledge success at all sites monitored was 1.12 fledglings/nest (143 fledglings/128 nests) or 1.68 fledglings/breeding pair (143 fledglings/85 breeding pairs; Table 14). The pair-based fledge ratio of 1.68 fledglings/breeding pair observed this year for terns is the highest observed since a higher standard was established in 2010 for fledging tern chicks at 21 days and represents an approximate 39% increase over the fledge ratio of 1.21 observed in 2021 (Table 14 and Figure 28). Fledgling counts have increased since 2001 with the additions of habitat and increased monitoring effort (Tables 13-14). During the 2010-2022 period that has had a consistent monitoring protocol, both tern fledgling counts and fledge ratios, which are used as an indicator of success by the Program, have experienced annual variability, but have remained within a relatively stable range with no evident trend (Table 14 and Figure 28). The observed fledge ratio for 2022 is approximately 48% higher than the mean pair-based fledge ratio of 1.14 from 2010 (when the benchmark for fledging was raised to 21 days) through 2021.

Incidental Take Summary and Mortality

The USFWS in its 2006 Biological Opinion (USFWS 2006) and 2018 Supplemental Biological Opinion (USFWS 2018) on the Program 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 was 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.

During the Program's First Increment (2007-2019), incidental take was minimal 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 February 12, 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).

An increased effort devoted to remote camera monitoring on Program managed sites allowed us to reduce uncertainties around causes of reproductive failures and mortality of terns on Program sites in 2022. For the entire AHR, spanning both Program and non-Program sites, there was no documented research related mortality. In 2022 there were two tern nests (2% of total tern nests) and zero broods determined to be abandoned. There were 15 tern nests (5%) and two broods (2%) lost to weather. Thirteen tern nests (10%) and two tern broods (2%) were lost to predation. In 2022, 12 tern nests (9%) were fated as failed-unknown due to loss from unknown causes. Eight tern broods (9%) were assigned a failed-unknown fate. These losses occur when loss stage is known,_but there is not enough evidence to assign a specific fate. Due to increased predator monitoring in the form of cameras and track surveys, more fating evidence was available and the total combined failed-unknown and unknown losses were lower than during previous years. In addition to mortality of nests and broods, mortality of five adult terns was attributed to hail in 2022.

Tern adults (top) and chick (bottom) mortality caused by hailstorms.

Much like with the plovers, collecting sufficient evidence to accurately fate tern nests and determine the causes of reproductive losses has previously been an area in need of improvement. The most frequently attributed category of loss since 2011 has consistently been losses failed due to unknown causes (failed-unknown; Figure 29) and is due to lack of adequate evidence that meets Program fating requirements. This was an issue that was present even when banding took place and monitoring was done from both inside and outside the nesting area, though a large increase in failed-unknown fates was seen after inside monitoring stopped in 2017. Though more variable in terns, predation is often the second highest cause of loss and likely contributes to a portion of the failed-unknown losses. Remote camera monitoring is being used to document predation events, determine the causes of failures, as well as determine the timing of loss during the incubation period (see Predator Management and Monitoring section for details). This information will inform future management decisions to reduce tern reproductive losses and improve productivity along the AHR.

Conclusions

The Program has observed an overall positive response in tern reproductive output to habitat creation, rehabilitation, and management. Breeding pair estimates, nest counts, and brood counts have all generally increased over the last 20 years with a noticeable increase in 2010 when the Program began adding OCSW habitat. Nest and chick success have both remained in a stable range when looking across data collected under similar protocols (2010-2022). Though we saw a dip in fledge ratio in 2019, the numbers have since returned to within a more typically seen stable range and 2022 saw a 48% increase from the 2010-2021 mean fledge ratio. Although we see a variation year to year in reproductive success for terns along the AHR, our numbers typically fall into a stable and acceptable range. This is also true when looking at reproductive metrics collected for terns nesting outside the AHR. For example, fledge ratios for terns along the Missouri River vary among years but these fluctuations tend to remain within a relatively stable range over the long term (USACE Unpublished).

The high tern fledge ratio over the AHR in 2022 can be attributed to higher than average fledge ratios at multiple OCSW sites this year (Table 15). The relatively new OSG Lexington site hosted nine tern nests this year with a fledge ratio of 2.38. Cottonwood Ranch also provided successful nesting habitat for terns in 2022, with ten nests producing a fledge ratio of 2.13. Whereas Blue Hole had low reproductive success in 2021, it hosted 13 tern nests this year with a fledge ratio of 2.17. Newark East has become one of the Program's most consistent sites for tern productivity, having high initial investment as well as good nest and brood survival, to produce a fledge ratio of 1.62 in 2022. Kearney Broadfoot South did well this year for terns, hosting 11 nests with a fledge ratio of 1.58, which was much higher than the 0.40 fledge ratio observed in 2021. In comparison, Dyer, one of the Program's most productive sites for terns in 2021 with a fledge ratio of 1.88, suffered losses to badger (*Meles meles*) predation this year that reduced nest survival (see Predator Management and Monitoring section for details). When coupled with low brood survival, we observed a fledge ratio of 0.83 for Dyer in 2022. Though terns nested on Leaman this year, they had poor nest survival and lost all nests to weather events this year. Only two tern nests were observed at NPPD Lexington this year and coupled with poor nest survival the site produced no tern fledges this year.

Though we have reduced the losses we attributed to a failed-unknown fate with the additional evidence provided by remote camera monitoring and track surveys (see Predator Management and Monitoring section), most losses for terns in 2022 still fall into the failed-unknown category (Figure 29). Due to the delisting of terns, plovers were given priority for receiving nest cameras, so fewer tern nests received cameras than plover nests. Even with the reduced camera monitoring effort focused on terns, they provided the information required to accurately fate eight tern nests that failed due to weather and four tern nests that failed to predation, which were the two biggest known contributors to reproductive loss for terns in 2022 (Table 33). In addition, cameras documented two tern nests that were abandoned and two predation events that occurred at nests eventually fated as successful, hatching at least one chick.

PREDATOR MANAGEMENT AND MONITORING

The Program employed additional predator monitoring in 2022 to improve our overall monitoring accuracy, reduce the number of losses attributed to unknown causes, and increase our understanding of the impacts of predation on our target species. This additional focus on predators was in response to low 2018-2019 fledge ratios and a decrease in the proportion of successful plover chicks over time, prompting the Program to research possible causes and management actions that could be implemented to improve these numbers. Prevention of predation by avian and terrestrial predators was identified as an important objective for increasing productivity of plovers. Building upon a 2020 pilot study, additional predator monitoring was deployed on all Program monitored and managed sites and included track surveys along the shoreline, as well as remote camera monitoring at a site, shoreline, and nest level.

The Program implemented several long-term management strategies to reduce the risk of predation at OCSW sites. Managed off-channel nesting sites were peninsulas surrounded by water to provide a ≥100 ft wide barrier to terrestrial predators. Nesting site entrances were protected by installing permanent and temporary electrified fences across the entrance of each nesting area. Non-electrified fence-panel wings were positioned on the ends of the electrified fence and extended 3-7 ft into the water to deter terrestrial predators from swimming from the mainland to the nesting peninsula. All trees within a ≥492 ft radius of the nesting site were removed, avian spikes were placed on all potential, non-removable perches, and the Program actively trapped and removed terrestrial predators around the periphery of the site.

Along with these existing management strategies, the Program began testing additional predator management in a 2020 pilot study. For the 2022 season, the basic design and implementation remained the same as in 2021 with additional management deployed on three Program monitored and managed sites: Kearney Broadfoot South, Newark West, and Leaman. This management included additional predator exclusion fences surrounding entire nesting peninsulas and predator deterrent lights. The Program will continue implementing these additional management strategies through 2024 to provide a multi-year data set that will be analyzed and used to inform management decisions moving forward.

PREDATOR MANAGEMENT

METHODS

Terrestrial Mammal Trapping

Terrestrial mammal trapping and lethal removal was performed by United States Department of Agriculture Animal and Plant Health Inspection Service (APHIS) Wildlife Services (WS) on Program and NPPD off-channel nesting sites in 2022 as it has been done in the past. Wildlife

Services deployed traps at each site prior to and during nesting which included live cage traps (cage traps), dog proof leg hold traps, and leg hold/foot hold traps or body hold snares (Table 24). Opportunistic firearm usage (firearm) also occurred at sites when deemed necessary. When each trap was initially placed, a trap identification number, site, date, and trap type was recorded. A total of 282 traps were set during the 2022 plover and tern nesting season across 10 sites (Table 24). Daily trapping logs were then kept for each site to record the time of personnel entry/exit of a site, 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. Each terrestrial mammal capture was identified by species, trap identification number, trap type, time, site, date, and then removed from the site. North American river otters were the only removal exception and were immediately released if captured.

We calculated trapping effort at each site as trap days. The number of days each trap was open over the entire monitoring season was summed over all traps at a site to get trap days for each site. Trap days between trapping visits were defined as the number of days from previous visit date to current visit date from each trap open at a site. To account for the closure of traps in between trap checks, we assumed if a trap was found closed on a subsequent survey (whether that closing resulted in a capture or not), trap days attributed to that trap were half that of time since last trap check. Firearm usage was not factored into trapping effort. We then summarized trapping effort and terrestrial mammal captures by site and trap type, which will help the Program evaluate effectiveness and efficiency of WS trapping efforts and possibly adjust trapping methods to better meet management objectives for off-channel plover and tern nesting sites.

Predator Exclosure Fencing

In addition to our pre-existing predator exclusion fences that were deployed across nesting peninsula entrances, additional predator exclusion fencing that completely surrounded our nesting areas was maintained on two OCSW sites, Kearney Broadfoot South and Newark West. An interior 4-ft woven wire predator fence, with 4x4 inch openings to allow plovers and terns to easily move through, was installed along the interior shoreline of the nesting area at Kearney Broadfoot South and included two electrified wires (Figure 30). One wire was mounted a few inches above the fence along the tops of the fence posts, both to prevent it from being used as a predator perch and to make climbing over the fence more difficult. The other wire was mounted at approximately the same height as the top of woven wire or slightly above but was offset to the side to also help prevent predators from climbing over. Newark West had an exterior predator exclusion fence deployed along the outside of the water moat along the property line (Figure 31). This fence was a 4-ft high woven wire fence, with one electrified wire mounted offset to the side about 3 ft off the ground. The ability of plover and terns to traverse through this fence was not a

Interior predator exclusion fence at Broadfoot-South Kearney.

concern as it was located outside the nesting and foraging areas, so the openings for the Newark West fence were 2x4 inch openings.

Predator Deterrent Lighting

Predator deterrent lights were deployed at three Program monitored and managed sites. The first site was Kearney Broadfoot South, which had a total of four motion activated predator deterrent 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). These blinking walking lights were mounted to the interior predator

Random pattern Foxlight.

Blinking RISOON solar strobe light.

Motion activated Luposwiten solar light.

exclusion fence along the shoreline and set to flash at alternate times to give the illusion of movement as the lights travelled down the fence. Motion activated and random pattern lights were deployed in sets of two, with one of each type per set, deployed evenly across the site at a density of approximately one set per four acres. These lights were installed on top of a seven ft high post, with avian spikes installed on top of the lights to prevent them from being used as predator perches. At Newark West, along with an exterior predator exclusion fence, this site also included four motion activated and four random pattern lights distributed between the two nesting peninsulas (Figure 31). Additional management at Leaman consisted only of predator deterrent lights, with three sets of motion activated and random pattern lights distributed across the site (Figure 32).

PREDATOR MONITORING

During the 2022 plover and tern nesting season, the Program monitored predator presence and predation events at six plover and tern nesting sites: Dyer, Cottonwood Ranch, Kearney Broadfoot South, Newark West, Newark East, and Leaman. Predator presence was documented through USDA-APHIS trapping of terrestrial mammals outside 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.

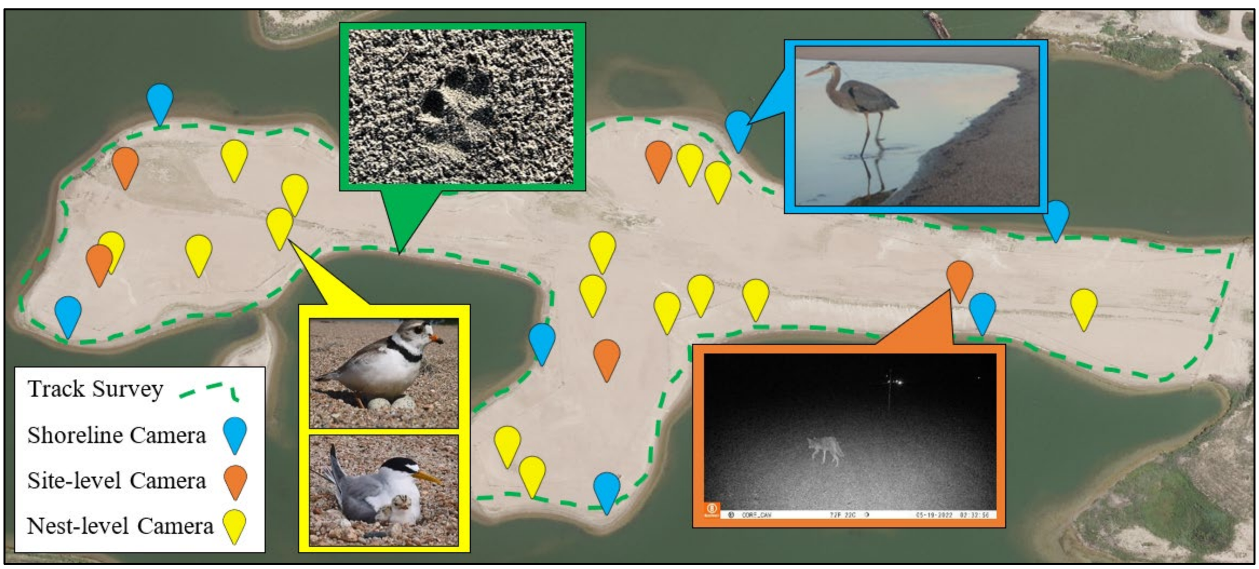
METHODS

Terrestrial mammal trapping

We used daily trapping logs as provide a source of information on potential terrestrial predator presence along external shorelines and along the outside of nesting peninsulas. The logs were used to identify the species of potential predators present at the site as well as the number of captures per unit of capture effort (trap days) as an indicator of relative abundance.

Track Surveys

Track surveys were conducted along peninsula shorelines at the six nesting sites once per week to document potential avian and terrestrial predator presence and access to the nesting peninsulas. We summarized track survey effort at each site by summing the number of surveys completed. Surveys started at the nesting peninsula entrance with two observers walking the entire stretch of the shoreline (represented in green in the figure below).



Example of the 2022 predator monitoring efforts and their field of view represented in the color-coded callouts. Kearney Broadfoot South is being used as an example.

Animal tracks, animal digs (i.e., disturbed sand under a fence due to animal digging, see figure to the right), fence turn backs (i.e., the animal walked to the fence and retreated), and owl pellets detected for a given species during a single survey over an entire nesting peninsula were recorded as a single unique species register. Animal digs were attributed to an unknown species if unable to correctly identify the species responsible for the animal dig. An animal dig was counted as a unique register only if no other tracks of digging species were found during the survey. If other species tracks were found during the same survey, the animal dig was not counted as a unique register because it was likely caused by one of the identified species. Tracks were "wiped" at each survey to prevent double counting upon the next weekly survey. Tracks from Canada geese (*Branta canadensis*) were recorded during these surveys.

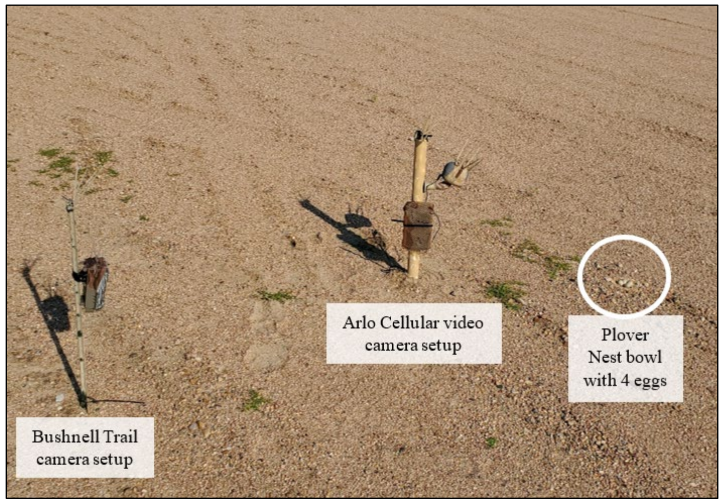
Example of an animal dig at the predator fence located at Dyer.

Remote trail and video cameras

Shoreline trail cameras (represented in blue in the figure above) were attached to 3-ft tall metal posts with avian spikes placed on top to prevent avian predator perching. The cameras were generally placed every 1,200 linear feet along the shorelines of the six nesting sites to document potential predator presence. When this regular spacing did not provide good coverage of shorelines used more by our target species for foraging or shorelines more easily accessible to predators because of narrow or shallow moats, the distance between shoreline cameras was adjusted to provide this coverage. We quantified shoreline camera monitoring effort at each site as the number of days each shoreline camera was deployed (camera days) summed over all cameras at each site. The trail cameras were programmed to take motion-triggered photos followed by a 30 second video. Animals registered on shoreline monitoring cameras were identified to species. Unique individuals could not be identified and multiple cameras at a single site could have captured the same individual several times; therefore, we reduced our dataset to include only unique potential predator registers captured by shoreline cameras. A unique register was defined as a register of a single species separated by at least 24-hours from a previous register of the same species. Multiple registers by shoreline cameras of the same species at the same site within the 24-hour period were considered a single unique register. Multiple individuals of the same species captured in a single photo or video were counted as one unique shoreline register (with the number of individuals in the register being documented). Unique potential predator registers were then summed over the entire nesting season on a site-by-site basis to arrive at a total number of unique potential predator registers for each nesting site.

Site-level trail cameras (represented in orange in the figure above) were attached to 4-ft tall PVC pipes with avian spikes placed on top to prevent avian predator perching. In 2021, site-level cameras were placed at heights of 5–6 ft, but the low number of site-level registers suggested that some terrestrial predators were missed on site cameras due to the height. In response, we modified the height of the site-level cameras from 5–6 ft in 2021 to 4 ft in 2022 to improve detection of potential terrestrial predators and avian predators that land on the site. This change in height still allowed for adequate coverage for flying avian species as well. Site-level cameras were placed at each of the six nesting sites at a density of one camera for every four acres near the edges of the peninsula facing inward to document potential predator presence. Site-level camera monitoring effort, camera days, camera programming, and unique registers, were calculated and defined the same as for shoreline cameras.

Nest-level cellular video and trail cameras (represented in yellow in the figure on the previous page) were placed at plover and tern nests at the same six nesting sites to document potential predator presence and predation events occurring at the nest. Not all nests were monitored by cameras, with preference for placing the predetermined number of cameras designated to a site at plover nests before placing on tern nests. Cameras were placed at a density of approximately one nest camera every two acres (5-10 nest cameras per site) and only placed at established nests (i.e., the nest contained at least one egg in the nest bowl). Cameras were removed once the nest was no longer active (i.e., successful or failed) and sometimes placed onto another nest if needed. To minimize disturbance to nesting adults, plover trail nest cameras were placed ~5 ft from the nest and tern trail nest cameras were placed ~7 ft from the nest. The trail cameras were positioned on 2-ft tall metal posts with avian spikes placed on top to prevent avian predator perching. Cellular video cameras were placed closer to the nest (i.e., 1.5-2 ft) because their purpose was to document 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 are not tolerant of cameras that close to their nest. Arlo cellular video cameras recorded continuous live video and stored the data remotely so the information can be accessed remotely in real time to check nest status or downloaded for review and storage. Nest camera monitoring effort, nest camera days, trail camera programming, and unique registers were calculated and defined the same as described for shoreline and site level cameras. Cellular video and trail cameras were deployed at active nests (i.e., adults were tending the nest until the nest was successful or failed) and registers were defined as either a register (potential predator documented on camera without predating the nest) or a predation event (predator documented predating the nest) for that specific nest. The type of predation (i.e., ate eggs, chicks, adult), date, time, and animal behavior/activity (e.g., approached nest and left, landed/walked over nest, etc.) was also documented for nest camera monitoring. If more than one predation event by the same predator species occurred in the same 24-hours at the same nesting site (whether at a single or at multiple nests), it was counted as one unique predation event, but all data documented during the predation event (i.e., number of nests, eggs, or chicks predated) were summed and included in the overall number of plover and tern nests, eggs, and chicks predated during the 2022 nesting season.



Example of a trail camera and cellular video camera setup.

To facilitate comparisons of potential predator presence across sites while controlling for monitoring effort, the number of unique potential predator registers at a site within a given monitoring method was divided by the monitoring effort devoted to that method within each site. This is shown as registers per weekly survey for track surveys and captures or registers per day for trapping or camera monitoring (e.g., as in Tables 25-26 and Tables 28-31; Figures 34-39). To give an overall picture of each site's relative contribution to the documented predator community resulting from monitoring effort over all six monitored plover and tern nesting sites, unique registers documented at a single site for a single type of monitoring were divided by total effort dedicated to that type of monitoring over all six monitored sites. For example, the number of unique registers of great-horned owl by nest cameras at Newark West were divided by the total nest camera days of effort over all six sites to represent Newark West's relative contribution to total great-horned owl registers given the total nest camera monitoring effort over all sites. As such the stacked bars (each color representing one of six sites) in Figures 40-42 represent the total number of registers for each species across all six sites using the indicated monitoring method normalized for the monitoring effort across all six sites. This is shown as captures or registers per total unit effort. When compared from top to bottom Figures 40-42 also reflect how the composition of the potential predator community changed as barriers/deterrents (trapping, moat, fencing, lighting) were encountered from the outside (trapping, tracks, shorelines) to the inside of the nesting peninsula (site and nest level).

To test whether cameras placed at plover or tern nests negatively impacted nest survival, we ran a mixed- and fixed-effect nest fate logistic exposure model to calculate daily survival rate (DSR) at sites with camera and non-camera nests. Models were run using the lme4 package (Bates et al. 2015) in Program R (R Core Team 2021) through the RStudio (Posit Team 2022). Combined plover and tern nest survival information was used from six sites that had nests both with and without cameras for comparison (Dyer, Cottonwood Ranch, Kearney Broadfoot South, Newark West, Newark East, and Leaman). Four pieces of information from each nest were used to calculate DSR: first date a nest was found; last date a nest was observed active; date a nest outcome was determined; and if a nest was successful or not. Nest information was then split into camera and non-camera nest data and DSR was calculated by site or species to address DSR of (1) all sites combined, species combined, (2) all sites combined, species specific, and (3) site specific, species combined. For models with sites combined, site was accounted for as a random variable. For the site-specific model, sites were included as fixed variables. We also made a fourth site-specific comparison between DSR of nests with cameras in 2022 to the average DSR of all nests at a given site calculated using data from 2010-2016 prior to any camera usage at sites. For example, the average DSR of all nests with cameras at Kearney Broadfoot South in 2022 was compared to the average DSR of all nests monitored at Kearney Broadfoot South from 2010-2016. These comparisons were made to examine whether nest camera placement had a negative impact overall (regardless of site or species), whether impact was specific to plovers or terns, or whether camera placement had a negative impact on nest survival at some sites more than others.

RESULTS

Trapping of terrestrial mammals

Trapping of potential mammalian predators during 2012-2022 demonstrated high variability in the number of potential predators trapped and removed from OCSW sites over the years as well as across sites (Figure 33). During the 2022 nesting season, 341 terrestrial animals were captured and removed from 10 OCSW nesting sites representing 11 different species. These captures were the result of using 282 traps over 32,366 trap days and the use of a firearm to eliminate a bullsnake (*Pituophis catenifer sayi*) and a woodchuck (Tables 24-27). Raccoons (*Procyon lotor*) were the most frequently captured terrestrial mammal at every site, with a total of 303 raccoons captured over all sites (Tables 26-27). Eliminating the two species removed by firearm, 339 captures were made over 32,366 trap days for a mean capture efficiency of 0.0105 captures/trap day over all 10 sites, ranging from 0.0072 captures/trap day at Blue Hole to 0.0152 captures/trap day at NPPD Lexington (Table 25). The three sites with status quo predator management had a mean trapping efficiency of 0.00995 captures/trap day compared to the mean trapping efficiency of 0.0111 captures/trap day for the three sites with additional predator management (Figures 34 and 37). Overall, the contribution of status quo and additional management sites to total captures per total unit effort over all sites were the same (0.0051 and 0.0052, respectively); however, Newark West, an additional management site, had the highest number of predators trapped per total unit effort (Figure 40).

Shoreline track surveys

Shoreline track surveys documented a total of 258 unique registers over 83 surveys of the six Program nesting sites for a capture efficiency of 3.11 registers/survey (Table 28). The number of unique tracks registered per survey varied from 1.92 at Cottonwood Ranch to 4.5 at Kearney Broadfoot South in 2022. Mean number of track registers/survey at the three sites with additional management was 3.095 compared to a mean of 3.093 track registers/survey at the three sites with status quo predator management (Table 28). Kearney Broadfoot South, an additional predator management site, had the highest number of track survey registers per survey (Table 28). Dyer, a status quo site, had the second highest number of track survey registers per survey (Table 28). Sites with additional predator management (1.566 track registers/total unit effort) had a similar number of track registers per total unit effort to those of status quo sites (1.542 track registers/total unit effort) with total unit effort for track surveys defined as the total number of surveys at status quo and additional management sites combined. Avian track registers were the most common (Figures 35 and 38). Canada goose was the species most frequently observed during track surveys having highest number of registers per total unit effort over all six sites (0.976 track registers/total unit effort; Figure 41). Softshell turtles (Family Trionychidae; 0.795 track registers/total unit effort) and great blue heron (*Ardea herodias*; 0.542 track registers/total unit effort) had the next highest number of registers per total unit effort (Figure 41).

Shoreline and site-level camera monitoring

No predation events were documented by shoreline or site-level cameras at any of the six camera-monitored nesting sites. Shoreline cameras registered 746 unique potential predator registers over 3,933 camera days for a capture efficiency of 0.1897 registers/camera day (Table 29). Shoreline registers/camera day varied from 0.1044 at Cottonwood Ranch to 0.4615 at Leaman (Table 29). Mean registers/camera day at the three sites with additional management was 0.2694 compared to a mean of 0.1483 registers/camera day at sites with status quo predator management. Site-level cameras registered 163 unique potential predator registers over 2,939 camera days for a capture efficiency of 0.0555 registers/camera day (Table 30). Site-level registers/camera day varied from 0.0194 at Cottonwood Ranch to 0.1571 at Leaman (Table 30). Site-level mean registers/camera day at the three sites with additional predator management was 0.0851 compared to a mean of 0.0417 registers/camera day at sites with status quo predator management. A high number of registers/camera day at Leaman was responsible for higher mean shoreline and site-level camera trap efficiency at sites with additional predator management. Across the six Program sites monitored with cameras, avian registers were the most common species type registered on shoreline and site-level cameras (Figures 36, 39). There were more avian registers per camera day recorded at shorelines than on the interior portion of nesting peninsulas by site-level cameras (Figures 36, 39). Across all six camera-monitored sites, Canada goose was the most common species registered per total unit effort at the shoreline (0.125 registers/total unit effort) and site-level (0.042 registers/total unit effort; Figure 42A,B). Blue heron (0.033 registers/total unit effort) and raccoon (0.005 registers/total unit effort) had the second- and third-highest number of registers per total unit effort for shoreline cameras (Figure 42A). For site-level cameras, blue heron (0.003 registers/total unit effort) and great horned owl (*Bubo virginianus*) and badger (0.002 registers/total unit effort) had the second- and third-highest number of registers (Figure 42B). The contribution of sites with additional predator management to the total number of shoreline camera registers (0.109) and site-level camera registers (0.031) per total unit effort was greater than the contribution of status quo sites to the total number of shoreline (0.081) and site-level (0.024) registers per total unit effort.

Nest-site camera monitoring

On Program managed sites, nest cameras provided additional data to identify potential predators present at plover and tern nests, accurately fate nests, and quantify losses due to predation. Overall, 43 nest cameras monitored 82 nests (36 plover nests and 46 tern nests) for a combined effort of 1,116 camera days across all sites (Table 31). A total of 27 unique potential predator presence/predation events (hereafter, nest events) occurred at active camera monitored nests, but only 25 of these events were captured on camera. Nest cameras captured 25 unique nest events on camera/video for a capture efficiency of 0.0224 events/camera day (Table 31). Nest events/camera day varied from 0 at Leaman to 0.0583 at Newark West (Table 31). Nest events were documented at sites with additional predator management (mean of 0.0235 nest events/camera day) at a similar frequency to sites with status quo management (0.0222 nest events/camera day). However, predation events were documented more frequently at sites with additional management (0.0194 registers/camera day) than at status quo sites (0.0093 registers/day). For potential avian predators, the number of registers/camera day decreased moving from shorelines to the interior of the nesting peninsula (site-level), and further decreased at the nest-level for both status quo and additional management sites (Figures 36 and 39). For mammalian predators, this pattern was not consistently observed, with nest events documented more frequently than site-level registers at Dyer, Newark West, and Kearney

Badger predating eggs.

Broadfoot South (Figure 42B). Unfortunately, Leaman lost all nests early in the season to weather and provided no information on nest predation this year. Birds, mammals, and reptiles were registered at the nest and predated nests in 2022 (Figures 42C and 42D). Considering nest events (registers with and without predation occurring) from all six camera-monitored sites, great horned owl (0.0072) was the most frequently registered at the nest per total unit effort, badger the second-most common (0.0036 registers/total unit effort), and bullsnake the third-most common (0.0027 registers/total unit effort). Regarding nest predation events, great horned owl was the most frequently registered with 0.0054 registered predation events/total unit effort and badger the second-most common (0.0036 predation events/total unit effort). The contribution of additional management sites (0.0081) to the total number of nest events (registers with and without predation occurring) documented on camera per total unit effort was less than the contribution of status quo sites (0.0152). For nest predation events, the contribution was more evenly distributed with additional predator management sites contributing 0.0054 registers of nest predation/total unit effort compared to 0.0063 registers/total unit effort for the three status quo sites.

Of the 27 unique nest events, 12 were of potential predator registers where the animal approached the nest and left (i.e., did not predate the nest) and 13 were predation events where the predator was captured on camera consuming eggs and/or chicks in the nest bowl (Table 32). In addition to the 13 predation events at nests captured on camera, two additional camera-monitored nests were determined as predated though the actual predation event was not captured by the nest camera. One camera-monitored plover nest at Dyer was determined predated by a badger because the nest had digging and missing eggs and was inactive the following monitoring visit. There was also one camera-monitored plover nest at Newark West that was determined to be predated by a striped skunk (*Mephitis mephitis*) because a striped skunk was registered on a site level camera located near the nest and the nest was inactive the following monitoring visit. However, these nest cameras malfunctioned and did not register the individual predator or the predation event. In total, active camera-monitored nests suffered 15 unique predation events (including the two events not captured on camera) resulting in the predation of 19 individual nests. Badger at Dyer and great horned owl at Dyer and Newark West were the predator species responsible for the most predation events in 2022 (Figure 42D). Badger accounted for eight of the 19 (42%) individual predated nests and great horned owl accounted for seven of the 19 (37%) individual predated nests. Striped skunk at Newark West was responsible for two (11%) predated nests and a Virginia opossum (*Didelphis virginiana*) at Newark East and bullsnake at Newark West each predated one (5%) nest (Table 32). Mammals were responsible for 58%, avian species were responsible for 37%, and reptiles were responsible for 5% of the 19 losses of individual nests to predation (Table 32). Of the 19 camera-monitored nests predated, three occurred at successful nests (i.e., chicks and eggs present in the nest bowl) and 16 occurred at active nests (i.e., only eggs present in the nest bowl; Tables 33-34).

At the six camera-monitored OCSW sites, combining data from all monitoring sources at nests with and without cameras (outside/inside observers, nest, site, and shoreline camera data, and track surveys), we documented a total of 25 nests (13 plover nests; 12 tern nests) incurring losses due to predation in 2022 (Table 33). Twenty-two nests (12 plover; 10 tern) were fated as failed due to predation. An additional three more nests (one plover; two tern) that were fated as successful because at least one chick hatched, also experienced some loss to predation. For the 19 camera-monitored nests experiencing predation for which we have more information, we documented the loss of 39 plover eggs, 11 tern eggs, three plover chicks, and three tern chicks to predation (Table

34). Because of this detailed data, we were able to determine the fate for 94% of eggs laid (i.e., failed or hatched) and the fate for 96% of chicks (i.e., failed or successfully left the nest bowl with adults). Of the 20 eggs that were fated as failed abandoned, 71% (10 eggs) occurred after the nest was successful, 21% (3) were nests fated as abandoned, and 7% (1) was after predation occurred. The date predation occurred during incubation according to nest-level camera data was used to plot the timing and frequency of the predation events according to development stage. Plover nest predation occurred when nests averaged 41.4% developed and tern nest predation occurred when nests averaged 61.9% developed (Table 35, Figure 43). Predation of plover and tern eggs was distributed across 3-14 days of incubation, except for a single nest with addled eggs predated by an opossum (Figure 43).

Effect of nest-site cameras on daily survival rates

To test for a possible negative impact of placing cameras at nests on daily survival rates (DSR), we made comparisons of DSR between 82 nests with nest cameras and 52 nests without cameras Dyer, Cottonwood Ranch, Kearney Broadfoot South, Newark West, Newark East, and Leaman in 2022 (Table 33). Approximately 61% of nests had cameras placed to observe activity and determine nest fate. Sixty-one percent (50 of 82) of all camera nests and 52% (27 of 52) of all non-camera nests successfully hatched at least one chick. When combining data for both species across all six sites to look for overall effects of cameras on DSR, we found average daily nest survival rates were significantly higher for nests with cameras than nests without cameras [$z(1, N = 134) = 3.47$; $p < 0.001$] (Table 36, Figure 44). Of the 134 total nests, 39 were plover nests (36 with cameras and 3 without) and 95 were tern nests (46 with cameras and 49 without). Fifty percent (18 of 36) of plover camera nests hatched compared to 33% (one of three) of non-camera plover nests. Seventy percent (32 of 46) of tern camera nests hatched compared to 53% (26 of 49) of non-camera tern nests. Average daily nest survival rates were significantly higher for nests with cameras than nests without cameras for plovers [$z(1, N = 21) = 2.38$; $p = 0.02$] and terns [$z(1, N = 95) = 2.94$; $p = 0.003$] (Table 36). For species-specific comparisons of DSR between plover nests with cameras and plover nests without cameras, only plover nests at Dyer and Kearney Broadfoot South were included because only these two sites had plover nests both with and without cameras. Only three plover nests without cameras were observed at Dyer (one nest) and Kearney Broadfoot South (two nests) and their survival variability created a 95% confidence interval wider than other species and camera status categories with more nests (Figure 45). Additionally, we suspected that the effect of the camera may be site-specific given the particular composition of the predator community at that site. This turned out not to be the case. The overall effect of cameras was significant [$z(11, N = 134) = 2.90$; $p = 0.004$] and was a positive effect on nest DSR at all sites, but the interaction between site and camera was not significant at any site, thus the positive effect of cameras was similar across sites (Table 36, Figure 46). Cottonwood Ranch [$z(11, N = 11) = 2.08$; $p = 0.04$] and Newark East [$z(11, N = 44) = 4.09$; $p < 0.001$] had higher overall survival (due to a significant site effect). Combined plover and tern average DSR for nests with and without cameras were lower in 2022 than during 2010-2016 (prior to using cameras to monitor nests) at Dyer, Newark West, Newark East, and Leaman, but average DSR for nests with cameras were at or above camera-absent nest survival rates at all sites in 2022 (Figure 47).

DISCUSSION

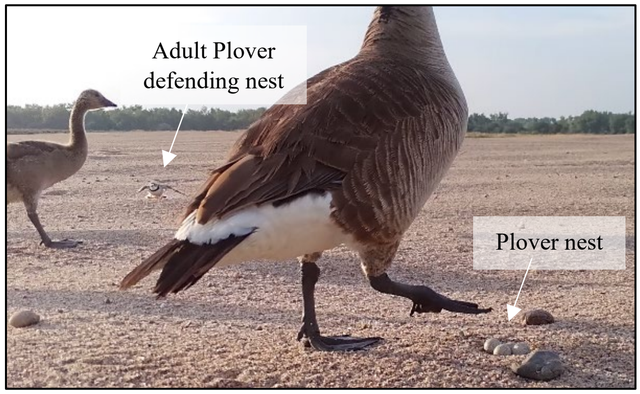
Great horned owl predating eggs.

The additional monitoring deployed on Program managed sites used a combination of trapping results, track surveys, and remote cameras to improve monitoring accuracy by providing more detailed nesting information, reduce unknown nest fates, and increase understanding of the impacts of predation on target species. Predator monitoring provided information about predator communities at each nesting site, identified predators responsible for nest predation, and provided data to quantify predator presence and evaluate effectiveness of predator management actions. No harm to or avoidance by our target species in the form of abnormal behavior or abrupt changes in nesting location were observed in response to the additional monitoring or management (Figures 30-32, 44).

Potential avian, mammalian, and reptilian predators were present across all levels of camera monitoring. However, presence of potential avian predators decreased from the outside of nesting peninsulas (i.e., the shoreline level) down to the nest level. Mammalian predators did not demonstrate the same pattern consistently across all levels or sites. Reptilian registers were less frequent; with turtles registered only at shorelines, whereas bullsnakes were registered at all levels from shorelines to the nest. Of the total 27 unique nest events in 2022 (including the two nest predation events not captured on camera), avian species were responsible for 44%, mammalian species for 41%, and reptilian species for 15%.

Trapping data showed raccoons were the most common mammalian predator trapped across all sites on the outside of nesting peninsulas. Dog proof traps were the most efficient trapping type to capture raccoons again in 2022 and should remain deployed across sites in the future. Cage traps were also effective at capturing raccoons and other species not captured by the dog proof traps. These two trap types have been paired at key locations to work together to capture a wider diversity of potential predators. These two trap types focus mainly on non-canid mesocarnivores. When canids and other species like badger are present at a site but not being caught by these paired traps (e.g., Blue Hole, Dyer, and Newark West), USDA/APHIS sets snares and leg/foot holds at targeted locations and in dig-outs under exterior exclusion fencing to increase the likelihood of capturing these species.

Track surveys together with shoreline cameras were helpful at showing which terrestrial species were able to cross water-filled moats and/or breach fences and help confirm the presence of potential avian predators at shorelines that are utilized by plovers for foraging. Even with predator barriers and deterrents in place, track surveys combined with shoreline cameras revealed that we had a diverse terrestrial and avian predator community present on the shoreline of nesting sites. Though not registered at high frequency, species like badger, bobcat (*Lynx rufus*), coyote (*Canis latrans*), mink (*Neovison vison*), opossum, red fox (*Vulpes vulpes*), river otter (*Lontra canadensis*), and striped skunk can predate multiple nests in a single night. Alternatively, raccoons were frequently registered across almost all sites by track surveys and shoreline cameras. Similar to beaver (*Castor canadensis*) that were registered frequently along shorelines at two sites, raccoon were not a common potential predator registered on site or nest-level cameras. This may be due to the tendency of both species to move and remain predominantly along the shoreline (as documented in track surveys). Softshell turtles and snapping turtles (*Chelydra serpentina*) were also detected only along shorelines in 2022. Canada goose and great blue heron were present at all sites along the shoreline and were the most frequently registered by shoreline cameras. Both avian species are unique because they rely more on terrestrial locomotion while on the nesting site than other avian species. Great blue heron is one potential predator suspected of having an impact on plover brood success because they are most common along shorelines where young plovers forage. Canada geese are present in large numbers and may dislocate and/or trample young plovers foraging along shorelines. Unlike the great blue heron, Canada goose were also documented (though infrequently) at the nest and may trample eggs in the nest bowl (see photo). Their presence on nesting peninsulas may be a source of stress to plover and tern adults, with nest defense behaviors (i.e., broken wing display for plovers and dive bombing for terns) documented on nest cameras. Data collected in 2022 once again emphasized the importance of utilizing both track surveys and shoreline cameras for complete documentation of shoreline potential predator communities.



Canada goose close to stepping on plover eggs.

Site-level cameras were more successful in 2022 at capturing potential terrestrial and avian predators than they were in 2021. Capture efficiencies of site-level cameras were higher in 2022 than in 2021 (PRRIP 2022a). Site-level cameras were positioned at a greater height than cameras at the shoreline and nest level to provide a higher and wider field of view (catching more potential avian predators) but reducing triggers from low to the ground terrestrial predators (Keldsen 2021a, b). However, this year we lowered the site level cameras to 4 ft to allow for better sampling of potential mammalian species while still being able to capture avian registers. Canada goose and great blue heron were the most frequently registered species at the site-level, though they are mainly terrestrial when locomoting over the nesting sites. After lowering the camera height, the number and diversity of mammalian species registered on site-level cameras improved in 2022. Site-level cameras captured six of ten species captured on nest cameras including birds, mammals, and a bullsnake.

Nest cameras showed us that great-horned owls and badgers were the greatest threats to nesting plovers and terns during the 2022 season. Nest cameras also provided important detail about great-horned owl and badger predatory behavior. When considering all camera-documented nest events, great-horned owls were the most common predator present at nests. They were documented predating seven individual nests in addition to being registered twice at nests without predating the nest. This is similar to what was observed for owls in 2021 (PRRIP 2022a). Using a potentially different predatory strategy, badgers predated eight individual nests but were not registered at any nest without predating it. Unlike 2021, great horned owls predated nests throughout incubation in 2022, consuming both eggs and chicks at the nest. The average nest incubation completed was 48% when great horned owls predated nests in 2022. Badgers consumed only eggs and average nest incubation was 41% completed prior to predation.

Images from nest cameras provided evidence to fate nests that were successful and to fate failed nests due to either predation, abandonment, or weather, reducing the number of failed unknown outcome fates compared to prior years of monitoring (PRRIP 2022a). Twenty-three percent of nests without cameras were fated as failed-unknown compared to 2% of nests with cameras due to the additional information that nest cameras provided. The nests with cameras that were fated as failed unknown were due to camera malfunction and the lack of evidence available for outside observers to determine the nest's true fate. Twenty percent of camera-monitored nests could be fated as failed due to predation compared to only 12% of nests without cameras. Abandonment of nests could only be determined for nests with cameras. The percentage of nests fated as failed due to weather was similar regardless of whether a camera was present or not, indicating categorizing nest failure due to weather is similar for both camera-monitored and non-camera nests.

Of nests with cameras deployed, 94% of the eggs laid and 96% of the chicks were fated. Nest cameras collected evidence to identify the predator responsible for 17 out of the 19 total nests predated. We were also able to determine the predators responsible for the two nest predations not documented on nest camera using the information provided by additional predator monitoring methods. Camera monitoring was especially beneficial in the case of avian predation, as several of these events lacked or had limited evidence seen or collected by outside observers, other than occasional opportunistic evidence. Prior to remote camera implementation less information was available on the timing of loss. In previous years, most notably in 2019, this lack of information resulted in the inability to fate nests as either failed or successful because loss occurred near the estimated hatch date, and it was unknown whether the nest had hatched or not prior to loss. Camera documented losses to predation in 2022 occurred throughout the incubation period as well as after hatching while both eggs and chicks were present at the nest. Based on our observations, losses incurred earlier in the season due to predation and weather in 2022 may have been replaced through renesting (Swift et al. 2020), thereby lessening the impact of early-season losses and improving end of the season fledge ratios.

The placement of remote cameras on nesting peninsulas did not reduce daily nest survival for plovers or terns at any of the six monitored sites. Daily nest survival rates for nests monitored with cameras were higher than nests without cameras for both plover and tern nests. There was also no site-specific effect of cameras on daily nest survival, thus there was no indication that predators at some sites were more likely to use cameras as a cue for nest predation when compared to other sites. Combined plover and tern average daily nest survival for both nests with and without cameras was lower for Dyer, Newark West, Newark East, and Leaman in 2022 when compared to the period from 2010-2016 prior to the use of cameras for monitoring predation. However, this was true for both nests with and without cameras, and nests with cameras had higher daily nest survival. We have no indication from analysis of nest survival that the use of remote cameras to identify potential predators and predation events at plover and tern nests negatively impacts nest success; however, the presence of cameras at nests provides reliable information to reduce uncertainties about losses to plover productivity. Semi-weekly monitoring from outside the nesting peninsula did not document any avoidance of cameras either in terms of behavior or nesting location. Observations from nest cameras did not indicate abnormal nesting behavior by either plovers or terns. No camera-monitored nests were abandoned following camera placement.

Effectiveness of Additional Management and Monitoring

Three lines of evidence are being gathered to evaluate the effectiveness of additional predator management: 1) predator presence on nesting peninsulas and, more specifically, at the nest; 2) losses to predation; and 3) productivity of plovers and terns. If management is effective at reducing predator presence, we would expect predator presence to decrease from the outside of nesting peninsulas to inside nesting areas and at individual nests as potential predators encounter barriers such as traps, water-filled moats, fences, and deterrent lighting. Potential avian, mammalian, and reptilian predators were present across all levels of monitoring. For potential avian predators, the number of registers/camera day decreased moving from shorelines to the interior of the nesting peninsula (site-level), and further decreased at the nest-level for both status quo and additional management sites. For mammalian predators, this pattern was not consistently observed. For most sites mammalian predators were registered less frequently at the nest than they were along shorelines, but there was not a consistent reduction in registers/unit effort from shoreline to site to nest-level across all sites. Though reducing the height of site-level cameras improved detection of terrestrial predators in 2022, those cameras may still underestimate their presence. Current predator management does not address access to nesting sites by snakes, and bullsnakes were registered across all levels this year, including the predation of one nest.

If additional predator management is effective, we also expect the reduction in predator presence to be greater at sites with additional management. The frequency of trapping, tracks, shoreline, site-level, and nest-level registers (each normalized for effort) varied among sites, but the variability was evenly distributed among sites with additional versus status quo management. Thus, potential predators were documented on average at a similar frequency at additional management and status quo sites. But examining results from individual sites provides site-specific information on the effectiveness of additional management implemented at that site. At Kearney Broadfoot South, track surveys and shoreline cameras registered predators frequently along interior shorelines outside the predator exclosure fence that surrounds the peninsula, but the frequency of registers decreased inside the nesting peninsula at the site-level and even further at the nest level. This was true for both birds and mammals for which the exclosure fencing and lighting implemented there were intended to deter. There was no documented nest predation (no failed-predated nests) at Kearney Broadfoot South in 2022. The story was different for Newark West with an exclosure fence outside the water-filled moat and deterrent lighting on the nesting peninsula. Though the number of predator registers outside the nesting peninsula and along shorelines were similar to other sites, the number of mammalian and reptilian registers did not decrease moving into the nest-level. Newark West lost a total of nine nests to predation this year. For the eight nests with cameras, we know that five nests were lost to great horned owl, two to striped skunk, and one to a bullsnake this year. At Leaman, where deterrent lighting specifically implemented to reduce presence of potential avian predators was implemented, potential avian predators were registered frequently on nesting shorelines and at the site-level. This site has consistently documented great blue heron, Canada goose, and great horned owl presence. This year was no exception. However, with all nests lost early in the season to weather, nest cameras were deployed for a limited amount of time and no information on potential predators or predation at the nest was provided by this site in 2022. At Dyer, a status quo site, a total of 12 nests were fated as failed due to predation this year. The number of avian predators registered per unit effort decreased from the outside to the inside of the nesting site, but predation by great horned owl still took two nests this year. Registers of mammalian predators remained high from the shoreline to the nest resulting in the predation of eight nests by a badger this year at Dyer. Cottonwood Ranch and Newark East had more registers per unit effort along the shorelines of nesting sites than at nests themselves across all taxa. Cottonwood Ranch lost no nests to predation in 2022, whereas Newark East lost one nest to an opossum this year.

When looking specifically at nest events (nest presence and nest predation) for all three potential predator species types (i.e., avian, mammalian, and reptilian) per total unit effort, more occurred at status quo sites than at sites that received additional management. Specifically, 63% of the 27 unique nest events (registers with and without predation) documented in 2022 occurred at status quo sites compared to 37% at additional management sites. The result was the same for both avian and mammalian predator presence at the nest. Of the 12 nest events involving potential avian predators, 58% occurred at status quo sites and 42% occurred at additional management sites. Of the 11 nest events involving potential mammalian predators, 64% occurred at status quo sites compared to 36% at additional management sites. The four nest events involving potential reptilian predator species were evenly split between status quo sites (50%) and sites that received additional management (50%). At a finer scale, looking only at the 15 documented nest predation events, eight (53%) occurred at status quo sites and seven (47%) occurred at sites with additional management, resulting in 11 (58%) individual nests predated at status quo sites versus eight (42%) nests at sites with additional management. Though differences are small, this may be an indication that additional predator management and deterrents deployed on additional management sites may be effective at reducing potential avian and mammalian presence at the nest level and reducing the number of nests lost to predation over time.

If additional predator management is effective at reducing the number of losses to predation, we should see improvements in productivity at sites where additional management has been implemented. All other things being equal, sites with additional predator management would be expected to have higher fledge ratios than sites with status quo management. This was not the case for either plovers or terns during 2022. Though Kearney Broadfoot South did well this year with a fledge ratio of 1.14 fledges/breeding pair for plovers and 1.58 fledges/breeding pair for terns, losses of all nests to weather at Leaman this year and the loss of nine nests and one brood to predation at Newark West (in addition to the loss of three nests and one brood to other causes) resulted in zero plover fledges and only five tern fledges for a fledge ratio of 0.83 for terns at Newark West in 2022. Thus, additional management sites (0.38 plover and 0.80 tern fledges/breeding pair) did not have higher fledge ratios overall than status quo sites (1.57 plover and 1.27 tern fledges/breeding pair) in 2022. Differences in habitat characteristics and quality, location, and disturbance among sites may have contributed to these differences in fledge ratios beyond predator management actions alone.

Given that productivity is highly variable across sites, perhaps a better comparison would be to look at how fledge ratios have changed since additional management has been implemented within a site. Systematic implementation of additional predator management on a full-scale began only in 2021. At Kearney Broadfoot South we implemented a predator exclosure fence around the entire nesting peninsula along the interior shoreline. That fence received walking lights on the exclosure fence posts surrounding the entire site. In addition, three paired sets of predator deterrent lights were placed in nesting areas. Thus, this site received both fencing and lighting in an attempt to reduce predation. The average plover fledge ratio at Kearney Broadfoot South has increased from 0.43 plover fledges/breeding pair (range 0 – 1.0) from 2010-2020 to 0.70 fledges/breeding pair (range 0.25 – 1.14) in 2021-2022. For terns, the fledge ratio at this site has increased from an average of 0.90 fledges/breeding pair (range 0.33 – 1.5) from 2010-2020 to 0.98 fledges/breeding pair (range 0.38 – 1.58) in 2021-2022. At Newark West, where an exclosure fence further outside the nesting area was maintained in addition to three sets of predator deterrent lights within the nesting area, fledge ratios have not improved over pre-implementation averages, though 2021 demonstrated a much better outcome for both plovers and terns at this site than that observed in 2022. Leaman has not fledged any plover or tern chicks since 2016. Though predation by great horned owl was the documented culprit in 2021, weather destroyed all nests at Leaman in 2022.

Variability in productivity over time and across sites makes the evaluation of effectiveness of management less straightforward. A good way to take pre-existing background variability among sites through time into account is to utilize a before-after-control-impact treatment design (Conner et al. 2016). This design is especially useful when the number of sites for comparison is limited and control sites cannot be randomly assigned. Rather than comparing directly between additional management and status quo sites, it may be more informative to divide productivity observed at additional management sites by the productivity observed at status quo sites each season. This approach takes advantage of the long-term dataset the Program has gathered on productivity at these sites to calculate the ratio between productivity at additional management and status quo sites each season prior to the implementation of additional management and after its implementation. This allows incorporating existing differences in productivity among these sites prior to implementation of additional management (background variability). An increase in this ratio following implementation would be one line of evidence supporting the effectiveness of additional management for improving productivity. Moving forward the Program will continue to implement additional predator management and monitoring to gather the information needed on predator presence at nesting sites and their impact on plover and tern productivity to evaluate the effectiveness of predator management over time.

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
- Predator Monitoring and Management

Prior to Program implementation (2001- 2007) reports produced by West Incorporated 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 (2008-2020), 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 in Table 37.

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TABLES

Table 1. Summary of historic piping plover reproductive success at OCSW and river-island sites on the central Platte River in Nebraska, 2001–2009. This table encompasses data that were collected under different monitoring protocols than from 2010 on, making these data more difficult to directly compare to those after 2009. Changes include fledge age increasing from 15 days to 28 days, an increase in monitoring effort, and additions of more off-channel sites beginning in 2010.

	Piping Plover								
Reproductive Parameter	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Max Adult Counts	25	40	34	51	48	47	66	45	47
Peak Breeding Pair Estimate (BPE)	10	13	14	11	14	13	16	13	12
Total Nests Observed	11	15	15	13	20	15	20	18	14
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
Broods Observed	9	13	13	9	15	11	15	8	9
Chicks Observed (<15D)	30	28	43	34	46	37	45	26	30
Hatch Ratio (<15D Chicks/Nest)	2.73	1.87	2.87	2.62	2.30	2.47	2.25	1.44	2.14
Hatch Ratio (<15D Chicks/BPE)	3.00	2.15	3.07	3.09	3.29	2.85	2.81	2.00	2.50
Chicks (≥15D)	25	28	22	23	28	29	27	10	12
Fledglings (28D)	---	---	---	---	---	---	---	---	---
Historic Fledge Ratio (≥15D Chicks/Nest)	2.27	1.87	1.47	1.77	1.40	1.93	1.35	0.56	0.86
Fledge ratio (28D Chicks/Nest)	---	---	---	---	---	---	---	---	---
Historic Fledge Ratio (≥15D Chicks/BPE)	2.50	2.15	1.57	2.09	2.00	2.23	1.69	0.77	1.00
Fledge Ratio (28D Chicks/BPE)	---	---	---	---	---	---	---	---	---
Daily Brood Survival Rate	---	---	---	---	---	---	---	0.94	0.98
Brooding-period Survival Rate	---	---	---	---	---	---	---	0.42	0.79

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

Table 2. Summary of piping plover reproductive success at OCSW and river island sites along the central Platte River in Nebraska, 2010–2022. This table encompasses data that were collected under different monitoring protocols than prior to 2010, making these data more difficult to directly compare to those collected prior to 2010. Changes include fledge age increasing from 15 days to 28 days, an increase in monitoring effort, and additions of more off-channel sites beginning in 2010.

	Piping Plover												
Reproductive Parameter	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Max Adult Counts	96	71	73	94	108	99	108	77	74	88	71	67	74
Peak Breeding Pair Estimate (BPE)	20	28	30	27	30	40	43	40	37	45	32	36	38
Total Nests Observed	35	34	46	31	43	54	60	50	47	60	49	50	55
Successful Nests (≥1 egg hatched)	21	27	32	23	34	34	40	30	35	31	28	30	30
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
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
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
Broods Observed	21	27	32	23	34	34	40	30	35	31	28	30	30
Chicks Observed (<15D)	76	88	99	80	116	119	120	92	95	94	98	99	100
Hatch Ratio (<15D 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
Hatch Ratio (<15D 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
Chicks (≥15D)	50	61	68	43	67	73	70	53	36	42	52	45	65
Fledglings (28D)	41	46	59	28	55	52	55	47	23	30	39	35	52
Historic Fledge Ratio (≥15D 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
Fledge ratio (28D 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
Historic Fledge Ratio (≥15D 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
Fledge Ratio (28D 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
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
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

Table 3. Site-specific numbers of adults, nests, chicks, and fledglings observed while monitoring OCSW nesting sites for piping plover reproduction during 2022. Chick and fledgling counts represent numbers documented from each site. See the Management Section of this report for a detailed description of management actions taken at each site. Site numbers correspond with Figure 5.

Site				Piping Plover										
Site Name/#	**Mgmt[A]**	**Surveys**	**Hours of Observation**	**Peak BPE (AHR peak date[B])**	**Peak BPE (Site peak date[C])**	**Adult Counts**	**Nests**	**Nests Hatched**	**Chicks 0-14 days**	**Chicks 15-28 days**	**Fledglings**	**Apparent Nest Success**	**Fledge Ratio (AHR peak date[B])**	**Fledge Ratio (Site peak date[C])**
1. OSG Lexington	FHMPT	32	40	3	3	6	3	3	11	6	4	1.00	1.33	1.33
2. NPPD Lexington	FPT	31	45	4	5	9	7	3	9	4	0	0.43	0.00	0.00
3. Dyer	FHPT	32	34	7	7	12	11	7	22	18	14	0.64	2.00	2.00
4. Cottonwood Ranch	FHPT	24	30	1	1	2	1	1	2	1	1	1.00	1.00	1.00
5. T&F Lakeside	N	7	3	0	0	0	0	0	0	0	0	---[D]	---[D]	---[D]
6. Blue Hole	PT	34	55	3	4	8	5	4	13	11	12	0.80	4.00	3.00
7. Johnson	FP	5	3	0	0	0	0	0	0	0	0	---	---	---
8. Ed Broadfoot and Sons	N	28	16	0	0	0	0	0	0	0	0	---	---	---
9. Kearney Broadfoot South	FHILMPT	35	27	7	7	10	10	5	19	9	8	0.50	1.14	1.14
10. NAI Kearney Broadfoot South	T	28	16	0	0	1	0	0	0	0	0	---	---	---
11. Newark West	EFHLPT	30	17	4	4	6	8	1	3	0	0	0.13	0.00	0.00
12. Newark East	FHPT	35	23	7	7	13	7	5	20	15	12	0.71	1.71	1.71
13. Leaman	FHLPT	27	14	1	1	5	2	0	0	0	0	0.00	0.00	0.00
14. Trust Wildrose East	D	7	4	0	0	0	0	0	0	0	0	---	---	---
15. Follmer	HPT	7	4	0	0	0	0	0	0	0	0	---	---	---
16. DeWeese	N	7	4	0	0	0	0	0	0	0	0	---	---	---
17. Hooker Brothers Southeast	N	25	14	1	1	2	1	1	1	1	1	1.00	1.00	1.00
18. Hooker Brothers East	N	7	4	0	0	0	0	0	0	0	0	---	---	---

[A] Mgmt—management actions applied to each site: disking (D), exterior predator fencing (E), peninsula entry predator fencing (F), fall 2021 herbicide (H), interior predator fencing (I), predator deterrent lights (L), mechanical dirt work (M), no management (N), spring 2022 pre-emergent herbicide (P), or predator trapping (T).

[B] AHR Peak Breeding Pair counts represent the estimated number of breeding pairs (BPE) at each site as calculated using the Program's BPE calculator (pg. 20 of this report) on 7 June for piping plovers, when numbers of breeding pairs observed within the entire Program Associated Habitat Reach first peaked. AHR Peak Breeding Pair counts do not necessarily represent the highest estimate of piping plover breeding pairs observed at any site throughout the year as some adults are known to have re-nested at different sites after losing their first nest or brood.

[C] Site Peak Breeding Pairs 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. 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, 2001–2022.

Year	Piping Plover Off-Channel Peak BPE[A]	Nests	Successful Nests	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
Mean	**24.77**	**32.68**	**21.55**	**33.59**	**1.49**

[A] BPE represents the peak off-channel. Peaks dates differ on- vs. off-channel, due to this the sum of these may not match the AHR peak.

[B] The dotted black line represents a change in protocol. 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 interval.

Table 5. Estimated number of breeding pairs (BPE), number of nests and successful nests, and productivity by year for piping plovers at on-channel sites along the central Platte River in Nebraska, 2001–2022.

Year	Piping Plover				
	On-Channel Peak BPE[A]	Nests	Successful Nests	Fledglings[B]	Fledglings Per Peak BPE[ABC]
2001	0	0	0	0	---
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	---
Mean	**1.09**	**1.64**	**1.18**	**1.41**	**1.55**

[A] BPE represents the peak on-channel. Peaks dates differ on- vs. off-channel, due to this the sum of these may not match the AHR peak.
[B] The dotted black line represents a change in protocol. 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 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 breeding pairs (BPE), nests, chicks, and fledglings documented from outside the nesting area during semi-monthly OCSW site surveys in 2022.

Survey	Piping Plover				
	Adults	BPE[A]	Nests	Chicks	Fledglings
1-May	24	1	1	0	0
15-May	34	21	16	0	0
1-Jun	42	32	22	1	0
15-Jun	45	33	12	36	0
1-Jul	39	33	7	35	5
15-Jul	21	18	2	29	1
1-Aug	6	7	0	8	3

[A] BPE represents the number of breeding pairs present on OCSW and river islands on 1 and 15 May, June, and July, and 1 August. Breeding pair counts were obtained using the Program's BPE calculator (pg. 20). Quantities 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 breeding pairs (BPE), nests, chicks, and fledglings observed during semi-monthly airboat surveys of the Platte River between Lexington and Chapman, Nebraska, in 2022.

Survey	Piping Plover				
	Adults	BPE[A]	Nests	Chicks	Fledglings
1-May	4	0	0	0	0
15-May[B]	1	0	0	0	0
1-Jun	2	0	0	0	0
15-Jun	6	0	0	0	0
1-Jul	10	0	0	0	0
15-Jul[B]	6	0	0	0	1
1-Aug[B]	2	0	0	0	0

[A] BPE represents the number of breeding pairs present on OCSW and river islands on 1 and 15 May, June, and July, and 1 August. Breeding pair counts were obtained using the Program's BPE calculator (pg. 20). Quantities 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 limited monitoring accessibility and habitat availability for terns and plovers.

Table 8. Daily and incubation-period survival rates (RMark estimates), standard errors (SE), and 95% confidence intervals (CI) for piping plover nests monitored on OCSW sites during 2022. Incubation-period nest survival rate = daily nest survival rate[28].

Site	Mgmt[A]	# Nests	# Nests Lost	Exposure Days	Daily Nest Survival Rate	Daily Nest Survival SE	Daily Nest Survival Rate 95% CI		Incubation Period Survival Rate	Incubation Period Survival Rate 95% CI	
							Lower	Upper		Lower	Upper
OSG Lexington	FHMPT	3	0	62	1	0	1	1	1	1	1
NPPD Lexington	FPT	7	4	122	0.9677	0.0159	0.9172	0.9878	0.3991	0.0888	0.7099
Dyer	FHPT	11	4	177	0.9776	0.0111	0.9420	0.9916	0.5310	0.1875	0.7893
Cottonwood Ranch	FHPT	1	0	16	1	0	0.9999	1	1	0.9985	1
Blue Hole	PT	5	1	62	0.9840	0.0159	0.8950	0.9978	0.6365	0.0447	0.9389
Kearney Broadfoot South	FHILMPT	10	5	173	0.9715	0.0126	0.9333	0.9881	0.4450	0.1449	0.7150
Newark West	EFHLPT	8	7	84	0.9195	0.0293	0.8403	0.9612	0.0953	0.0076	0.3305
Newark East	FHPT	7	1	165.5	0.9940	0.0060	0.9585	0.9992	0.8444	0.3053	0.9765
Leaman	FHLPT	2	2	31	0.9372	0.0431	0.7803	0.9843	0.1626	0.0010	0.6419
Hooker Brothers Southeast	N	1	0	23	1	0	0	1	1	0	1
All Sites		**55**	**24**	**915.5**	**0.9741**	**0.0052**	**0.9617**	**0.9826**	**0.4798**	**0.3347**	**0.6115**

[A] Mgmt—management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2020 herbicide (H), interior predator fencing (I), predator deterrent lights (L), mechanical dirt work (M), no management (N), spring 2021 pre-emergent herbicide (P), or predator trapping (T).

Table 9. Daily and incubation-period survival rates (RMark estimates), standard errors (SE), and 95% confidence intervals (CI) for piping plover nests monitored on Program and non-Program OCSW sites during 2022. Incubation-period nest survival rate = daily nest survival rate[28].

Site	# Nests	# Nests Lost	Exposure Days	Daily Nest Survival Rate	Daily Nest Survival SE	Daily Nest Survival Rate 95% CI		Incubation Period Survival Rate	Incubation Period Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Program[A]	42	19	708.5	0.9735	0.0060	0.9589	0.9831	0.4717	0.3084	0.6196
Non-Program[B]	13	5	207	0.9761	0.0106	0.9439	0.9900	0.5083	0.1987	0.7554
All Sites	**55**	**24**	**915.5**	**0.9741**	**0.0052**	**0.9617**	**0.9826**	**0.4798**	**0.3347**	**0.6115**

[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 Hooker Brothers Southeast.

Table 10. Daily and brooding-period survival rates (RMark estimates), standard errors (SE), and 95% confidence intervals (CI) for observed piping plover broods (≥1 chicks) on OCSW sites during 2022. Brooding-period survival rate = daily brood survival rate[28].

Site	Mgmt[A]	# Broods	# Broods Lost	Exposure Days	Daily Brood Survival Rate[B]	Daily Brood Survival SE	Daily Brood Survival Rate 95% CI		Brooding Period Survival Rate	Brooding Period Survival Rate 95% CI	
							Lower	Upper		Lower	Upper
OSG Lexington	FHMPT	3	0	83	1	0	1	1	1	1	1
NPPD Lexington	FPT	3	3	40	0.9275	0.0404	0.7977	0.9765	0.1216	0.0018	0.5134
Dyer	FHPT	7	0	192	1	0	1	1	1	1	1
Cottonwood Ranch	FHPT	1	0	28	1	0	1	1	1	1	1
Blue Hole	PT	4	0	92	1	0	1	1	1	1	1
Kearney Broadfoot South	FHILMPT	5	2	104.5	0.9810	0.0133	0.9273	0.9953	0.5850	0.1210	0.8753
Newark West	EFHLPT	1	1	1	0	0	0	0	0	0	0
Newark East	FHPT	5	0	132	1	0	1	1	1	1	1
Hooker Brothers Southeast	N	1	0	27	1	0	1	1	1	1	1
All Sites		**30**	**6**	**699.5**	**0.9915**	**0.0035**	**0.9811**	**0.9962**	**0.7865**	**0.5864**	**0.8978**

[A] Mgmt—management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2020 herbicide (H), interior predator fencing (I), predator deterrent lights (L), mechanical dirt work (M), no management (N), spring 2021 pre-emergent herbicide (P), or predator trapping (T).
[B] The site-specific model (AICc = 48.8661) was a better model to predict daily survival rates than the null model (AICc = 58.9719).

Table 11. Daily and brooding-period survival rates (RMark estimates), standard errors (SE), and 95% confidence intervals (CI) for piping plover broods (1 or more chicks) on Program and non-Program sites during 2022. Brooding-period survival rate = daily brood survival rate[28].

Site	# Broods	# Broods Lost	Exposure Days	Daily Brood Survival Rate	Daily Brood Survival SE	Daily Brood Survival Rate 95% CI		Brooding Period Survival Rate	Brooding Period Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Program[A]	22	3	540.5	0.9945	0.0032	0.9830	0.9982	0.8561	0.6184	0.9512
Non-Program[B]	8	3	159	0.9813	0.0107	0.9437	0.9940	0.5895	0.1971	0.8439
All Sites	**30**	**6**	**699.5**	**0.9915**	**0.0035**	**0.9811**	**0.9962**	**0.7865**	**0.5864**	**0.8978**

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

Table 12. Piping plover incidental take under five take categories as specified by USFWS 2006 and USFWS 2018.

		Allowable Take[A]	First Increment													Extension		
			2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
		Inundating Flow																
		Inland Lakes																1[B]
		Habitat Restoration and Land Manag.								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%
		Cottonwood Ranch								50%								
		Blue Hole	17%		20%					13%		38%	8%	25%		14%	43%	20%
		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%
		Leaman														50%	100%	
		Trust Wildrose East										25%		50%				
		Hooker Brothers Southeast																
	Chicks	OSG Lexington																
		NPPD Lexington														20%		
		Dyer								33%								
		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																

Table Color Code:

No data available
Below established limit for allowable take for a given year. Shaded cells without values had no documented take.
Exceeded the established limit for allowable take for a given year.

[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 06/05/2022 (see pg 25 in text for details on reasonable and prudent measures).
[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 3 of 5 years for sites that average at least 3 plover nests).

Table 13. Summary of historic least tern reproductive success at OCSW and river-island sites on the central Platte River in Nebraska, 2001–2009. This table encompasses data that were collected under different monitoring protocols than from 2010 on, making these data more difficult to directly compare to those after 2009. Changes include fledge age increasing from 15 days to 21 days, an increase in monitoring effort, and additions of more off-channel sites beginning in 2010.

	Least Tern								
Reproductive Parameter	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Max Adult Counts	45	117	105	133	184	122	133	145	114
Peak Breeding Pair Estimate (BPE)	22	33	38	39	45	33	38	36	42
Total Nests Observed	27	39	49	48	56	49	49	55	54
Successful Nests (≥1 egg hatched)	20	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]
Broods Observed	20	27	31	33	38	19	22	29	29
Chicks Observed (<15D)	42	65	62	72	73	38	49	59	68
Hatch Ratio (<15D Chicks/Nest)	1.56	1.67	1.27	1.50	1.30	0.78	1.00	1.07	1.26
Hatch Ratio (<15D Chicks/BPE)	1.91	1.97	1.63	1.85	1.62	1.15	1.29	1.64	1.62
Chicks (≥15D)	45	59	57	60	62	25	40	44	46
Fledglings (21D)	---[B]	---	---	---	---	---	---	---	---
Historic Fledge Ratio (≥15D Chicks/Nest)	1.67	1.51	1.16	1.25	1.11	0.51	0.82	0.80	0.85
Fledge ratio (21D Chicks/Nest)	---	---	---	---	---	---	---	---	---
Historic Fledge Ratio (≥15D Chicks/BPE)	2.05	1.79	1.50	1.54	1.38	0.76	1.05	1.22	1.10
Fledge Ratio (21D 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 success at OCSW and river-island sites on the central Platte River in Nebraska, 2010–2022. This table encompasses data that were collected under different monitoring protocols than prior to 2010, making these data more difficult to directly compare to those collected prior to 2010. Changes include fledge age increasing from 15 days to 28 days, an increase in monitoring effort, and additions of more off-channel sites beginning in 2010.

	Least Tern												
Reproductive Parameter	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Max Adult Counts	170	150	137	197	260	262	200	159	174	169	158	166	188
Peak Breeding Pair Estimate (BPE)	53	62	66	65	94	141	88	77	88	95	84	84	85
Total Nests Observed	76	90	88	96	146	187	122	118	112	132	105	99	128
Successful Nests (≥1 egg hatched)	48	52	63	51	82	116	77	63	79	67	74	64	86
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
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
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
Broods Observed	48	52	63	51	82	116	77	63	79	67	74	64	86
Chicks Observed (<15D)	122	125	144	118	180	258	170	129	168	137	160	158	196
Hatch Ratio (<15D 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
Hatch Ratio (<15D 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
Chicks (≥15D)	76	101	95	70	104	158	91	78	117	74	107	100	141
Fledglings (21D)	75	96	84	64	91	146	80	76	117	71	107	102	143
Historic Fledge Ratio (≥15D 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
Fledge ratio (21D 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
Historic Fledge Ratio (≥15D 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
Fledge Ratio (21D 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
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
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

Table 15. Site-specific numbers of adults, nests, chicks, and fledglings observed while monitoring OCSW nesting sites for least tern reproduction during 2022. Chick and fledgling counts represent numbers observed from each site. See the Management Section of this report for a detailed description of management actions taken at each site. Site numbers correspond with Figure 5.

Site				Least Tern										
Site Name/#	**Mgmt[A]**	**Surveys**	**Hours of Observation**	**Peak BPE (AHR peak date[B])**	**Peak BPE (Site peak date[C])**	**Adult Counts**	**Nests**	**Nests Hatched**	**Chicks 0-14 days**	**Chicks 15-21 days**	**Fledglings**	**Apparent Nest Success**	**Fledge Ratio (AHR peak date[B])**	**Fledge Ratio (Site peak date[C])**
1. OSG Lexington	FHMPT	32	40	8	9	18	9	8	23	19	19	0.89	2.38	2.11
2. NPPD Lexington	FPT	31	45	0	2	12	2	0	0	0	0	0.00	---[D]	0.00
3. Dyer	FHPT	32	34	6	9	25	16	6	11	5	5	0.38	0.83	0.56
4. Cottonwood Ranch	FHPT	24	30	8	10	18	10	8	20	17	17	0.80	2.13	1.70
5. T&F Lakeside	N	7	3	0	0	0	0	0	0	0	0	---[D]	---	---[D]
6. Blue Hole	PT	34	55	12	12	20	13	12	30	26	26	0.92	2.17	2.17
7. Johnson	FP	5	3	0	0	2	0	0	0	0	0	---	---	---
8. Ed Broadfoot and Sons	N	28	16	0	0	0	0	0	0	0	0	---	---	---
9. Kearney Broadfoot South	FHILMPT	35	27	12	12	17	17	11	24	17	19	0.65	1.58	1.58
10. NAI Kearney Broadfoot South	T	28	16	0	0	0	0	0	0	0	0	---	---	---
11. Newark West	EFHLPT	30	17	4	6	14	9	4	8	5	5	0.44	1.25	0.83
12. Newark East	FHPT	35	23	26	27	36	37	29	64	42	42	0.78	1.62	1.56
13. Leaman	FHLPT	27	14	0	6	12	6	0	0	0	0	0.00	---	0.00
14. Trust Wildrose East	D	7	4	0	0	0	0	0	0	0	0	---	---	---
15. Follmer	HPT	7	4	0	0	0	0	0	0	0	0	---	---	--
16. DeWeese	N	7	4	0	0	0	0	0	0	0	0	---	---	---
17. Hooker Brothers Southeast	N	25	14	9	9	14	9	8	16	10	10	0.89	1.11	1.11
18. Hooker Brothers East	N	7	4	0	0	0	0	0	0	0	0	---	---	---

[A] Mgmt—management actions applied to each site: disking (D), exterior predator fencing (E), peninsula entry predator fencing (F), fall 2021 herbicide (H), interior predator fencing (I), predator deterrent lights (L), mechanical dirt work (M), no management (N), spring 2022 pre-emergent herbicide (P), or predator trapping (T).

[B] AHR Peak Breeding Pair counts represent the estimated number of breeding pairs at each site as calculated using the Program's BPE calculator (pg. 20 of this report) on 2 July for least terns, when numbers of breeding pairs observed within the entire Program Associated Habitat Reach first peaked. AHR Peak Breeding Pair counts do not necessarily represent the highest estimate of least tern breeding pairs observed at any site throughout the year as some adults are known to have re-nested at different sites after losing their first nest or brood.

[C] Site Peak Breeding Pairs 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. Estimated number of breeding pairs (BPE), number of nests and successful nests, and productivity by year for least terns at OCSW sites along the central Platte River in Nebraska, 2001–2022.

Year	Least Tern				
	Off-Channel Peak BPE[A]	Nests	Successful Nests	Fledglings[B]	Fledglings 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
Mean	**62.55**	**84.68**	**52.23**	**76.14**	**1.28**

[A] BPE represents the peak on-channel. Peaks dates differ on- vs. off-channel, due to this the sum of these may not match the AHR peak.

[B] The dotted black line represents a change in protocol. 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 interval.

Table 17. Estimated number of breeding pairs (BPE), number of nests and successful nests, and productivity by year for least terns at on-channel sites along the central Platte River in Nebraska, 2001–2022.

Year	Least Tern				
	On-Channel Peak BPE[A]	Nests	Successful Nests	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	---
Mean	**1.77**	**2.68**	**0.82**	**0.68**	**0.29**

[A] BPE represents the peak on-channel. Peaks dates differ on- vs. off-channel, due to this the sum of these may not match the AHR peak.

[B] The dotted black line represents a change in protocol. 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 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 breeding pairs (BPE), nests, chicks, and fledglings documented from outside the nesting area during semi-monthly OCSW site surveys in 2022.

	Least Tern				
Survey	**Adults**	**BPE[A]**	**Nests**	**Chicks**	**Fledglings**
1-May	0	0	0	0	0
15-May	39	0	4	0	0
1-Jun	105	50	42	0	0
15-Jun	93	72	48	13	0
1-Jul	98	83	29	46	5
15-Jul	88	85	8	49	44
1-Aug	33	76	1	31	7

[A] BPE represents the number of breeding pairs present on sandpits and river islands on 1 and 15 May, June, and July, and 1 August. Breeding pair counts were obtained using the Program's BPE calculator (pg. 20). Quantities 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 breeding pairs (BPE), nests, chicks, and fledglings observed during semi-monthly airboat surveys of the Platte River between Lexington and Chapman, Nebraska in 2022.

	Least Tern				
Survey	**Adults**	**BPE[A]**	**Nests**	**Chicks**	**Fledglings**
1-May	0	0	0	0	0
15-May[B]	21	0	0	0	0
1-Jun	28	0	0	0	0
15-Jun	25	0	0	0	0
1-Jul	17	0	0	0	0
15-Jul[B]	22	0	0	0	6
1-Aug[B]	21	0	0	0	10

[A] BPE represents the number of breeding pairs present on OCSW sites and river islands on 1 and 15 May, June, and July, and 1 August. Breeding pair counts were obtained using the Program's BPE calculator (pg. 20). Quantities 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 limited monitoring accessibility and habitat availability for terns and plovers.

Table 20. Daily and incubation-period survival rates (RMark estimates), standard errors (SE), and 95% confidence intervals (CI) for least tern nests monitored on OCSW sites during 2022. Incubation-period nest survival rate = daily nest survival rate[21].

Site	Mgmt[A]	# Nests	# Nests Lost	Exposure Days	Daily Nest Survival Rate[B]	Daily Nest Survival SE	Daily Nest Survival Rate 95% CI		Incubation Period Survival Rate	Incubation Period Survival Rate 95% CI	
							Lower	Upper		Lower	Upper
OSG Lexington	FHMPT	9	1	164.5	0.9939	0.0060	0.9583	0.9991	0.8801	0.4085	0.9822
NPPD Lexington	FPT	2	2	21	0.9086	0.0618	0.6980	0.9771	0.1335	0.0005	0.6151
Dyer	FHPT	16	10	141.5	0.9314	0.0210	0.8770	0.9628	0.2249	0.0636	0.4507
Cottonwood Ranch	FHPT	10	2	179	0.9889	0.0078	0.9567	0.9972	0.7908	0.3945	0.9432
Blue Hole	PT	13	1	227.5	0.9956	0.0044	0.9695	0.9994	0.9118	0.5223	0.9871
Kearney Broadfoot South	FHILMPT	17	6	255.5	0.9768	0.0094	0.9493	0.9895	0.6105	0.3351	0.8017
Newark West	EFHLPT	9	5	132.5	0.9629	0.0163	0.9139	0.9845	0.4522	0.1511	0.7202
Newark East	FHPT	37	8	682	0.9883	0.0041	0.9769	0.9942	0.7816	0.6115	0.8842
Leaman	FHLPT	6	6	30	0.8106	0.0712	0.6329	0.9140	0.0122	0.0001	0.1514
Hooker Brothers Southeast	N	9	1	174.5	0.9943	0.0057	0.9606	0.9992	0.8866	0.4298	0.9832
All Sites		**128**	**42**	**2008**	**0.9793**	**0.0032**	**0.9721**	**0.9847**	**0.6444**	**0.5519**	**0.7228**

[A] Management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2020 herbicide (H), interior predator fencing (I), predator deterrent lights (L), mechanical dirt work (M), no management (N), spring 2021 pre-emergent herbicide (P), or predator trapping (T).
[B] The site-specific model (AICc = 289.1261) was a better model to predict daily survival rates than the null model (AICc = 316.2179).

Table 21. Daily and incubation-period survival rates (RMark estimates), standard errors (SE), and 95% confidence intervals (CI) for least tern nests monitored on Program and non-Program sites during 2022. Incubation-period nest survival rate = daily nest survival rate[21].

Site	# Nests	# Nests Lost	Exposure Days	Daily Nest Survival Rate[C]	Daily Nest Survival SE	Daily Nest Survival Rate 95% CI		Incubation Period Survival Rate	Incubation Period Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Program[A]	104	38	1585	0.9763	0.0038	0.9676	0.9827	0.6042	0.5006	0.6933
Non-Program[B]	24	4	423	0.9906	0.0047	0.9752	0.9965	0.8199	0.5901	0.9283
All Sites	**128**	**42**	**2008**	**0.9793**	**0.0032**	**0.9721**	**0.9847**	**0.6444**	**0.5519**	**0.7228**

[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 Hooker Brothers Southeast.
[C] The ownership model (AICc = 314.1962) was a better model to predict daily survival rates than the null model (AICc = 316.2179).

Table 22. Daily and brooding-period survival rates (RMark estimates), standard errors (SE), and 95% confidence intervals (CI) for least tern broods (≥1 chicks) monitored on OCSW sites during 2022. Brooding-period brood survival rate = daily brood survival rate[21].

Site	Mgmt[A]	# Broods	# Broods Lost	Exposure Days	Daily Brood Survival Rate[B]	Daily Brood Survival SE	Daily Brood Survival Rate 95% CI		Brooding Period Survival Rate	Brooding Period Survival Rate 95% CI	
							Lower	Upper		Lower	Upper
OSG Lexington	FHMPT	8	0	151	1	0	1	1	1	1	1
Dyer	FHPT	6	3	58.5	0.9499	0.0282	0.8559	0.9838	0.3401	0.0381	0.7093
Cottonwood Ranch	FHPT	8	0	151	1	0	1	1	1	0.9998	1.0002
Blue Hole	PT	12	1	227.5	0.9956	0.0044	0.9695	0.9994	0.9118	0.5223	0.9871
Kearney Broadfoot South	FHILMPT	11	0	222	1	0	1	1	1	1	1
Newark West	EFHLPT	4	1	72.5	0.9863	0.0136	0.9091	0.9981	0.7484	0.1351	0.9603
Newark East	FHPT	29	5	466.5	0.9893	0.0047	0.9746	0.9956	0.7984	0.5831	0.9107
Hooker Brothers Southeast	N	8	2	123.5	0.9839	0.0113	0.9380	0.9960	0.7116	0.2610	0.9189
All Sites		**86**	**12**	**1472.5**	**0.9919**	**0.0023**	**0.9858**	**0.9954**	**0.8427**	**0.7400**	**0.9074**

[A] Mgmt—management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2021 herbicide (H), interior predator fencing (I), predator deterrent lights (L), mechanical dirt work (M), no management (N), spring 2022 pre-emergent herbicide (P), and/or predator trapping (T).
[B] The site-specific model (AICc = 115.0676) was a better model to predict daily survival rates than the null model (AICc = 117.3176).

Table 23. Daily and brooding-period survival rates (RMark estimates), standard errors (SE), and 95% confidence intervals (CI) for least tern broods (≥1 chicks) monitored on Program and non-Program sites during 2022. Brooding-period brood survival rate = daily brood survival rate[21].

Site	# Broods	# Broods Lost	Exposure Days	Daily Brood Survival Rate	Daily Brood Survival SE	Daily Brood Survival Rate 95% CI		Brooding Period Survival Rate	Brooding Period Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Program[A]	66	9	1121.5	0.9920	0.0027	0.9847	0.9958	0.8449	0.7236	0.9161
Non-Program[B]	20	3	351	0.9915	0.0049	0.9739	0.9973	0.8357	0.5745	0.9439
All Sites	**86**	**12**	**1472.5**	**0.9919**	**0.0023**	**0.9858**	**0.9954**	**0.8427**	**0.7400**	**0.9074**

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

Table 24. Number of traps by trap type deployed for terrestrial mammal trapping at Program and Nebraska Public Power District owned piping plover and least tern off-channel OCSW nesting sites in 2022.

		Trap Type			
Site	**Mgmt[A]**	**Cage Trap**	**Dog Proof Trap**	**Leg Hold/ Snare**	**Total Traps**
OSG Lexington	FHMPT	9	13	2	24
NPPD Lexington	FPT	8	11		19
Dyer	FHPT	19	18	5	42
Cottonwood Ranch	FHPT	16	19		35
Blue Hole	PT	8	8	6	22
Kearney Broadfoot South	FHILMPT	10	10	1	21
Newark West	EFHLPT	12	14	17	43
Newark East	FHPT	14	15		29
Leaman	FHLPT	10	17		27
Follmer	HPT	10	10		20
Total		**116**	**135**	**31**	**282**

[A] Mgmt—management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2021 herbicide (H), interior predator fencing (I), predator deterrent lights (L), mechanical dirt work (M), spring 2022 pre-emergent herbicide (P), and/or predator trapping (T).

Table 25. Summary of terrestrial predator trapping activities at Program and Nebraska Public Power District owned piping plover and least tern off-channel OCSW nesting sites in 2022.

Site	**Mgmt[A]**	**Traps Deployed**	**Trap Days**	**Captures**	**Captures/ trap day**
OSG Lexington	FHMPT	24	2,905	39	0.0134
NPPD Lexington	FPT	19	1,313	20	0.0152
Dyer	FHPT	42	5,133	45	0.0088
Cottonwood Ranch[B]	FHPT	35	3,717	39	0.0102
Blue Hole	PT	22	1,806	13	0.0072
Kearney Broadfoot South	FHILMPT	21	3,073	35	0.0114
Newark West[B]	EFHLPT	43	5,383	54	0.0098
Newark East	FHPT	29	3,772	41	0.0109
Leaman	FHLPT	27	3,024	36	0.0119
Follmer	HPT	20	2,243	19	0.0085
Total[B]		**282**	**32,366**	**341**	**0.0105**

[A] Mgmt—management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2021 herbicide (H), interior predator fencing (I), predator deterrent lights (L), mechanical dirt work (M), spring 2022 pre-emergent herbicide (P), and/or predator trapping (T).

[B] Removed one bullsnake at Cottonwood Ranch 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 mammal trapping captures, effort, and captures per effort at Program and Nebraska Public Power District owned piping plover and least tern off-channel OCSW nesting sites in 2022.

Site	Mgmt[A]	Species Captured											Total Captures by Site	Traps deployed	Trap days	Captures/trap day
		Badger	Beaver	Bullsnake	Coyote	Domestic cat	Opossum	Raccoon	Red fox	Otter	Striped skunk	Woodchuck				
OSG Lexington	FHMPT							37	2				39	24	2,905	0.0134
NPPD Lexington	FPT							20					20	19	1,313	0.0152
Dyer	FHPT	2					1	42					45	42	5,133	0.0088
Cottonwood Ranch[B]	FHPT			1				35		2	1		39	35	3,717	0.0102
Blue Hole	PT				5			7		1			13	22	1,806	0.0072
Kearney Broadfoot South	FHILMPT						1	32			2		35	21	3,073	0.0114
Newark West[B]	EFHLPT	5				2	3	40			4		54	43	5,383	0.0098
Newark East	FHPT							39			1	1	41	29	3,772	0.0109
Leaman	FHLPT		1				3	32					36	27	3,024	0.0119
Follmer	HPT							19					19	20	2,243	0.0085
Total[B]		**7**	**1**	**1**	**5**	**2**	**8**	**303**	**2**	**3**	**8**	**1**	**341**	**282**	**32,366**	**0.0105**

[A] Mgmt—management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2021 herbicide (H), interior predator fencing (I), predator deterrent lights (L), mechanical dirt work (M), spring 2022 pre-emergent herbicide (P), and/or predator trapping (T).
[B] Removed one bull snake at Cottonwood Ranch 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 27. Total number of terrestrial mammal captures by species and trap type at Program and Nebraska Public Power District owned piping plover and least tern off-channel OCSW nesting sites in 2022.

Species	Trap Type				
	Cage Trap	Dog Proof Trap	Firearm[A]	Leg Hold/ Snare	Captures
Badger	1			6	7
Beaver	1				1
Bullsnake			1		1
Coyote				5	5
Domestic cat				2	2
Opossum	4	1		3	8
Raccoon	106	189		8	303
Red fox	2				2
Otter	3				3
Striped skunk	3	1		4	8
Woodchuck			1		1
Total	**120**	**191**	**2**	**28**	**341**

[A] Removed one bull snake at Cottonwood Ranch 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 28. Summary of track surveys conducted at piping plover and least tern nesting sites at OCSW nesting sites in 2022.

Nesting Site	Mgmt[A]	Total Track Surveys	Total Unique Track Registers	Track Registers / Week
Dyer	FHPT	14	61	4.3571
Cottonwood Ranch	FHPT	13	25	1.9231
Kearney Broadfoot South	FHILMPT	14	63	4.5000
Newark West	EFHLPT	14	28	2.0000
Newark East	FHPT	14	42	3.0000
Leaman	FHLPT	14	39	2.7857
Total		**83**	**258**	**3.1084**

[A] Mgmt—management actions applied to each site: exterior predator fencing (E), peninsula entry predator fencing (F), fall 2020 herbicide (H), interior predator fencing (I), predator deterrent lights (L), mechanical dirt work (M), no management (N), spring 2021 pre-emergent herbicide (P), or predator trapping (T).

Table 29. Summary of registers of potential piping plover and least tern predators captured by shoreline cameras deployed at OCSW nesting sites during the 2022 nesting season

Nesting Site	Mgmt[A]	No. of Shoreline Cameras	Total Shoreline Camera Days	Total Unique Predator Registers	Registers / Camera Day
Dyer	FHPT	6	996	172	0.1727
Cottonwood Ranch	FHPT	4	412	43	0.1044
Kearney Broadfoot South	FHILMPT	8	968	187	0.1932
Newark West	EFHLPT	5	625	96	0.1536
Newark East	FHPT	5	620	104	0.1677
Leaman	FHLPT	3	312	144	0.4615
Total		**31**	**3,933**	**746**	**0.1897**

[A] Mgmt—management actions applied to each site: disking (D), exterior predator fencing (E), peninsula entry predator fencing (F), fall 2021 herbicide (H), interior predator fencing (I), predator deterrent lights (L), mechanical dirt work (M), no management (N), spring 2022 pre-emergent herbicide (P), or predator trapping (T).

Table 30. Summary of registers of potential piping plover and least tern predators captured by site-level cameras at OCSW nesting sites during the 2022 nesting season.

Nesting Site	Mgmt[A]	No. of Site Cameras	Total Site-level Camera Days	Total Unique Predator Registers	Registers / Camera Day
Dyer	FHPT	5	580	37	0.0638
Cottonwood Ranch	FHPT	4	412	8	0.0194
Kearney Broadfoot South	FHILMPT	5	640	15	0.0234
Newark West	EFHLPT	3	375	28	0.0747
Newark East	FHPT	5	620	26	0.0419
Leaman	FHLPT	3	312	49	0.1571
Total		**25**	**2,939**	**163**	**0.0555**

[A] Mgmt—management actions applied to each site: disking (D), exterior predator fencing (E), peninsula entry predator fencing (F), fall 2021 herbicide (H), interior predator fencing (I), predator deterrent lights (L), mechanical dirt work (M), no management (N), spring 2022 pre-emergent herbicide (P), or predator trapping (T).

Table 31. Summary of registers of potential predators and predation events at plover and tern nests captured by nest-level cameras at during the 2022 nesting season.

Nesting Site	Mgmt[A]	No. of Nest Cameras Allocated to Site	Max No. of Nest Cameras Used	Max # of Nests Monitored	Total Nest Camera Days	Total Unique Predator Registers or Predation Events	Registers/Camera Day
Dyer	FHPT	10	7	19	240	12	0.0500
Cottonwood Ranch	FHPT	8	8	7	119	1	0.0084
Kearney Broadfoot South	FHILMPT	8	9[B]	15	243	3	0.0123
Newark West	EFHLPT	7	6	13	103	6	0.0583
Newark East	FHPT	8	8	22	361	3	0.0083
Leaman	FHLPT	5	5	6	50	0	0.0000
Total		**46**	**43**	**82**	**1,116**	**25**	**0.0224**

[A] Mgmt—management actions applied to each site: disking (D), exterior predator fencing (E), peninsula entry predator fencing (F), fall 2021 herbicide (H), interior predator fencing (I), predator deterrent lights (L), mechanical dirt work (M), no management (N), spring 2022 pre-emergent herbicide (P), or predator trapping (T).
[B] For two days, nine nest cameras were present at Kearney Broadfoot South.

Table 32. Summary of unique predator registers and predation events at active plover and tern camera monitored nests in 2022.

Site	Date	Nest ID	Target Species	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	05/19/22	O-DS-04-22	PIPL	Mammalian	Badger			1	1	1
Dyer	05/23/22	O-DS-01-22	PIPL	Avian	Great h. owl	1				1
Dyer	05/24/22	O-DS-10-22 O-DS-14-22	LETE	Mammalian	Badger		1		2	1
Dyer	05/26/22	O-DS-02-22 O-DS-03-22 O-DS-05-22	PIPL	Mammalian	Badger		1		3	1
Dyer	06/02/22	O-DS-15-22	LETE	Mammalian	Badger		1		1	1
Dyer	06/08/22	O-DS-19-22	PIPL	Avian	Juv. b. eagle	1				1
Dyer	06/24/22	O-DS-19-22	PIPL	Avian	Canada goose	1				1
Dyer	06/27/22	O-DS-19-22	PIPL	Avian	Canada goose	1				1
Dyer	06/27/22	O-DS-21-22	LETE	Avian	Great h. owl	1				1
Dyer	06/30/22	O-DS-18-22	PIPL	Reptilian	Bullsnake	1				1
Dyer	07/06/22	O-DS-21-22	LETE	Avian	Great h. owl		1		1	1
Dyer	07/20/22	O-DS-23-22	LETE	Avian	Great h. owl		1		1	1
Dyer	07/25/22	O-DS-28-22	LETE	Mammalian	Badger		1		1	1
CWR	06/09/22	O-CWR-05-22	LETE	Mammalian	Striped skunk	1				1
BFS	05/28/22	O-BFS-09-22	LETE	Mammalian	Coyote	1				1
BFS	05/29/22	O-BFS-02-22	PIPL	Mammalian	Coyote	1				1
BFS	06/14/22	O-BFS-12-22	PIPL	Reptilian	Toad	1				1
NW	05/27/22	O-NW-01-22	PIPL	Mammalian	Striped skunk			1	1	1
NW	06/07/22	O-NW-08-22 O-NW-09-22	PIPL	Avian	Great h. owl		1		2	1
NW	06/08/22	O-NW-02-22	PIPL	Mammalian	Striped skunk		1		1	1
NW	06/13/22	O-NW-11-22	PIPL	Reptilian	Bullsnake		1		1	1
NW	06/23/22	O-NW-13-22	PIPL	Avian	Great h. owl		1		1	1
NW	06/25/22	O-NW-12-22	PIPL	Avian	Great h. owl		1		1	1
NW	07/06/22	O-NW-16-22	PIPL	Avian	Great h. owl		1		1	1
NE	06/10/22	O-NE-19-22	LETE	Avian	Europ. Starl.	1				1
NE	06/20/22	O-NE-27-22	PIPL	Reptilian	Bullsnake	1				1
NE	07/18/22	O-NE-27-22	PIPL	Mammalian	Opossum		1		1	1
TOTAL						**12**	**13**	**2**	**19**	**27**

[A] Predators that were 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] Predators that 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. 44).
[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.

Table 33. Piping plover and least tern nest fate comparison for nests that received cameras and nests that did not receive nest cameras during 2022. All monitoring sources (i.e., outside/inside observers; nest, site, and shoreline camera data; and track surveys) were used to determine nest fates. Site abbreviations are Cottonwood Ranch = CWR, Kearney Broadfoot South = BFS, Newark West = NW, Newark East = NE, and Leaman = LES. Nest fates are defined as: SUCC = successful, Pred = predated, UNK = unknown, WX = weather, and Aband = Abandoned.

	No. of Nests		**No. of Successful Nests**		**No. Successful Nests w/ Pred[A]**		**No. Failed-Pred[B]**		**No. Failed-UNK**		**No. Failed-WX**		**No. Failed-Aband**	
Nests With Cameras	**82**	**61%**	**47**	**57%**	**3**	**4%**	**16**	**20%**	**2**	**2%**	**11**	**13%**	**3**	**4%**
Piping Plover	**36**	**44%**	**17**	**47%**	**1**	**3%**	**12**	**33%**	**2**	**6%**	**3**	**8%**	**1**	**3%**
Dyer	10	28%	6	35%			4	33%						
CWR	1	3%	1	6%										
BFS	8	22%	5	29%					1	50%	1	33%	1	100%
NW	8	22%			1	100%	7	58%						
NE	7	19%	5	29%			1	8%	1	50%				
LES	2	6%									2	67%		
Least Tern	**46**	**56%**	**30**	**65%**	**2**	**4%**	**4**	**9%**	**0**	**0%**	**8**	**17%**	**2**	**4%**
Dyer	9	20%	3	10%	2	100%	4	100%						
CWR	6	13%	5	17%									1	50%
BFS	7	15%	6	20%									1	50%
NW	5	11%	4	13%							1	13%		
NE	15	33%	12	40%							3	38%		
LES	4	9%									4	50%		
Nests Without Cameras	**52**	**39%**	**27**	**52%**	**0**	**0%**	**6**	**12%**	**12**	**23%**	**7**	**13%**	**0**	**0%**
Piping Plover	**3**	**6%**	**1**	**33%**	**0**	**0%**	**0**	**0%**	**2**	**67%**	**0**	**0%**	**0**	**0%**
Dyer	1	33%	1	100%										
CWR														
BFS	2	67%							2	100%				
NW														
NE														
LES														
Least Tern	**49**	**94%**	**26**	**53%**	**0**	**0%**	**6**	**12%**	**10**	**20%**	**7**	**14%**	**0**	**0%**
Dyer	7	14%	1	4%			4	67%	2	20%				
CWR	4	8%	3	12%					1	10%				
BFS	10	20%	5	19%					3	30%	2	29%		
NW	4	8%					2	33%	2	20%				
NE	22	45%	17	65%					2	20%	3	43%		
LES	2	4%									2	29%		
Total	**134**	**100%**	**74**	**55%**	**3**	**2%**	**22**	**16%**	**14**	**10%**	**18**	**13%**	**3**	**2%**

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

[B] Includes data from nests O-NW-01-22 and O-DS-04-22 where plover nest/eggs were predated but the individual predator or predation event was not captured on camera because the camera malfunctioned (refer to pg. 44 for evidence).

Table 34. Information gained from nests that received nest camera monitoring summarizing piping plover and least tern reproductive effort, success and failure in 2022. 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. Site abbreviations are Cottonwood Ranch = CWR Kearney Broadfoot South = BFS, Newark West = NW, Newark East = NE, and Leaman = LES. Nest fates are defined as: SUCC = successful, PRED = Predated, UNK = unknown, WX = weather, and Aband = Abandoned.

		Nests								Eggs						Chicks			
Species	Nesting Site	No. Monitored	No. Successful	No. Successful Nests w/ PRED	No. PRED[A]	No. Fail-UNK	No. Fail-WX	No. Fail Aband	No. Nest Camera Days	No. Laid	No. Hatch	No. PRED	No. Fail UNK	No. Fail-WX	No. Fail Aband	No. Left Nest	No. PRED	No. UNK Left Nest[B]	No. Fail-WX
Piping Plover	Dyer	10	6		4				156	33	20	9			4	20			
	CWR	1	1						18	4	2			1	1	1			1
	BFS	8	5			1	1	1	131	25	19		4	1	1	19			
	NW	8		1	7				57	32	3	29					3		
	NE	7	5		1	1			174	28	20	1	4		3	16			
	LES	2					2		29	8				8					
	TOTAL	**36** **44%**	**17** **47%**	**1** **3%**	**12** **33%**	**2** **6%**	**3** **8%**	**1** **3%**	**565** **51%**	**130**	**64** **49%**	**39** **30%**	**8** **6%**	**10** **8%**	**9** **7%**	**56**	**3** **5%**	**0** **0%**	**1** **2%**
Least Tern	Dyer	9	3	2	4				84	21	9	11			1	6	3		
	CWR	6	5					1	101	18	12		2		4	11		1	
	BFS	7	6					1	112	18	14				4	14			
	NW	5	4				1		46	13	9			4		9			
	NE	15	12				3		187	41	27		6	6	2	25		1	1
	LES	4					4		21	11				11					
	TOTAL	**46** **56%**	**30** **65%**	**2** **4%**	**4** **9%**	**0** **0%**	**8** **17%**	**2** **4%**	**551** **49%**	**122**	**71** **58%**	**11** **9%**	**8** **7%**	**21** **17%**	**11** **9%**	**65** **92%**	**3** **4%**	**2** **3%**	**1** **1%**
GRAND TOTAL		**82**	**47** 57%	**3** 4%	**16** 20%	**2** 2%	**11** 13%	**3** 4%	**1116**	**252**	**135** 54%	**50** 20%	**16** 6%	**31** 12%	**20** 8%	**121** 90%	**6** 4%	**2** 1%	**2** 1%

[A] Includes data from nests O-NW-01-22 and O-DS-04-22 where plover nest/eggs were predated but the individual predator or predation event was not captured on camera because the camera malfunctioned (refer to pg. 44 for evidence).

[B] Unknown if chicks successfully left the nest or failed because it was not documented on camera.

Table 35. Timing of plover and tern nest predation during the 2022 season based on the estimated incubation day the nest was predated.

Species	Nesting Site	Nest ID	Nest Status When Predated	Developmental Stage of Predation and # of Pred Eggs/Chicks	Incubation Day of Predation	% Incubation Completed	Predator Species
Plover	Dyer	O-DS-02-22	Active	Eggs 1	14	50%	Badger
Plover	Dyer	O-DS-03-22	Active	Eggs 3	14	50%	Badger
Plover	Dyer	O-DS-04-22[A]	Active	Eggs 2	7	25%	Badger
Plover	Dyer	O-DS-05-22	Active	Eggs 3	11	39%	Badger
Tern	Dyer	O-DS-10-22	Active	Eggs 1	6	29%	Badger
Tern	Dyer	O-DS-14-22	Active	Eggs 3	6	29%	Badger
Tern	Dyer	O-DS-15-22	Active	Eggs 3	11	52%	Badger
Tern	Dyer	O-DS-21-22	Hatched	Eggs 1 & Chicks 2	23	100%	Great horned owl
Tern	Dyer	O-DS-23-22	Hatched	Eggs 1 & Chicks 1	21	100%	Great horned owl
Tern	Dyer	O-DS-28-22	Active	Eggs 2	11	52%	Badger
Plover	Newark West	O-NW-01-22[A]	Active	Eggs 4	12	43%	Striped skunk
Plover	Newark West	O-NW-02-22	Hatched	Eggs 1 & Chicks 3	29	100%	Striped skunk
Plover	Newark West	O-NW-08-22	Active	Eggs 4	12	43%	Great horned owl
Plover	Newark West	O-NW-09-22	Active	Eggs 4	8	29%	Great horned owl
Plover	Newark West	O-NW-11-22	Active	Eggs 4	14	50%	Bullsnake
Plover	Newark West	O-NW-12-22	Active	Eggs 4	5	18%	Great horned owl
Plover	Newark West	O-NW-13-22	Active	Eggs 4	3	11%	Great horned owl
Plover	Newark West	O-NW-16-22	Active	Eggs 4	10	36%	Great horned owl
Plover	Newark East	O-NE-27-22	Active	Addled Egg 1	43[B]	100%[B]	Opossum
Average Incubation Completed for Piping Plovers					**11.6**	**41.4%**	
Average incubation completed for Least Terns					**13.0**	**61.9%**	

[A] Includes data from indicated nests where plover nest/eggs were predated but the individual predator or predation event was not captured on camera because the camera malfunctioned (refer to pg. 44 for evidence).
[B] Not included in calculation of the average incubation completed for plovers.

Table 36. Nest fate logistic exposure model results for comparison of daily nest survival (DSR) of piping plover and least tern nests with a nest camera present or not present across and within six off-channel nesting sites. Model results included model variable, fixed effect size (β), standard error (SE), z-value (z), and p-value. Nests with cameras placed at nests (Camera) had significantly higher DSR than nests without cameras during the 2022 nesting season.

Model variable	β	SE	z	p-value[A]
Both Species Across Sites				
Intercept	2.78	0.47	5.88	<0.001*
Camera	1.04	0.30	3.47	<0.001*
Plover Only Across Sites				
Intercept	1.82	0.77	2.38	0.02*
Camera	2.04	0.86	2.38	0.02*
Tern Only Across Sites				
Intercept	2.81	0.53	5.31	<0.001*
Camera	1.11	0.38	2.94	0.003*
Both Species Within Sites				
Intercept[B]	1.93	0.42	4.66	<0.001*
Camera	1.58	0.55	2.90	0.004*
Cottonwood Ranch	2.25	1.08	2.08	0.04*
Kearney Broadfoot South	0.98	0.56	1.75	0.08
Newark West	0.32	0.66	0.49	0.63
Newark East	2.50	0.61	4.09	<0.001*
Leaman	-6.92	NE[C]	-0.03	0.98
Camera/Cottonwood Ranch	-0.91	1.51	-0.60	0.55
Camera/Kearney Broadfoot South	-0.21	0.83	-0.25	0.81
Camera/Newark West	-0.77	0.82	-0.93	0.35
Camera/Newark East	-1.36	0.86	-1.57	0.12
Camera/Leaman	5.60	NE[C]	0.02	0.98

[A]Alpha level of significance = 0.05.
[B]Dyer is the reference site and included with intercept and camera variables.
[C]Non-estimable (NE) due to all camera nests failing at a site.
*Camera nests had statistically significant higher daily nest survival rates at p-value indicated.

Table 37. Research relevant to the Program's objectives and to our understanding of piping plover and interior least tern ecology.

Study Years	Study Topic	Document Title	Summary	Primary Findings	Citation
2021	Additional predator management and monitoring via trapping, track surveys, and remote cameras	Platte River Recovery Implementation Program 2021 piping plover and interior least tern monitoring and research report, central Platte River, Nebraska ATTN: PREDATOR MANAGEMENT AND MONITORING	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.	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.
2020	Additional predator management and monitoring via trapping, track surveys, and remote cameras	Platte River Recovery Implementation Program 2020 interior least tern and piping plover monitoring and research report, central Platte River, Nebraska ATTN: PREDATOR CAMERA STUDIES AND 2020 ADDITIONAL PREDATOR MANAGEMENT PILOT STUDIES	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.	Mohlman, K.L. 2021. Platte River Recovery Implementation Program: 2020 interior least tern and piping plover monitoring and research report, central Platte River, Nebraska.

Study Years	Study Topic	Document Title	Summary	Primary Findings	Citation
2020	Turtle trapping and exclosures	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	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.	Mohlman, K.L. 2021. Platte River Recovery Implementation Program: 2020 interior least tern and piping plover monitoring and research report, central Platte River, Nebraska.
2019	Predator monitoring via remote cameras	Platte River Recovery Implementation Program 2020 interior least tern and piping plover monitoring and research report, central Platte River, Nebraska ATTN: PREDATOR CAMERA STUDIES	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.	Mohlman, KL. 2020. Platte River Recovery Implementation Program: 2019 interior least tern and piping plover monitoring and research report, central Platte River, Nebraska.

Study Years	Study Topic	Document Title	Summary	Primary Findings	Citation
2017-2018	Predator monitoring via remote cameras	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	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.	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.
2017-2019	Predator monitoring via remote camera	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	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.	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.

Study Years	Study Topic	Document Title	Summary	Primary Findings	Citation
2016-2018	Habitat selection	Adult piping plover habitat selection varies by behavior	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.	Robinson S, Bellman H, Walker K, Catlin D, Karpanty K, Ritter S, Fraser, J. 2021. Adult piping plover habitat selection varies by behavior. *Ecosphere* 12(12): e03870. https://doi.org/10.1002/ecs2.3870
2014-2019	Population dynamics	Dispersal distance is driven by habitat availability and reproductive success in northern Great Plains piping plovers	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.	Swift RJ, Anteau MJ, Ellis KS, Ring MM, Sherfy MH, Toy DL. 2021. Dispersal distance is driven by habitat availability and reproductive success in northern Great Plains piping plovers. *Movement Ecology* 9:59. https//doi.org/10.1186/s40462-021-00293-3

Study Years	Study Topic	Document Title	Summary	Primary Findings	Citation
2014-2017	Population dynamics	Implications of habitat-driven survival and dispersal on recruitment in a spatially structured piping plover population	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.	Swift RJ, Anteau MJ, Ellis KS, Ring MM, Sherfy MH, Toy DL, Koons DN. 2022. Implications of habitat-driven survival and dispersal on recruitment in a spatially structured piping plover population. *Ecosphere* 13: e4190. https://doi.org/10.1002/ecs2.4190
2014-2016	Effectiveness of predator management	Experimental evaluation of predator exclosures on nest, chick, and adult survival of piping plovers	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.	Anteau MJ, Swift RJ, Sherfy MH, Koons DN, Ellis KS, Shaffer TL, Toy DL, Ring MM. 2021. Experimental evaluation of predator exclosures on nest, chick, and adult survival of Piping Plovers. *Journal of Wildlife Management* 86:e22139. https://doi.org/10.1002/jwmg.22139

Study Years	Study Topic	Document Title	Summary	Primary Findings	Citation
2013-2019	Plover chick habitat selection	Piping plover chick ecology following landscape-level disturbance	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.	Robinson SG, Walker KM, Bellman HA, Gibson D, Catlin DH, Karpanty SM, Ritter SJ, Fraser JD. 2021. Piping plover chick ecology following landscape-level disturbance. *Journal of Wildlife Management* 87: e22325. https://doi.org/10.1002/jwmg.22325
2013-2016	Shorebird productivity monitoring protocols	Reducing effort when monitoring shorebird productivity	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	Farrell PD, Baasch, DM. 2020. Reducing effort when monitoring shorebird productivity. *Waterbirds* 43(2): 123-133. https://doi.org/10.1675/063.043.0201
2009-2020	Population dynamics of piping plovers	Spatial variation in population dynamics of northern Great Plains piping plovers	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.	Swift, RJ, Anteau M, Ellis K, Ring M, Sherfy M, Toy D, Koons D. Spatial variation in population dynamics of Northern Great Plains piping plovers. U.S. Geological Survey Open-File Report 2020–1152, 211 p.

Study Years	Study Topic	Document Title	Summary	Primary Findings	Citation
2009-2014	Demographics and movements of piping plovers and least terns	Demographics and movements of least terns and piping plovers in the central Platte River valley, Nebraska: U.S.	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.	Roche, E.A., Sherfy, M.H., Ring, M.M., Shaffer, T.L., Anteau, M.J., and Stucker, J.H., 2016, Demographics and movements of least terns and piping plovers in the Central Platte River Valley, Nebraska: U.S. Geological Survey Open-File Report 2016–1061, 27 p.
2009-2010	Foraging ecology of piping plovers and least terns	Foraging ecology of least terns and piping plovers nesting on central Platte River sandpits and sandbars	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.	Sherfy, MH, Anteau, MJ, Shaffer, TL, Sovada, MA, Stucker, JH. 2012. Foraging ecology of least terns and piping plovers nesting on Central Platte River sandpits and sandbars: U.S. Geological Survey Open-File Report 2012–1059, 50 p.

Study Years	Study Topic	Document Title	Summary	Primary Findings	Citation
2009-2010	Foraging movements and colony attendance during breeding season of least terns	Foraging movements and colony attendance of least terns (*Sternula antillarum*) on the central Platte River, Nebraska, USA	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.	Sherfy MH, Ring MM, Stucker JH, Anteau MJ, Shaffer TL, Sovada MA. 2021. Foraging movements and colony attendance of Least Terns (*Sternula antillarum*) on the central Platte River, Nebraska, USA. *Waterbirds* 44(1): 38-54. https://doi.org/10.1675.063.044.0104
2008-2021	Annual piping plover and least tern synthesis reports	PRRIP tern and plover monitoring reports (2008-2021)	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.	Available on Program Online Library: https://platteriverprogram.org/program-library. Keywords: least tern, piping plover, technical reports

Study Years	Study Topic	Document Title	Summary	Primary Findings	Citation
2008-2021	Tern and Plover Conservation Partnership Annual Reports	Interior least tern and piping plover annual report for the lower Platte River, Nebraska	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.	Tern and Plover Conservation Partnership https://ternandplover.unl.edu/annual-reports
2007-2016	Heterospecific breeding association	Asymmetric benefits of heterospecific breeding association vary with habitat, conspecific abundance and breeding strategy	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.	Swift RJ, Anteau MJ, Roche EA, Sherfy MH Toy DL, Ring MM. 2020. Asymmetric benefits of heterospecific breeding association vary with habitat, conspecific abundance and breeding strategy. *Oikos* 129: 1504-1520. https://doi.org/10.1111/oik.07256
2002-2019	Piping plover survival and migratory connectivity	Impacts of extreme environmental disturbances on piping plover survival are partially moderated by migratory connectivity	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.	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. Impacts of extreme environmental disturbances on piping plover survival are partially moderated by migratory connectivity. *Biological Conservation*. 264: 1-11. https://doi.org/10.1016/j.biocon.2021.109371

Study Years	Study Topic	Document Title	Summary	Primary Findings	Citation
2001-2021	MRRP Annual Reports	MRRP ESA adaptive management compliance report	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.	Missouri River Recovery Program https://www.nwo.usace.army.mil/mrrp/Library/
2001-2015	Nest-site selection by piping plovers and least terns	Nest-site selection by interior least terns and piping plovers at managed, off-channel sites along the Central Platte River in Nebraska, USA	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.	Baasch DM, Farrell PD, Farnsworth JM, Smith CS. 2017. Nest site selection by Interior Least Terns and Piping Plovers at managed, off-channel sites along the Central Platte River in Nebraska, USA. *Journal of Field Ornithology* 88(3): 236-249. https://doi.org/10.1111/jofo.12206
2001-2015	Piping plover and least tern nest and brood survival	Interior least tern and piping plover nest and brood survival at managed, off-channel sites along the central Platte River, Nebraska, USA 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.	Farrell PD, Baasch DM, Farnsworth JM, Smith CS. 2018. Interior Least Tern and Piping Plover nest and brood survival at managed, off-channel sites along the central Platte River, Nebraska, USA 2001-2015. *Avian Conservation and Ecology* 13(1): 1. https://doi.org/10.5751/ACE-01133-130101

Study Years	Study Topic	Document Title	Summary	Primary Findings	Citation
2001-2014	Breeding population estimators	A comparison of breeding population estimators using nest and brood monitoring data	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.	Baasch DM, Hefley TJ, Cahis SD. 2015. A comparison of breeding population estimators using nest and brood monitoring data. *Ecology and Evolution* 5(18): 4197-4209. https://doi.org/10.1002/ece3.1680
2001-2007	Annual piping plover and least tern synthesis reports	Tern and plover monitoring protocol implementation reports (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.	Available on Program Online Library: https://platteriverprogram.org/program-library. Keywords: least tern, piping plover, technical reports
1993-2020	Habitat availability	Decline of novel ecosystems used by endangered species: the case of piping plovers, least terns, and aggregate mines	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.	Jorgensen JG, Brenner SJ, Greenwalt LR, Vrtiska, MP. 2021. Decline of novel ecosystems used by endangered species: the case of piping plovers, least terns, and aggregate mines. *Ecosphere* 12(4): e03474. https://doi.org/10.1002/ecs2.3471

FIGURES

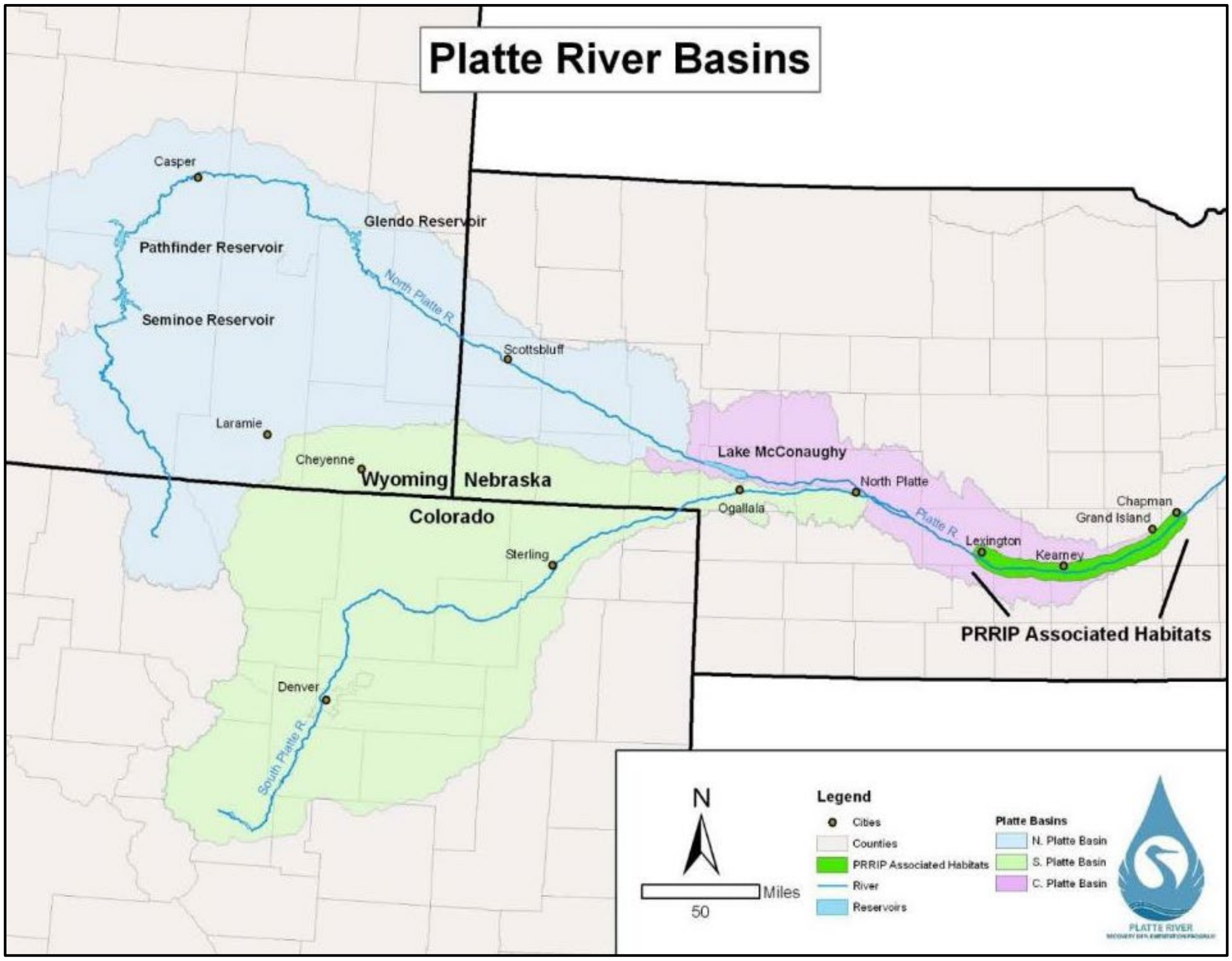

Figure 1. Platte River Basins extending from Colorado and Wyoming through Nebraska. The study area for our piping plover and least tern monitoring and research efforts was the PRRIP Associated Habitat Reach of the Platte River located between Lexington and Chapman, Nebraska (in dark green).

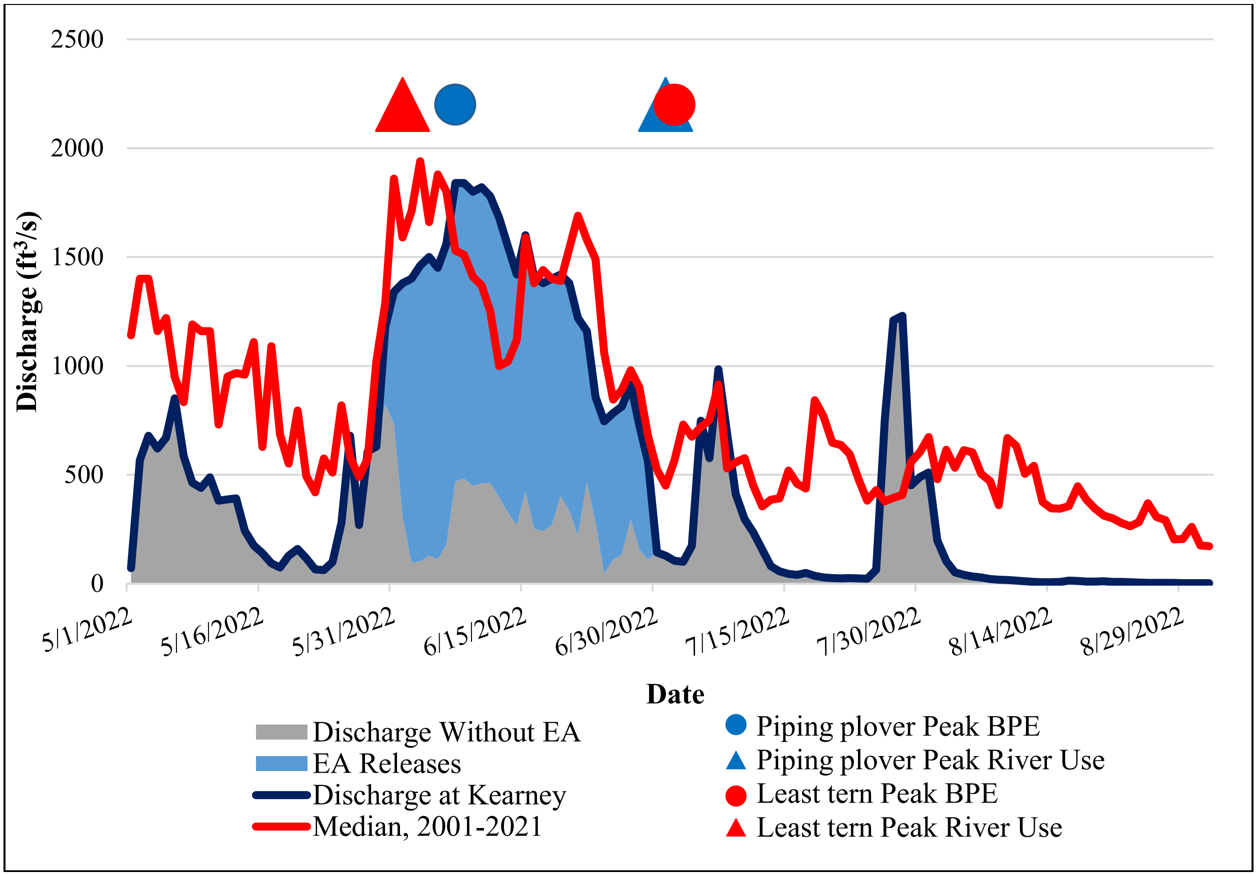

Figure 2. Daily discharge (ft^3/second) at Kearney, Nebraska (USGS gage 06770200; USGS 2022) between 1 May and 14 August, 2022 (navy line). See Figure 5 for the location of gage stations within our study area. Also depicted in the figure are the: median daily discharge from 2001–2022 at Kearney (red line); 2022 daily discharge without the inclusion of the Environmental Account (EA) releases (gray area); and 2022 daily discharge with EA releases (light blue area). Dates on which estimated breeding pairs/nesting (BPE) and river use for piping plovers and least terns peaked are denoted above the discharge. Plover BPE peaked at off-channel sand and water (OCSW) sites across the Associated Habitat Reach (AHR) on 7 June (blue circle); tern BPE peaked at OCSW sites across the AHR on 2 July (red circle); and adult counts observed on river surveys peaked for plovers on 1 July (blue triangle) and terns on 1 June (red triangle) and 15 July (purple triangle).

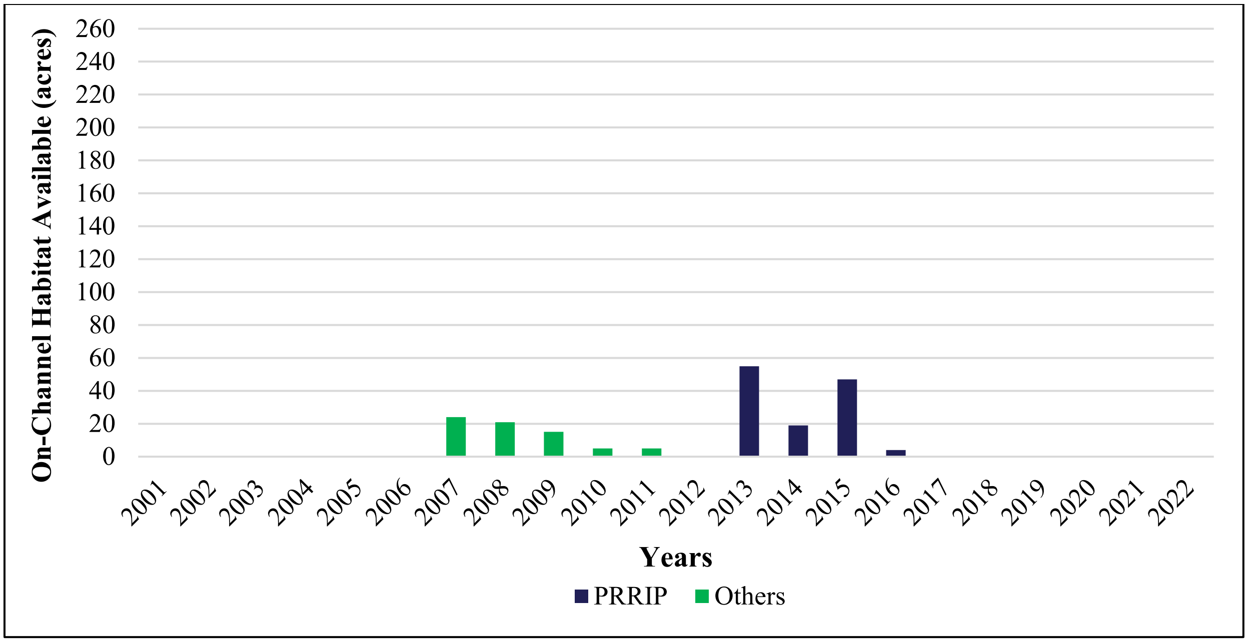

Figure 3. Monitored on-channel nesting habitat along the AHR from 2001-2022 that was created, rehabilitated, and managed by the Program and other organizations and that fits the accepted Program habitat requirements (PRRIP 2015). Available on-channel habitat from 2001-2006 only includes sites that were used in reproductive and survival calculations each year, but no nesting was observed during this time period

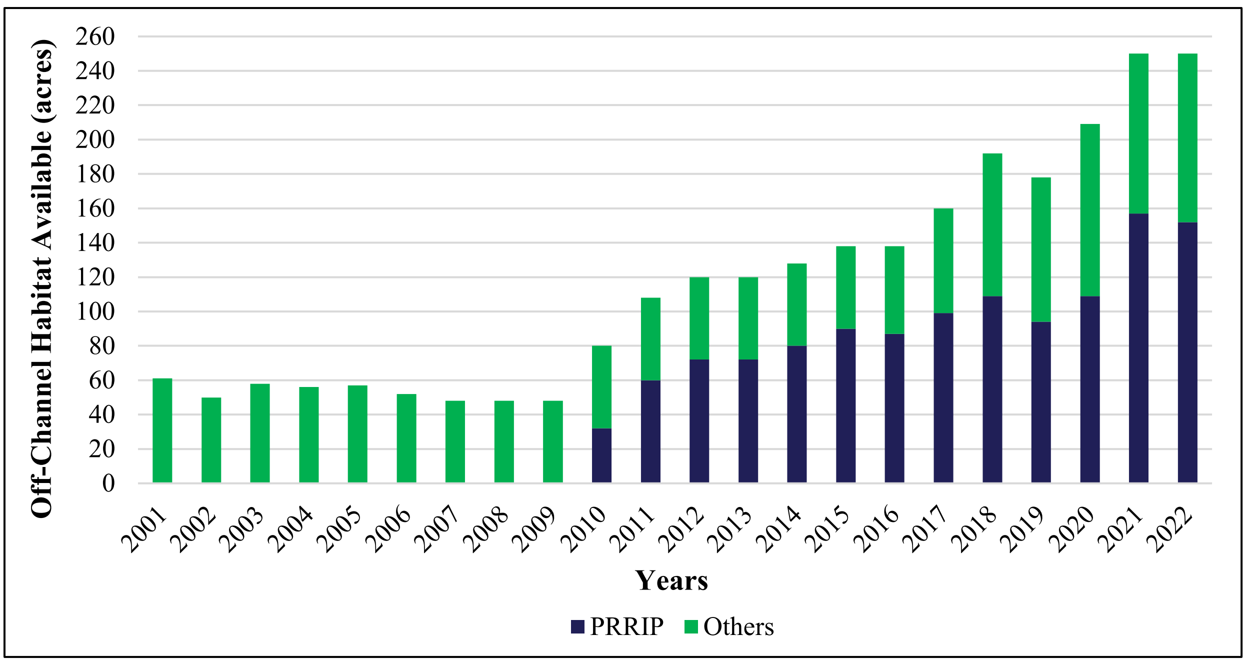

Figure 4. Off-channel nesting habitat along the AHR from 2001-2022 that were monitored by the Program and other organizations and that fits the accepted Program habitat requirements (PRRIP 2015). Due to access restrictions that limited monitoring at some sites, available OCSW habitat from 2001-2009 only includes sites that were used in the reproductive and survival calculations each year.

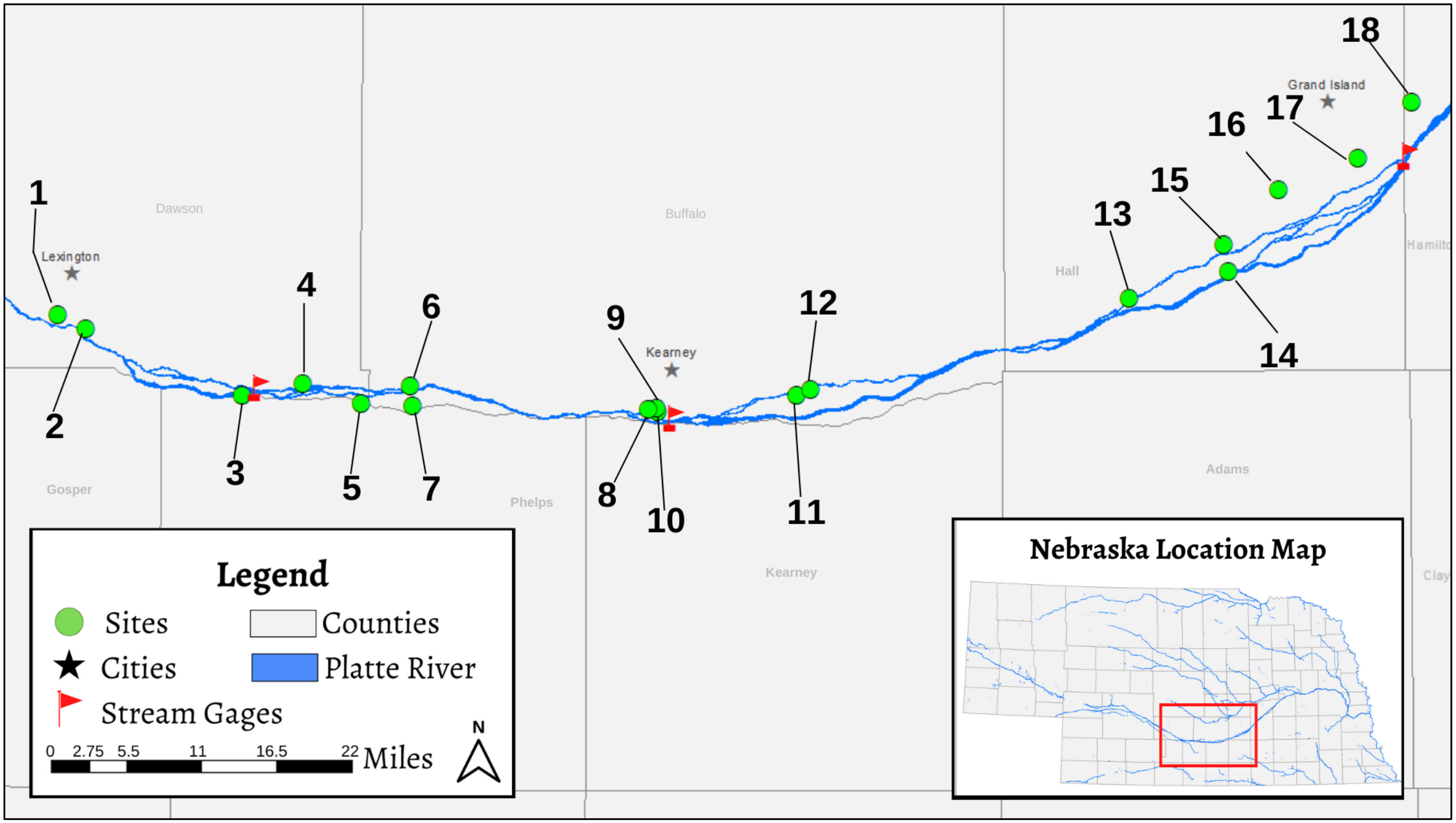

Figure 5. Study area including OCSW nesting sites (green circles) and river channels (blue) monitored for piping plover and least tern nesting and foraging activities during 2022. River gage locations are in red. The Kearney gage (USGS gage 06770200) location is denoted (USGS 2022). Names of numbered sites are included in Tables 3 and 15.

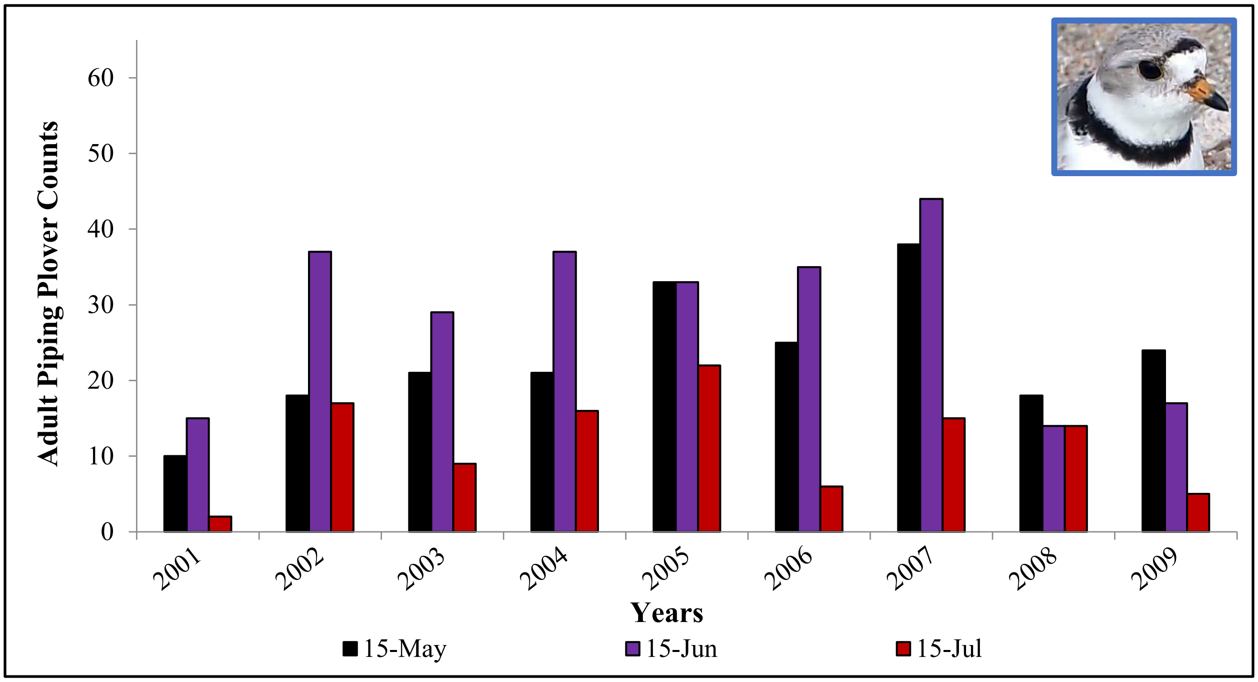

Figure 6. Numbers of piping plover adults observed during three semi-monthly surveys of OCSW sites along the Platte River between Lexington and Chapman, Nebraska, 2001–2009.

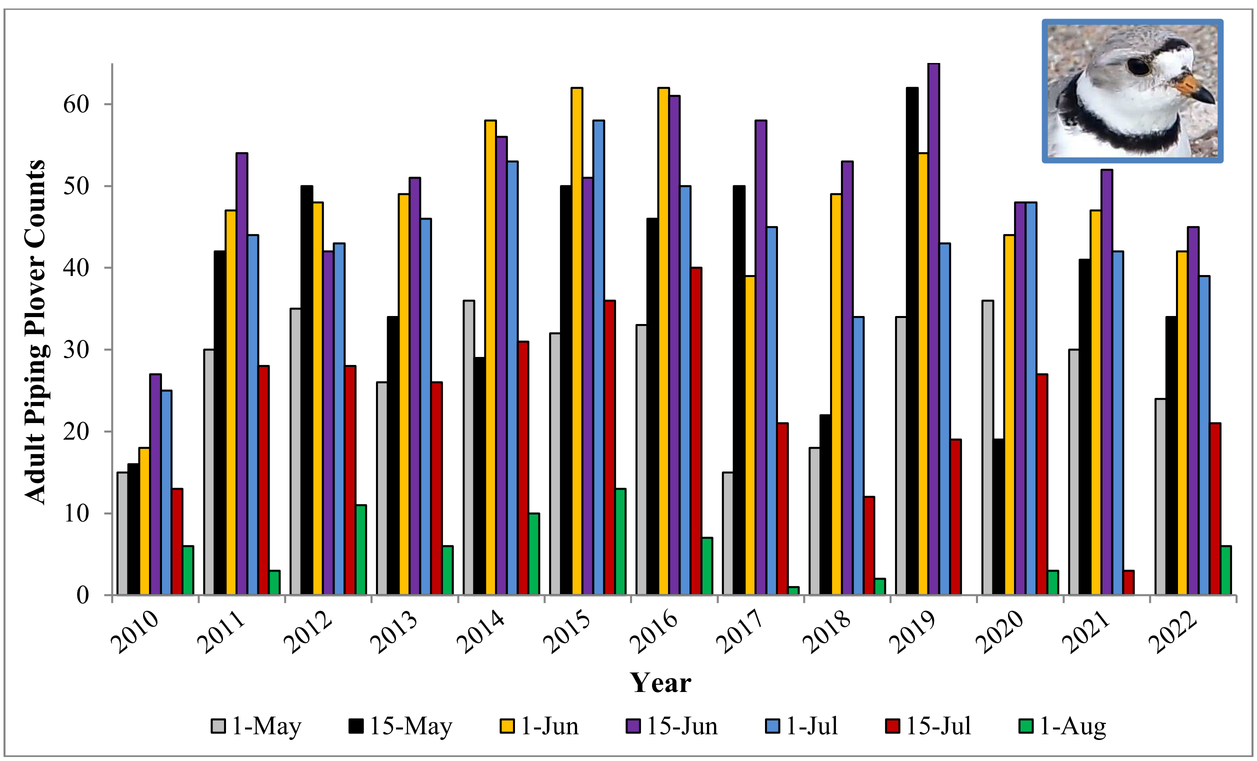

Figure 7. Numbers of piping plover adults observed during seven semi-monthly surveys of OCSW sites along the Platte River between Lexington and Chapman, Nebraska, 2010–2022.

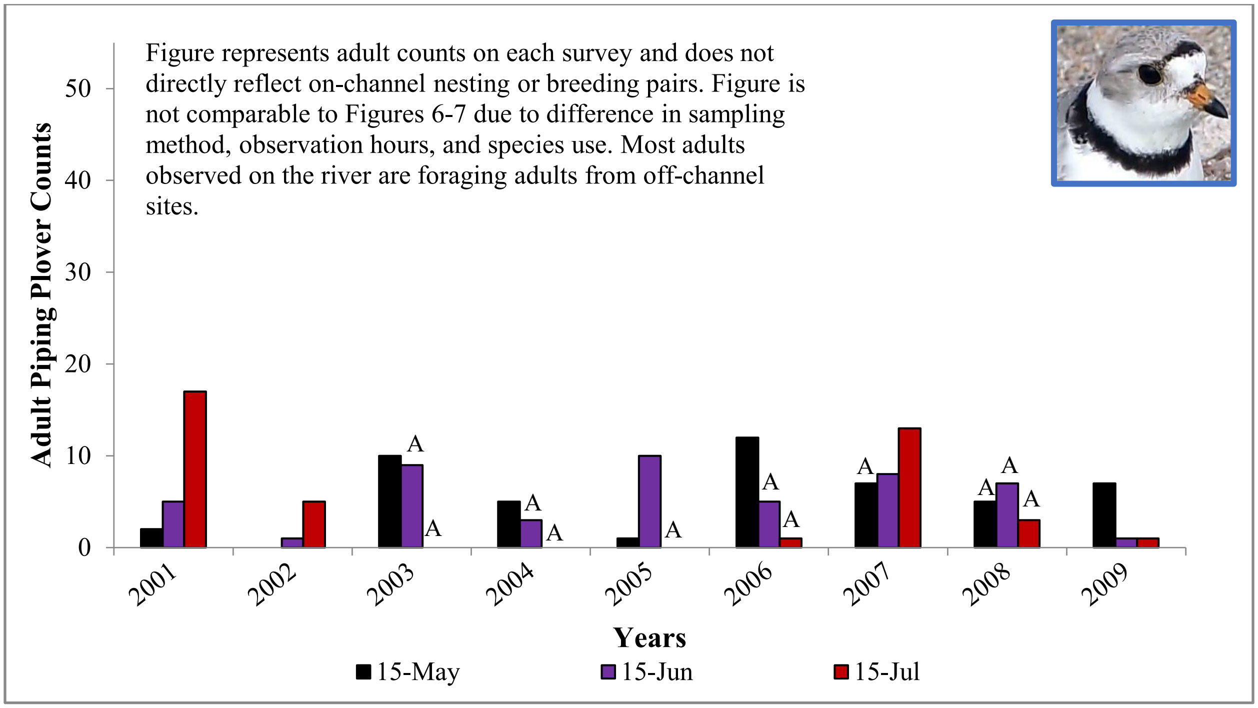

Figure 8. Numbers of piping plover adults observed during three semi-monthly surveys of the Platte River between Lexington and Chapman, Nebraska, 2001-2009.

[A] Sample periods for which at least one section of the river was not completed due to a lack of flow in the channel, high flow, or other restrictions.

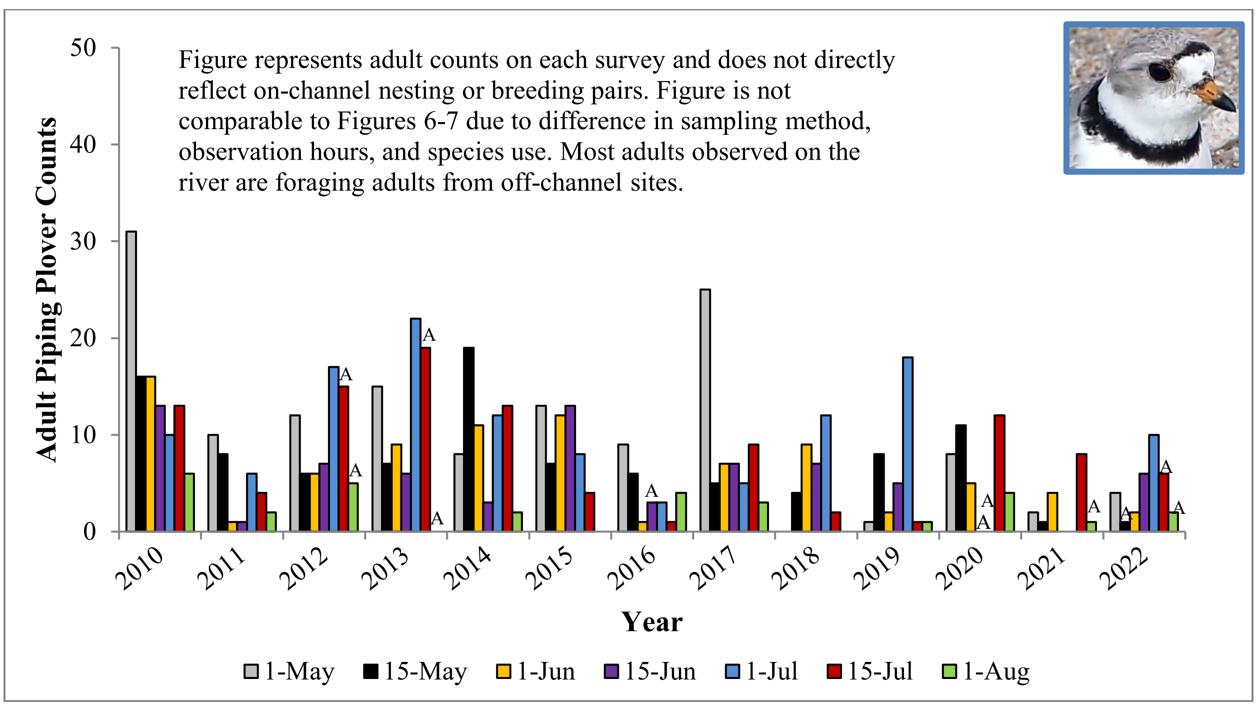

Figure 9. Numbers of piping plover adults observed during seven semi-monthly surveys of the Platte River between Lexington and Chapman, Nebraska, 2010-2022.

[A] Sample periods for which at least one section of the river was not completed due to a lack of flow in the channel, high flow, or other restrictions.

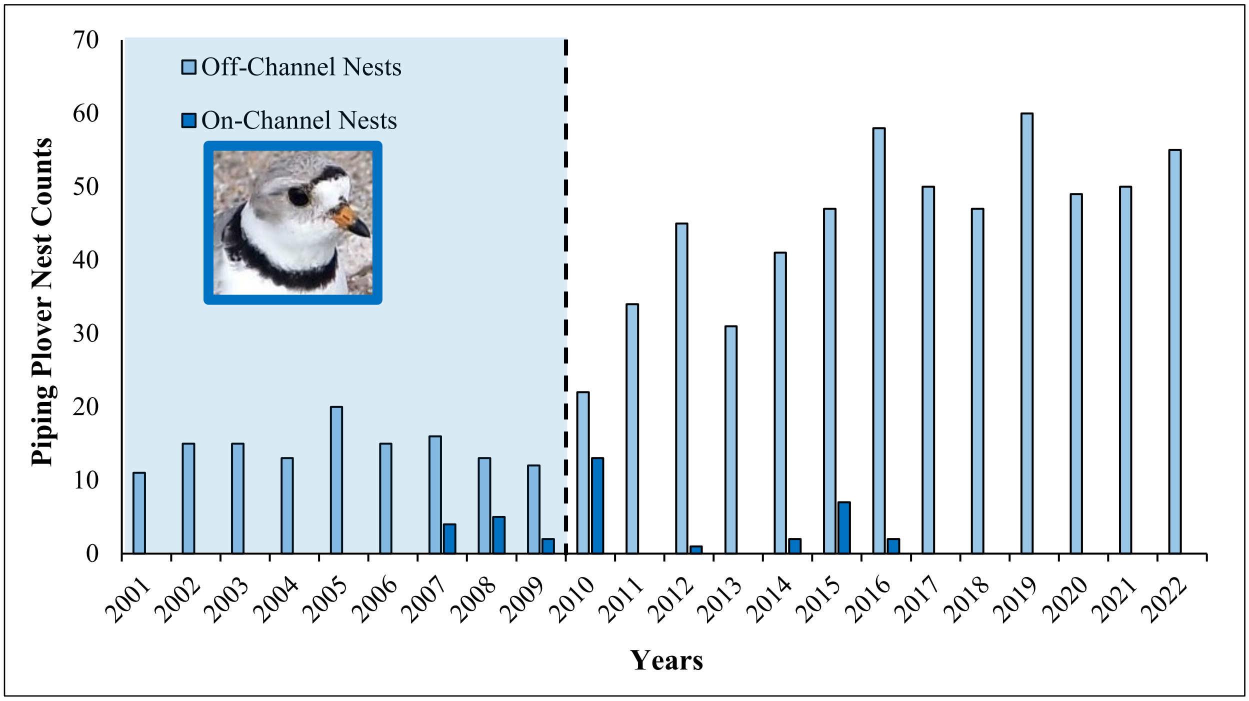

Figure 10. Comparison of numbers of piping plover nests found during off-channel (light blue bars) and on-channel (dark blue bars) surveys within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska, 2001-2022. The black dotted line represents changes in protocol, including an increase in monitoring effort, and the shaded area represent years that are not as easily comparable to current protocols.

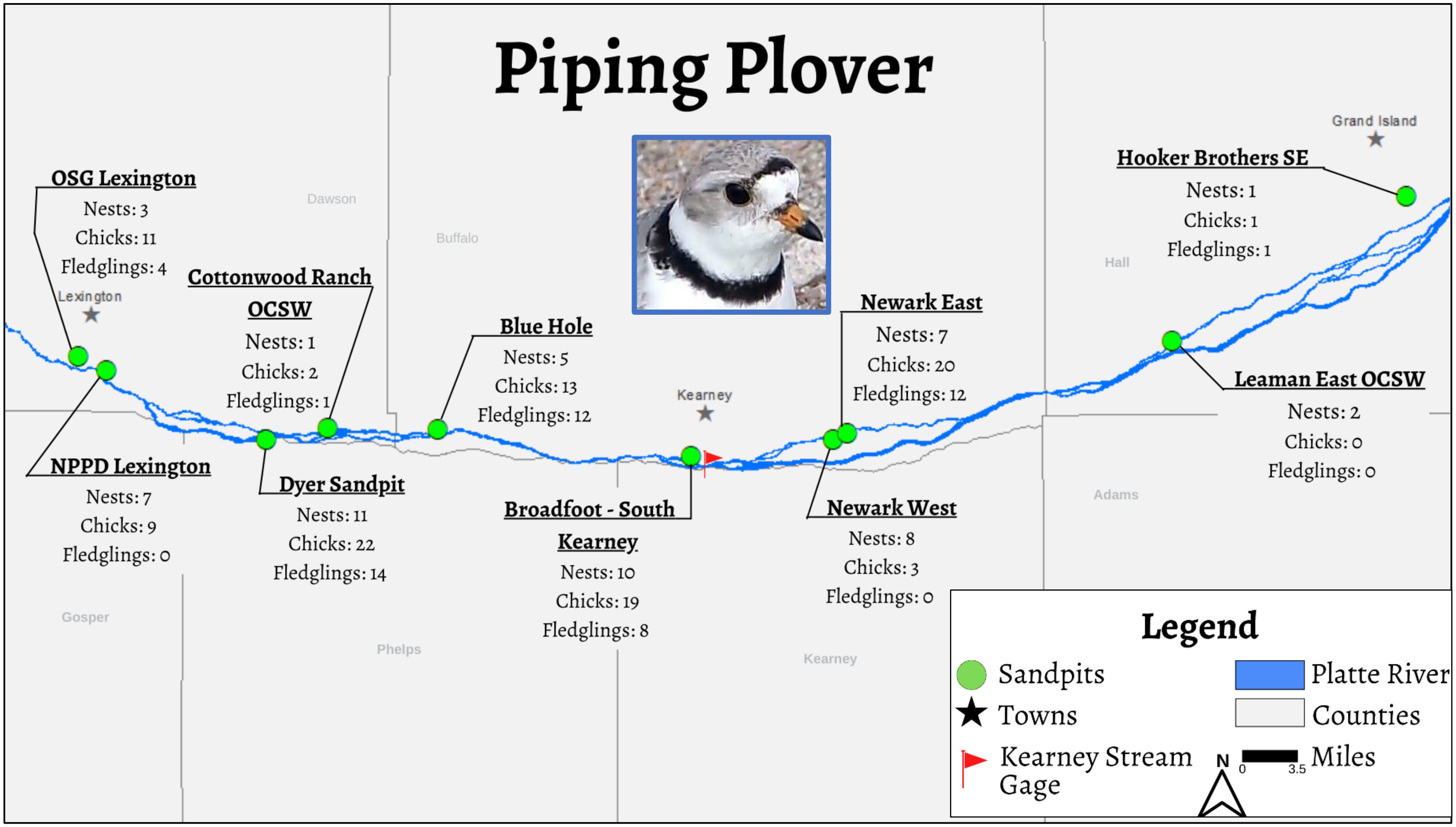

Figure 11. Distribution and numbers of piping plover nests, chicks, and fledglings observed within Program associated habitats during 2022 surveys along the Platte River between Lexington and Chapman, Nebraska. Piping plover nests and chicks were observed and monitored at 10 of the 18 off-channel sites monitored during 2022. Kearney stream gage (USGS gage 06770200) marked in red (USGS 2022).

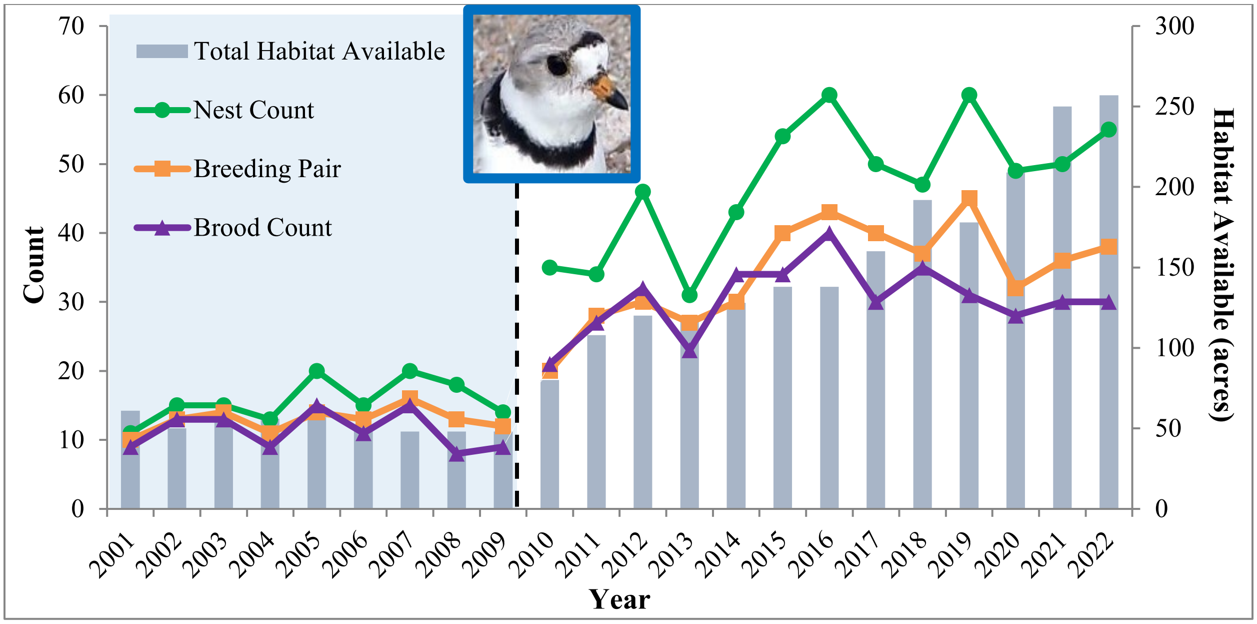

Figure 12. Annual total numbers of piping plover nests (green line), peak breeding pairs (orange line), brood counts (purple line), and total on- and off-channel habitat available (blue bars) observed within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska,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

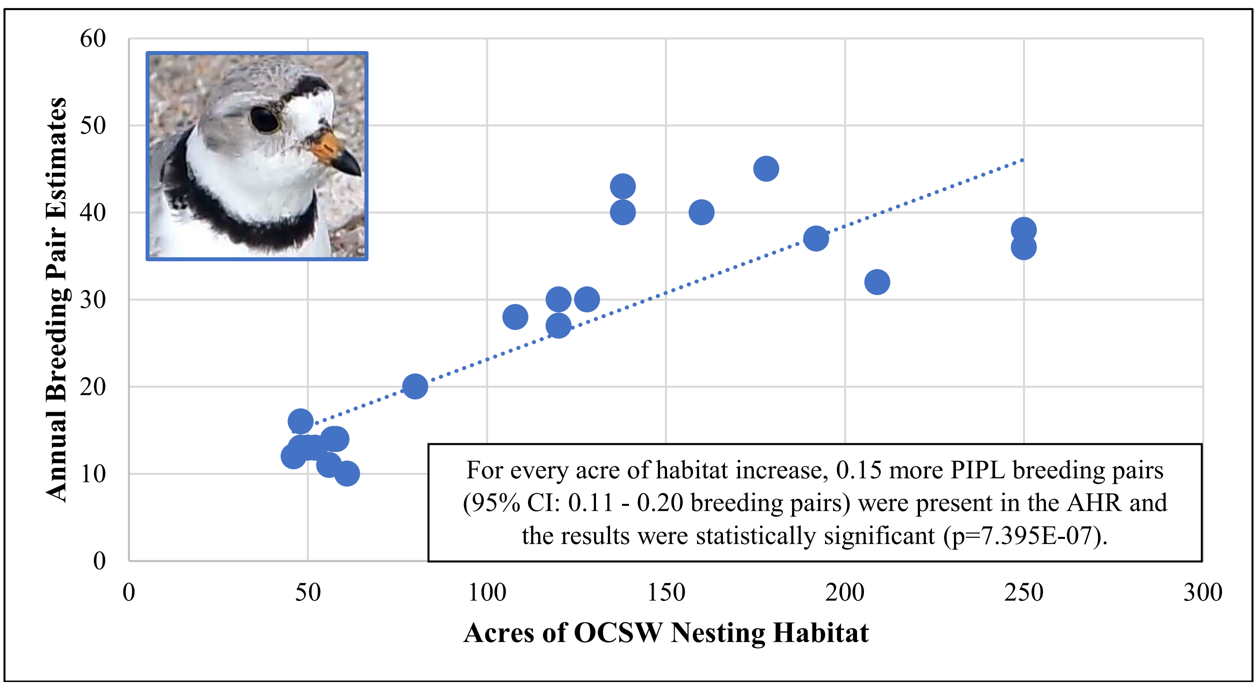

Figure 13. Relationship between the annual estimated numbers of piping plover (PIPL) breeding pairs and availability of monitored off-channel habitat (OCSW sites) within the Program Associated Habitat Reach, 2001-2022. Due to access restrictions that limited monitoring at some sites, available habitat from 2001-2009 only includes sites that were used in the reproductive and survival calculations each year.

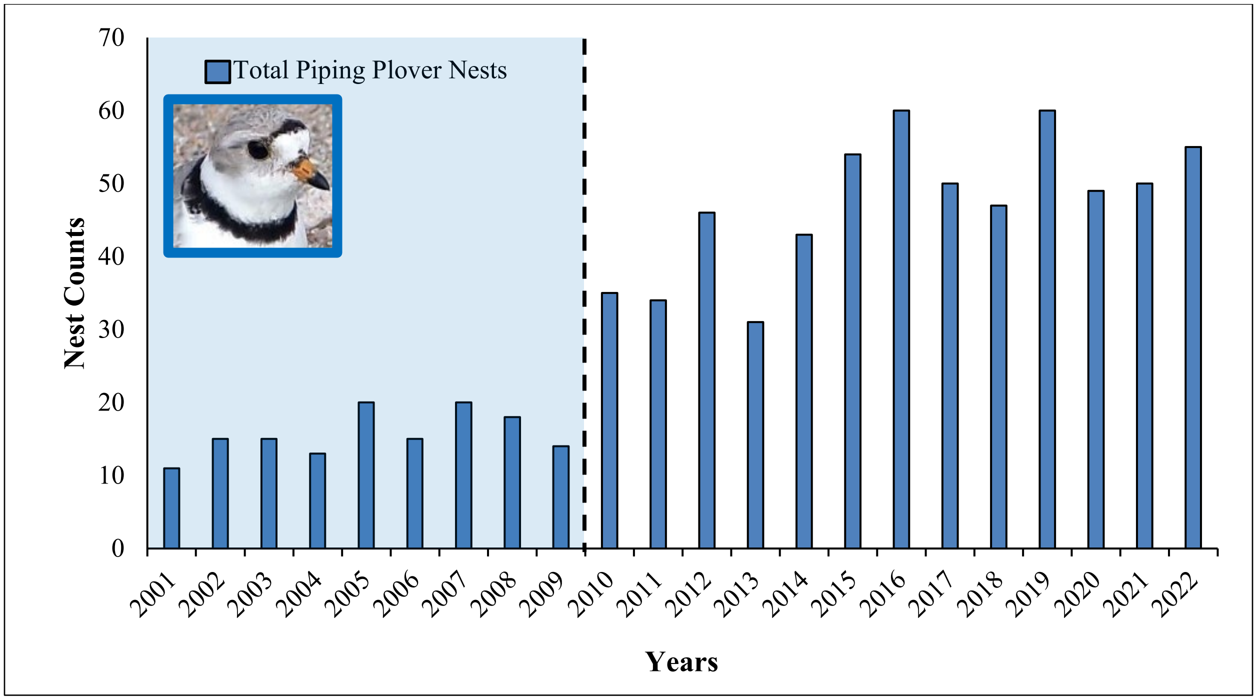

Figure 14. Total piping plover nests on- and off-channel within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska, 2001-2022. The black dotted line represents changes in protocol, including an increase in monitoring effort, and the shaded area represent years that are not as easily comparable to current protocols.

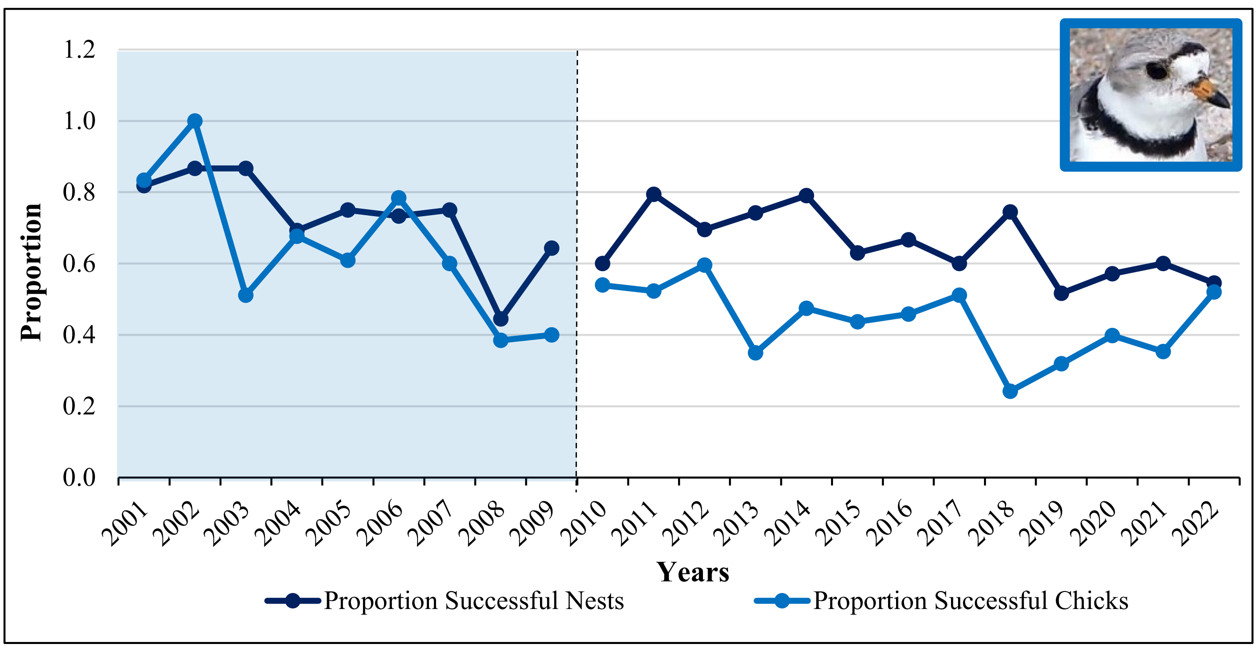

Figure 15. Proportion of successful nests (apparent nest success) and proportion of successful chicks (proportion of chicks fledged) for piping plovers from 2001-2022 within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska. The black dotted line represents changes in protocol, and the shaded area represents data that is not comparable. Among other changes, fledge age was changed from a 15-day success benchmark to 28 days for plovers.

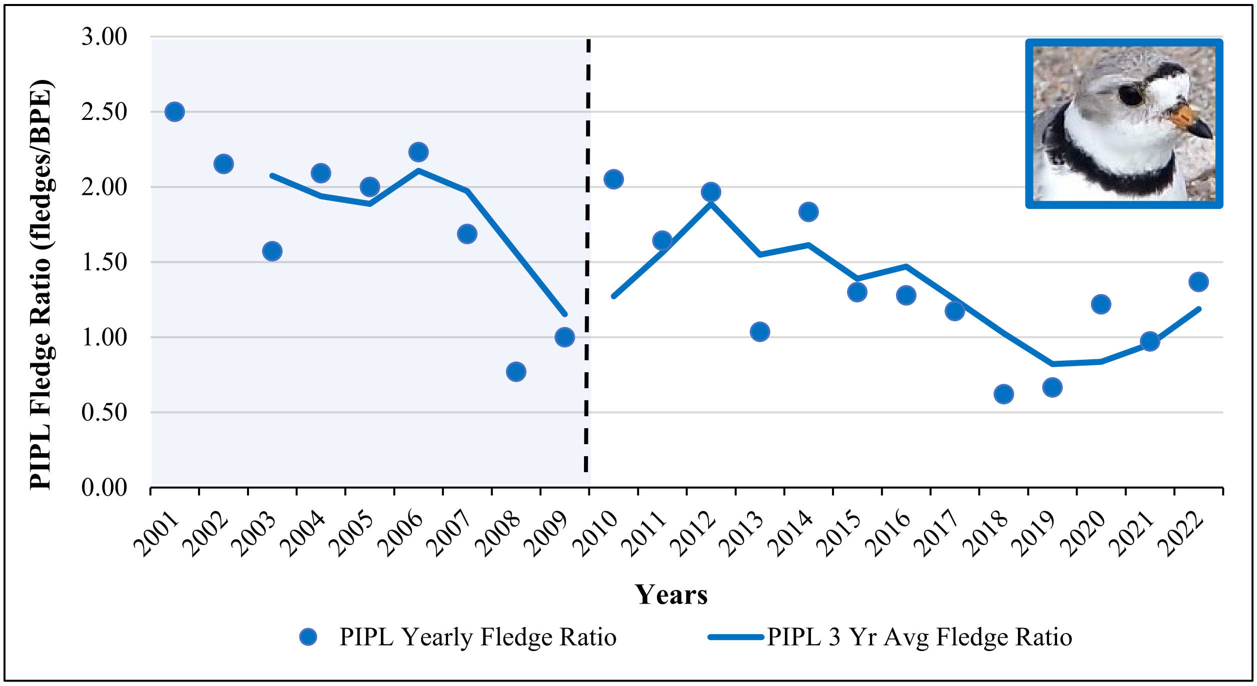

Figure 16. Piping plover (PIPL) fledge ratios (fledges/estimated breeding pair [BPE]) on annual (point) and 3-year running average (line) bases from 2001-2022 within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska. The black dotted line represents changes in protocol, and the shaded area represents data that is not comparable to that collected during 2010-2022. Among other changes, fledge age was changed from a 15-day success benchmark to 28 days for plovers. Protocols for the fating of nests and broods have evolved and have gradually become more accurate and consistent. For the purpose of this figure, all unknown nests from 2010-2021 were re-fated according to current protocol and definitions so they were directly comparable to those observed in 2022.

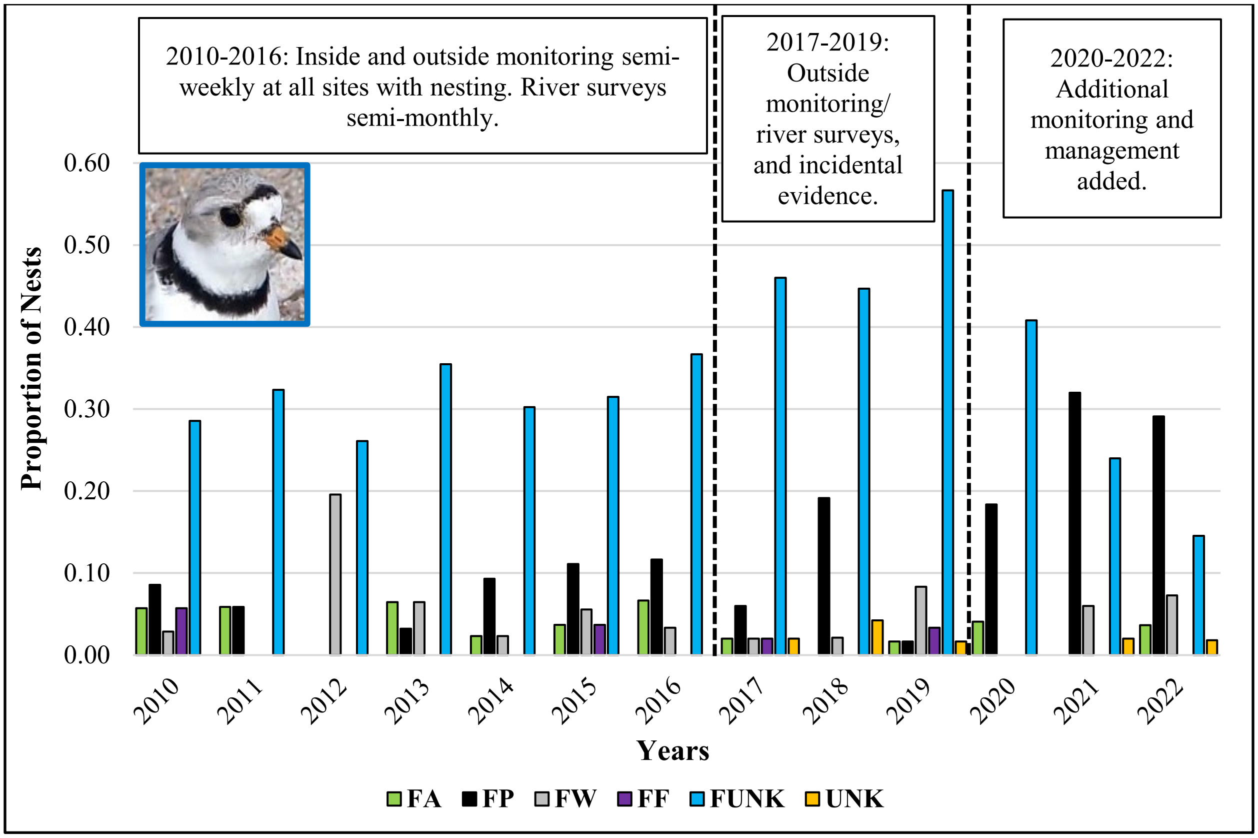

Figure 17. Proportion of nests lost by assigned cause of loss for piping plovers from 2010-2022 across the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska. Each loss represents a unique reproductive attempt. The assigned causes of loss include failed-abandoned (FA; green), failed-predated (FP; black), failed-weather (FW; grey), failed-flooded (FF; purple), failed-unknown (FUNK; blue), and unknown (UNK; orange). The dotted black lines represent changes in monitoring protocol. Protocols for the fating of nests and broods have evolved and have gradually become more accurate and consistent. For the purpose of this figure, all unknown nests from 2010-2021 were re-fated according to current protocol and definitions so they were directly comparable to those observed in 2022.

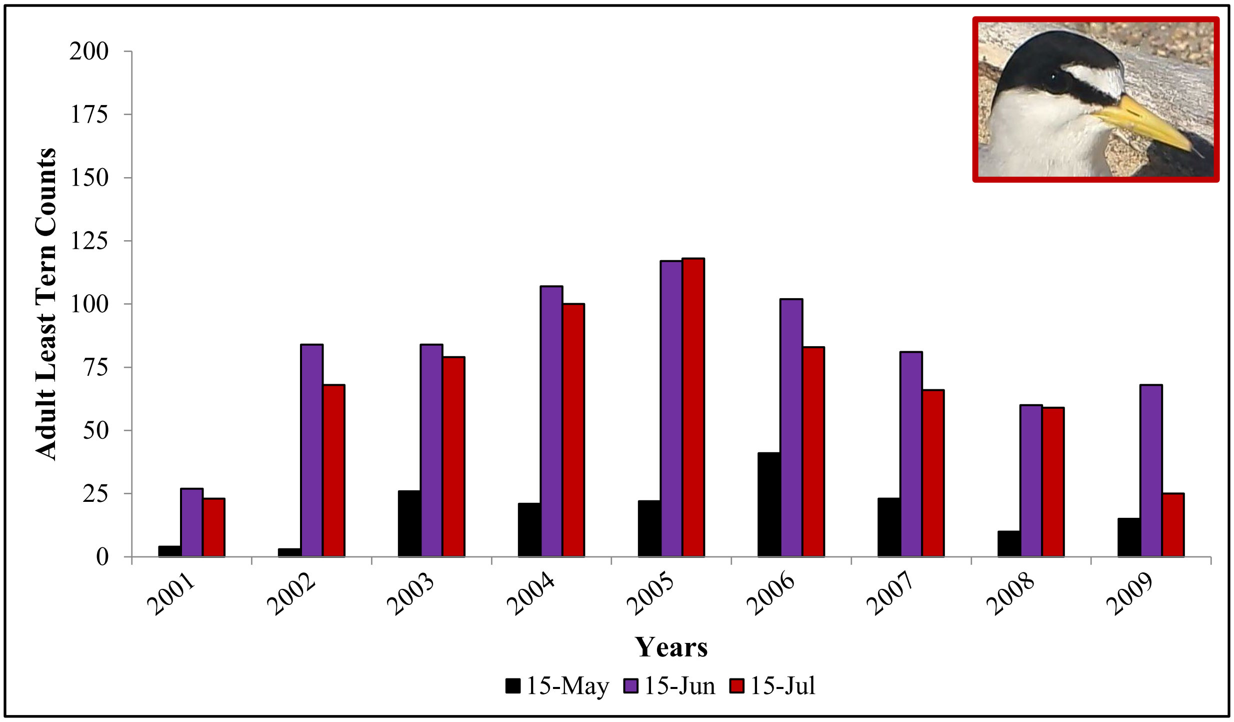

Figure 18. Numbers of least tern adults observed during three semi-monthly surveys of OCSW sites along the Platte River between Lexington and Chapman, Nebraska, 2001–2009.

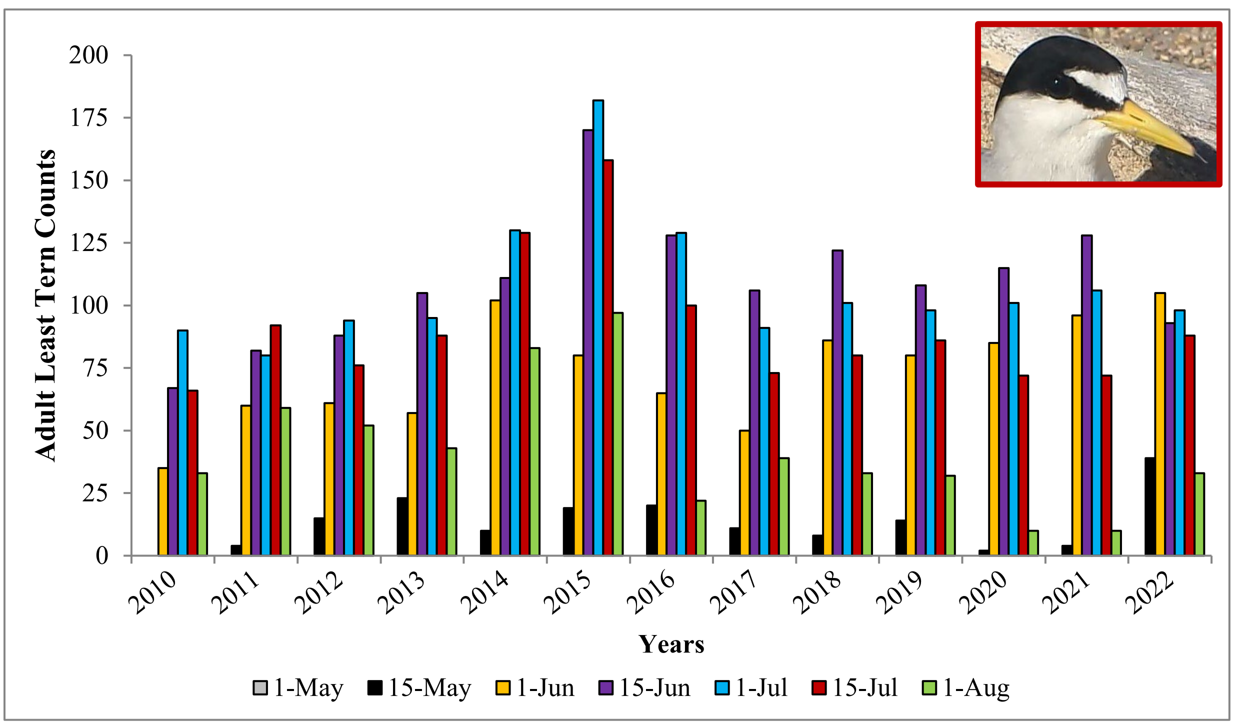

Figure 19. Numbers of least tern adults observed during seven semi-monthly surveys of OCSW sites along the Platte River between Lexington and Chapman, Nebraska, 2010–2022.

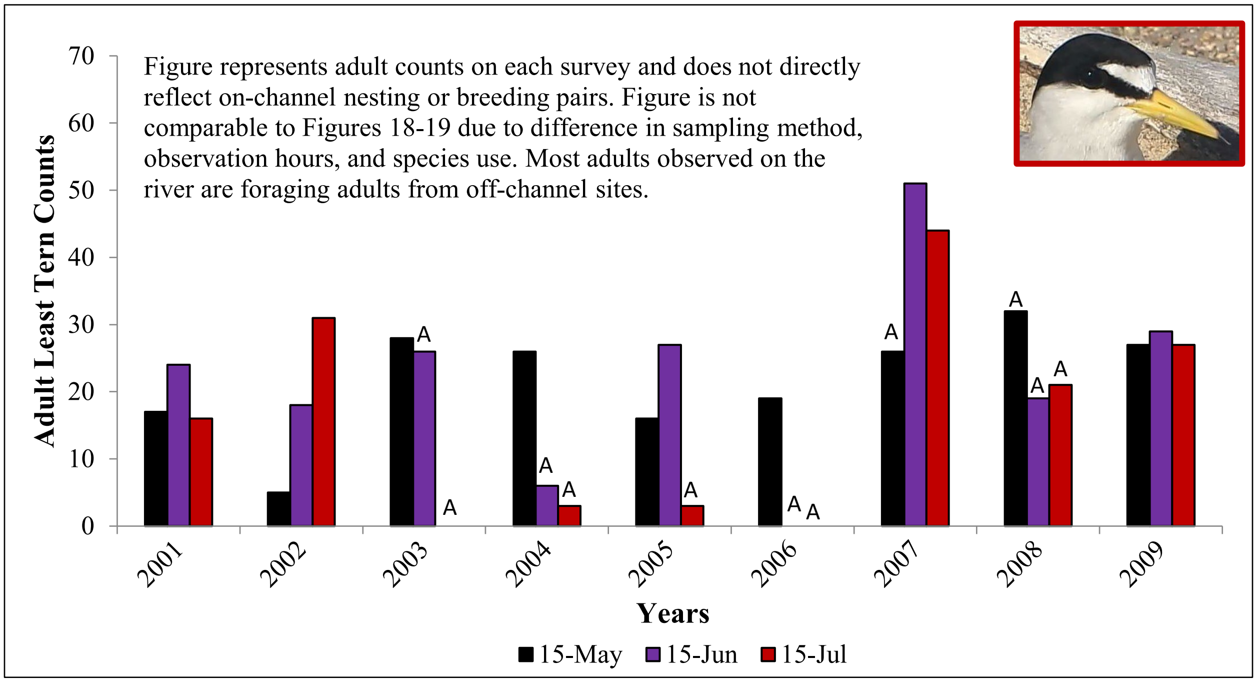

Figure 20. Numbers of least tern adults observed during three semi-monthly surveys of the Platte River between Lexington and Chapman, Nebraska, 2001-2009.

[A] Sample periods for which at least one section of the river was not completed due to a lack of flow in the channel, high flow, or other restrictions.

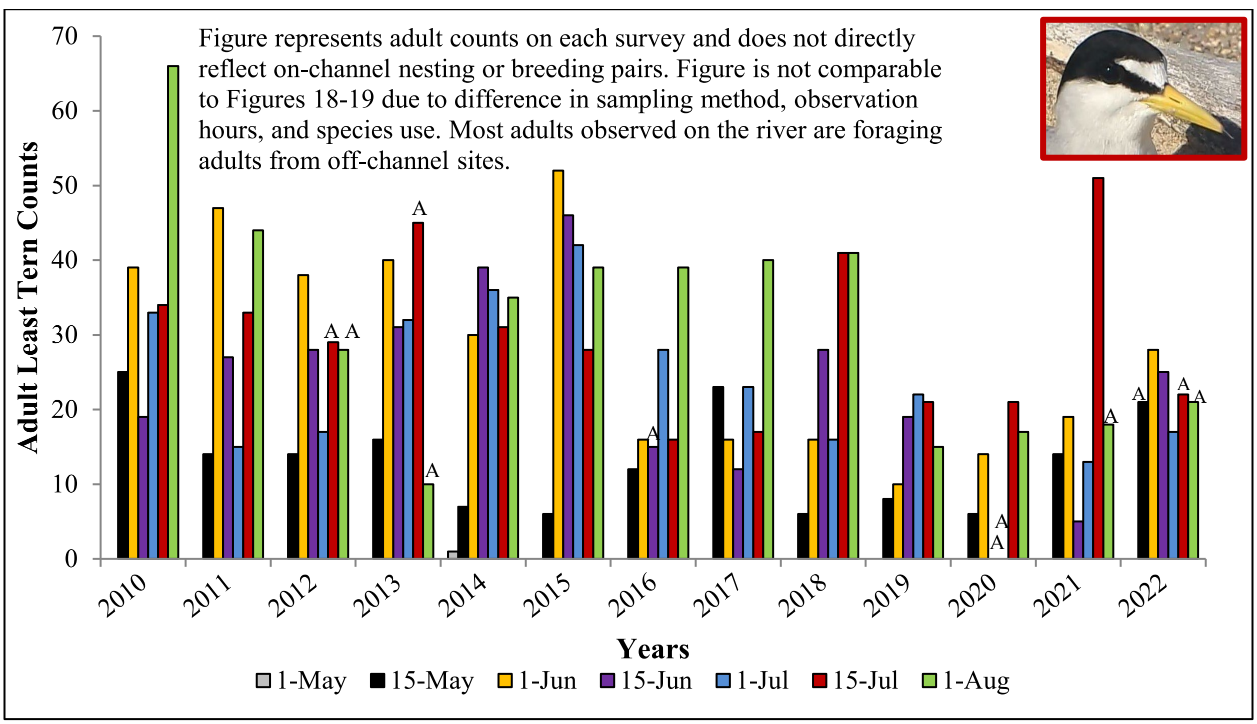

Figure 21. Numbers of least tern adults observed during seven semi-monthly surveys of the Platte River between Lexington and Chapman, Nebraska, 2010-2022.

[A] Sample periods for which at least one section of the river was not completed due to a lack of flow in the channel, high flow, or other restrictions.

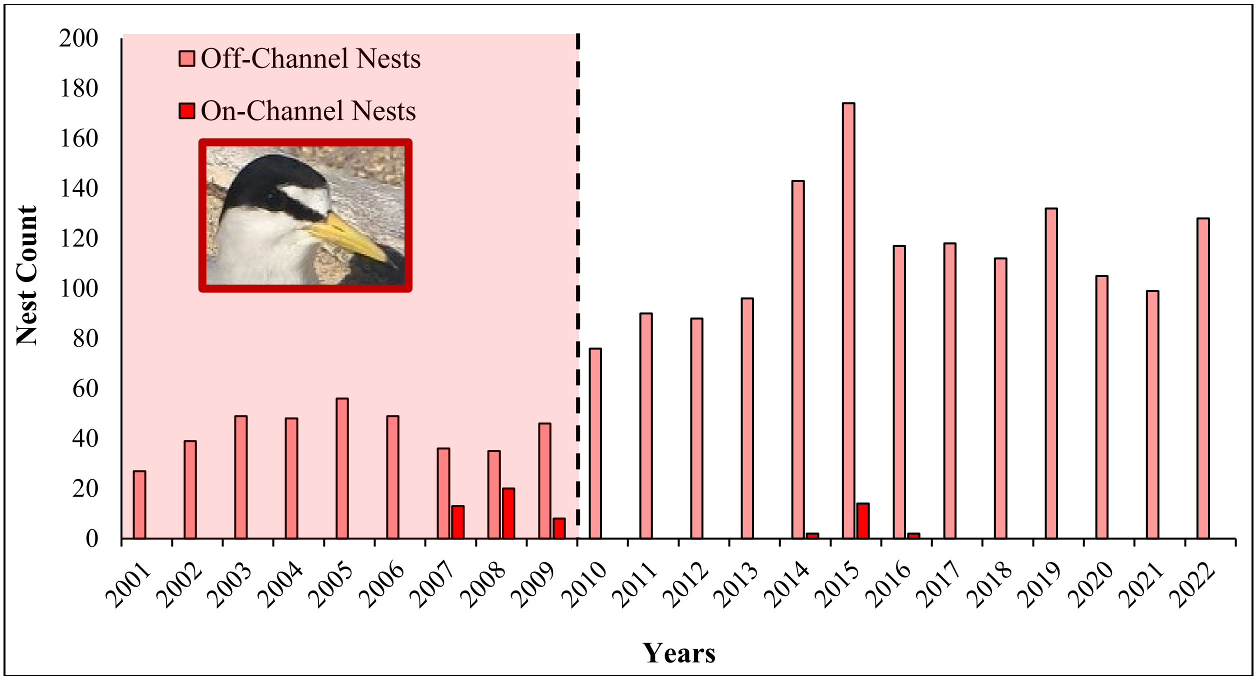

Figure 22. Comparison of the number of least tern off-channel (light red bars) and on-channel (dark red bars) nests observed within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska, 2001-2022. The black dotted line represents changes in protocol, including an increase in monitoring effort, and the shaded area represent years that are not as easily comparable to current protocols used during 2010-2022.

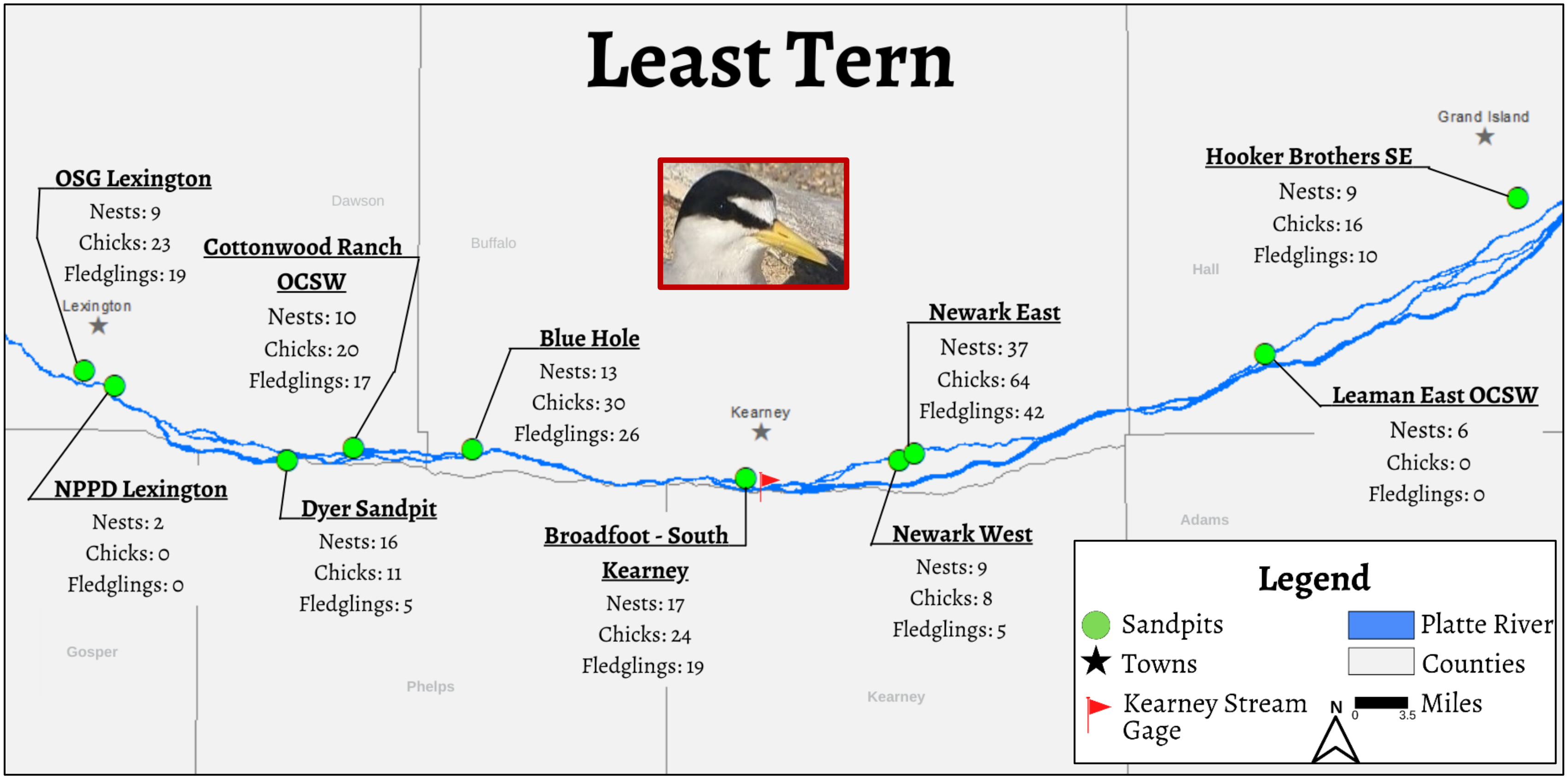

Figure 23. Distribution and numbers of least tern nests, chicks, and fledglings observed within the Program Associated Habitat Reach during 2022 surveys of the Platte River between Lexington and Chapman, Nebraska. Least tern nests and/or chicks were observed and monitored at 10 of the 18 off-channel sites. Kearney stream gage (USGS gage 06770200) marked in red (USGS 2022).

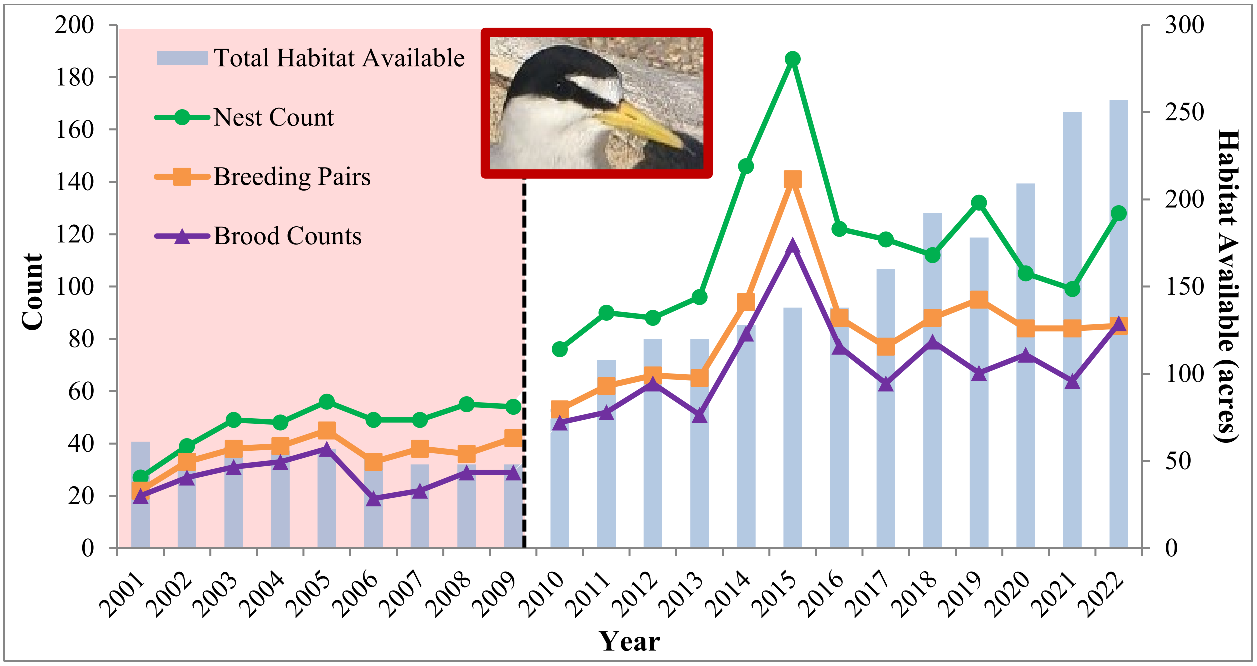

Figure 24. Annual total numbers of least tern nests (green line), peak breeding pairs (orange line), brood counts (purple line), and total habitat available (blue bars) observed within the Program Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska, 2001-2022. The black dotted line represents changes in protocol. Some data in the shaded area may not be comparable across all years. Due to access restrictions that limited monitoring at some sites, available habitat from 2001-2009 only includes sites that were used in the reproductive and survival calculations each year.

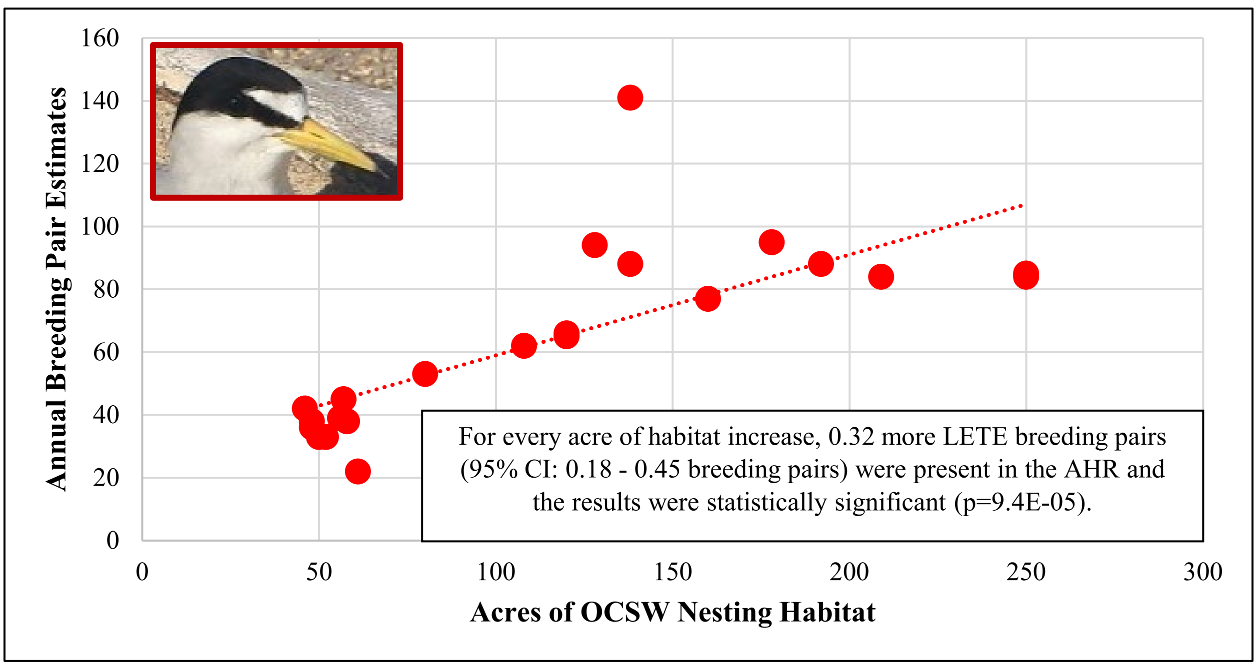

Figure 25. Relationship between numbers of least tern (LETE) breeding pairs and availability of monitored OCSW habitat within the Program Associated Habitat Reach (AHR) along the Platte River between Lexington and Chapman, Nebraska, 2001-2022. Due to access restrictions that limited monitoring at some sites, available habitat from 2001-2009 only includes sites that were used in the reproductive and survival calculations each year.

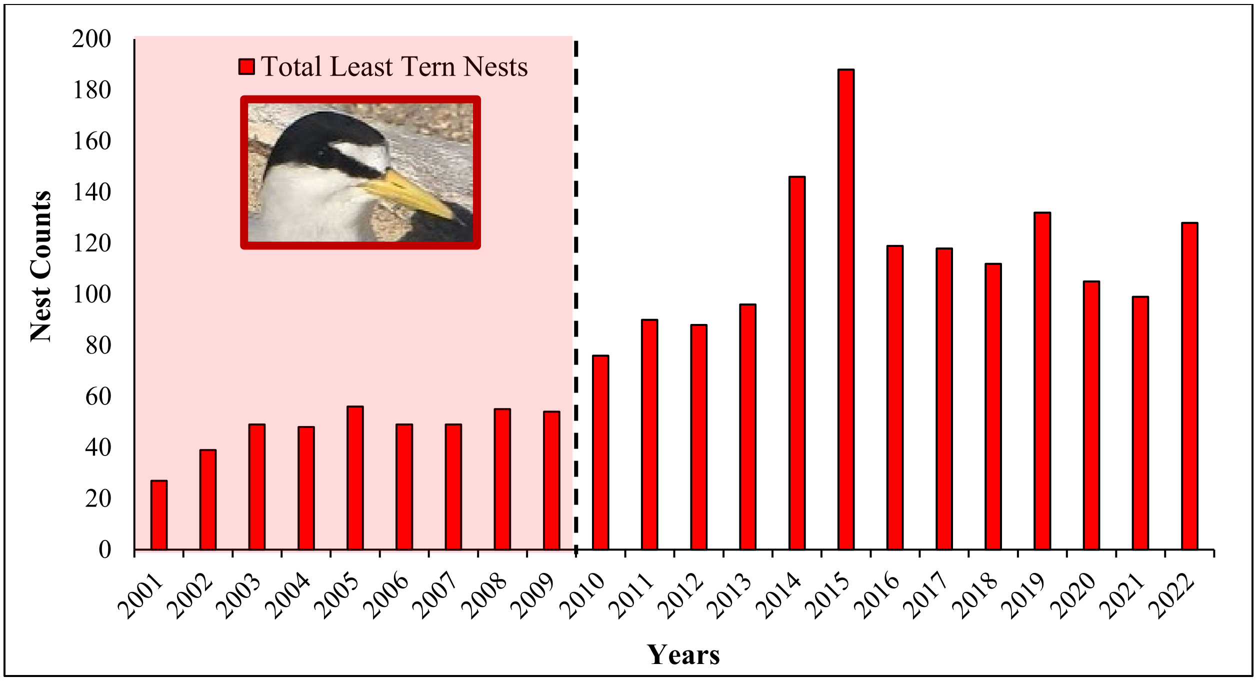

Figure 26. Total on- and off- channel least tern nests across the Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska, 2001-2022. The black dotted line represents changes in protocol, including an increase in monitoring effort, and the shaded area represent years that are not as easily comparable to current protocols used during 2010-2022.

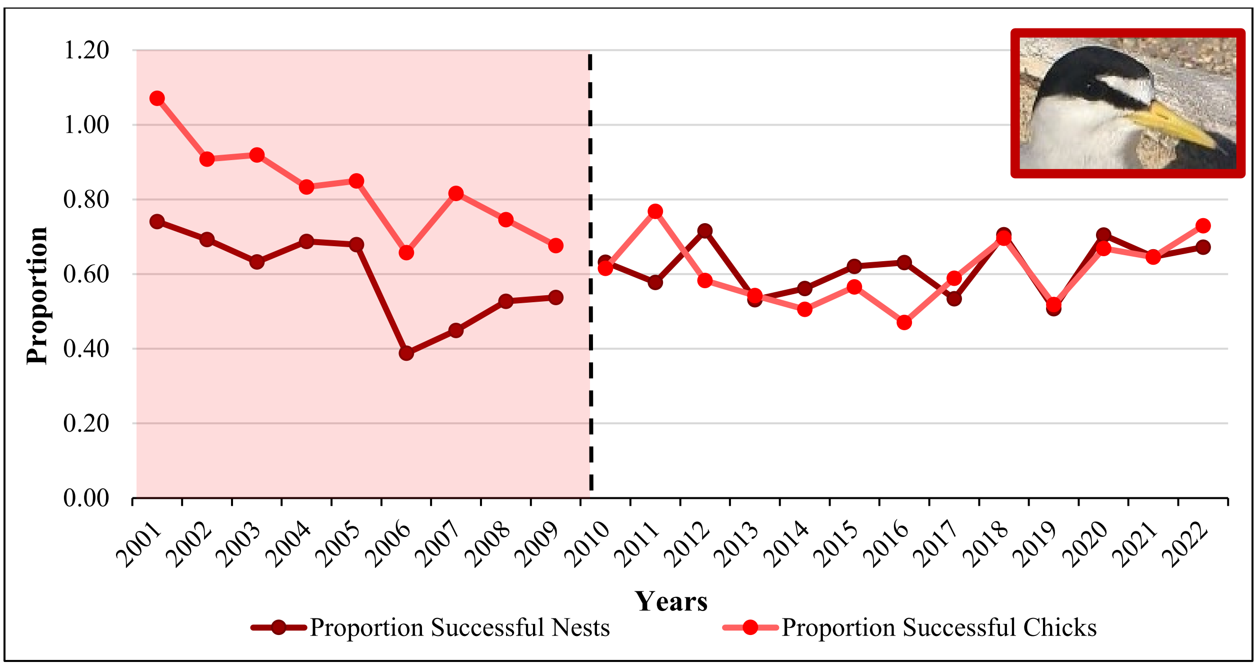

Figure 27. Proportion of successful nests (apparent nest success) and proportion of successful chicks (proportion of chicks fledged) for least terns from 2001-2022 across the Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska. The black dotted line represents changes in protocol, and the shaded area represents data that is not comparable to that from 2010-2022. Among other changes, fledge age was changed from a 15-day success benchmark to 21 days for terns.

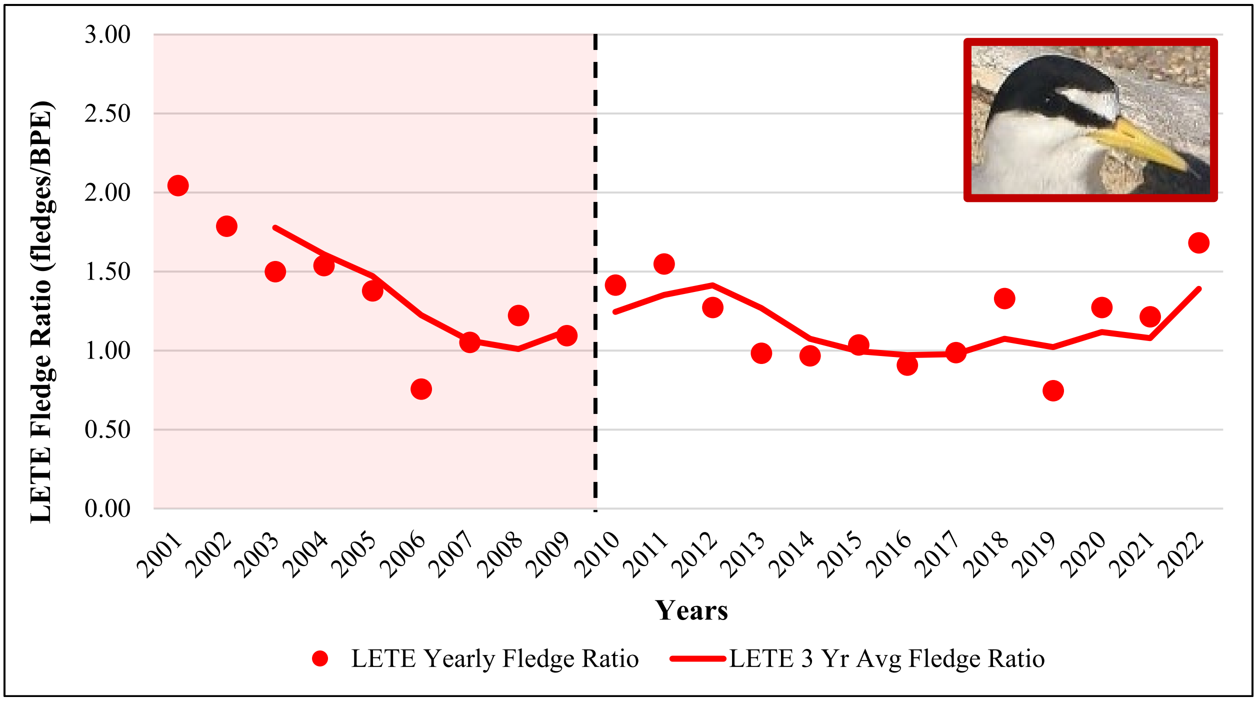

Figure 28. Least tern (LETE) fledge ratios (fledges/estimated breeding pairs [BPE]) on annual (point) and 3-year running average (line) bases from 2001-2022 across the Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska. The black dotted line represents changes in protocol, and the shaded area represents data that is not comparable to that from 2010-2022. Among other changes, fledge age was changed from a 15-day success benchmark to 21 days for terns.

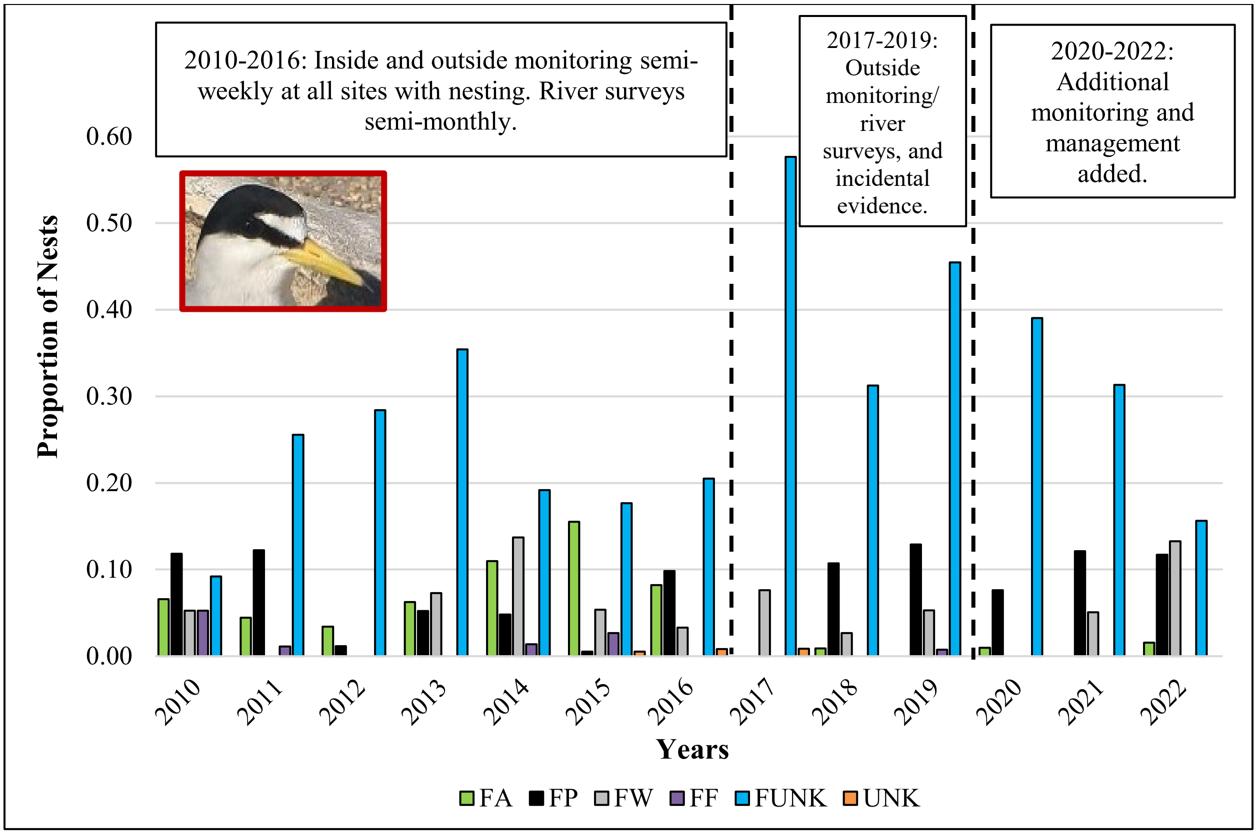

Figure 29. Proportion of combined nest and brood losses in each category for least terns from 2010-2022 across the Associated Habitat Reach along the Platte River between Lexington and Chapman, Nebraska. Each loss represents a unique reproductive attempt. The assigned causes of loss include failed-abandoned (FA; green), failed-predated (FP; black), failed-weather (FW; grey), failed-flooded (FF; purple), failed-unknown (FUNK; blue), and unknown (UNK; orange). The dotted black lines represent changes in monitoring protocol. Protocols for the fating of nests and broods have evolved and have gradually become more accurate and consistent. For the purpose of this figure, all unknown nests from 2010-2021 were re-fated according to current protocol and definitions so they were directly comparable.

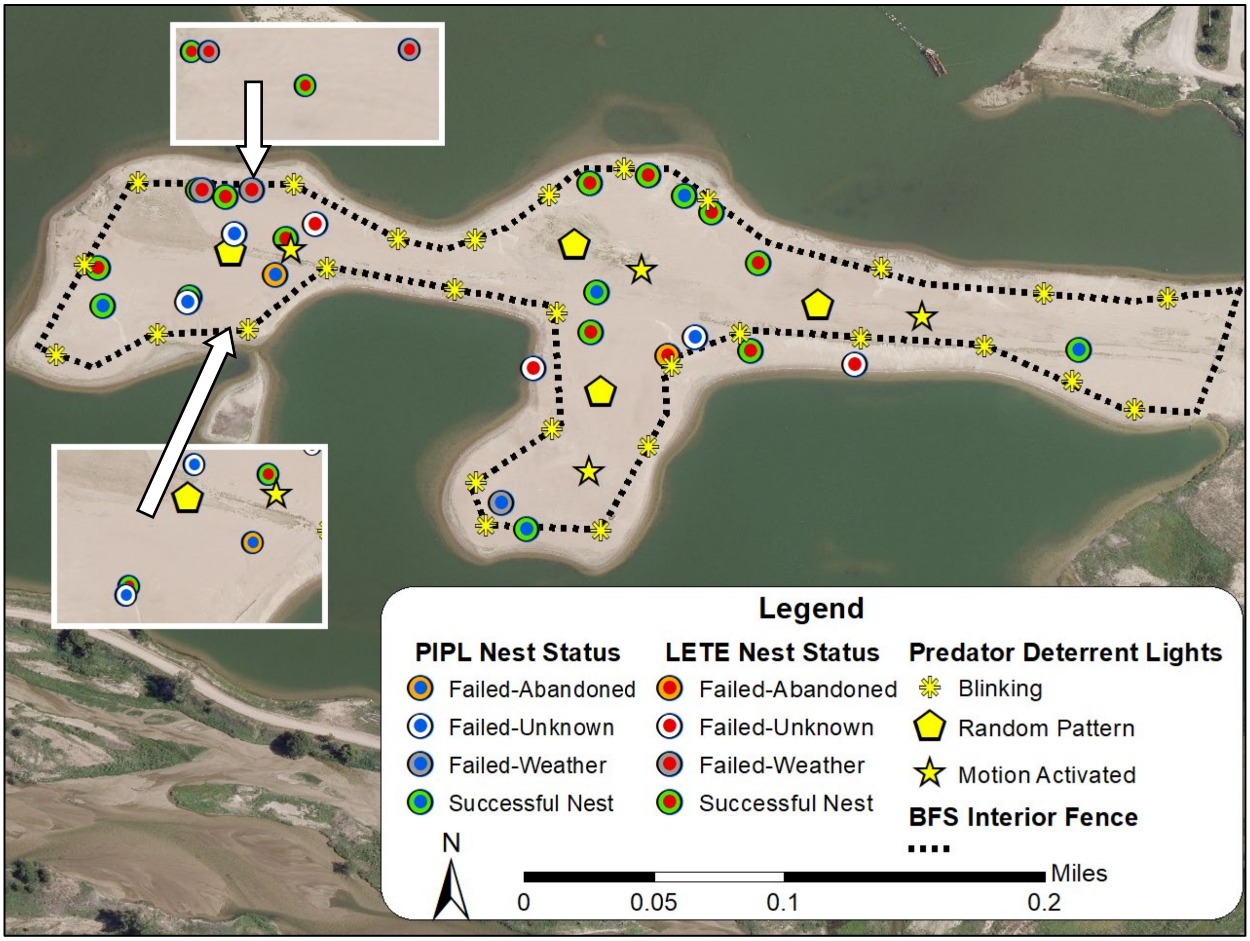

Figure 30. Piping plover (PIPL, blue inner dot) and least tern (LETE, red inner dot) nest locations and additional management setup on the Broadfoot-South Kearney OCSW site. The interior predator exclusion fence (black dashed line) was deployed along the shoreline, random pattern lights (yellow hexagon) and motion activated lights (yellow stars) deployed in sets and evenly distributed, and the blinking walking lights (yellow asterics) were mounted to the fenceline to give the illusion of movement. Final nest status is denoted by colored outer rings. Failed-abandoned is light orange, failed-unknown is white, failed-weather is gray, and successful nests are green.

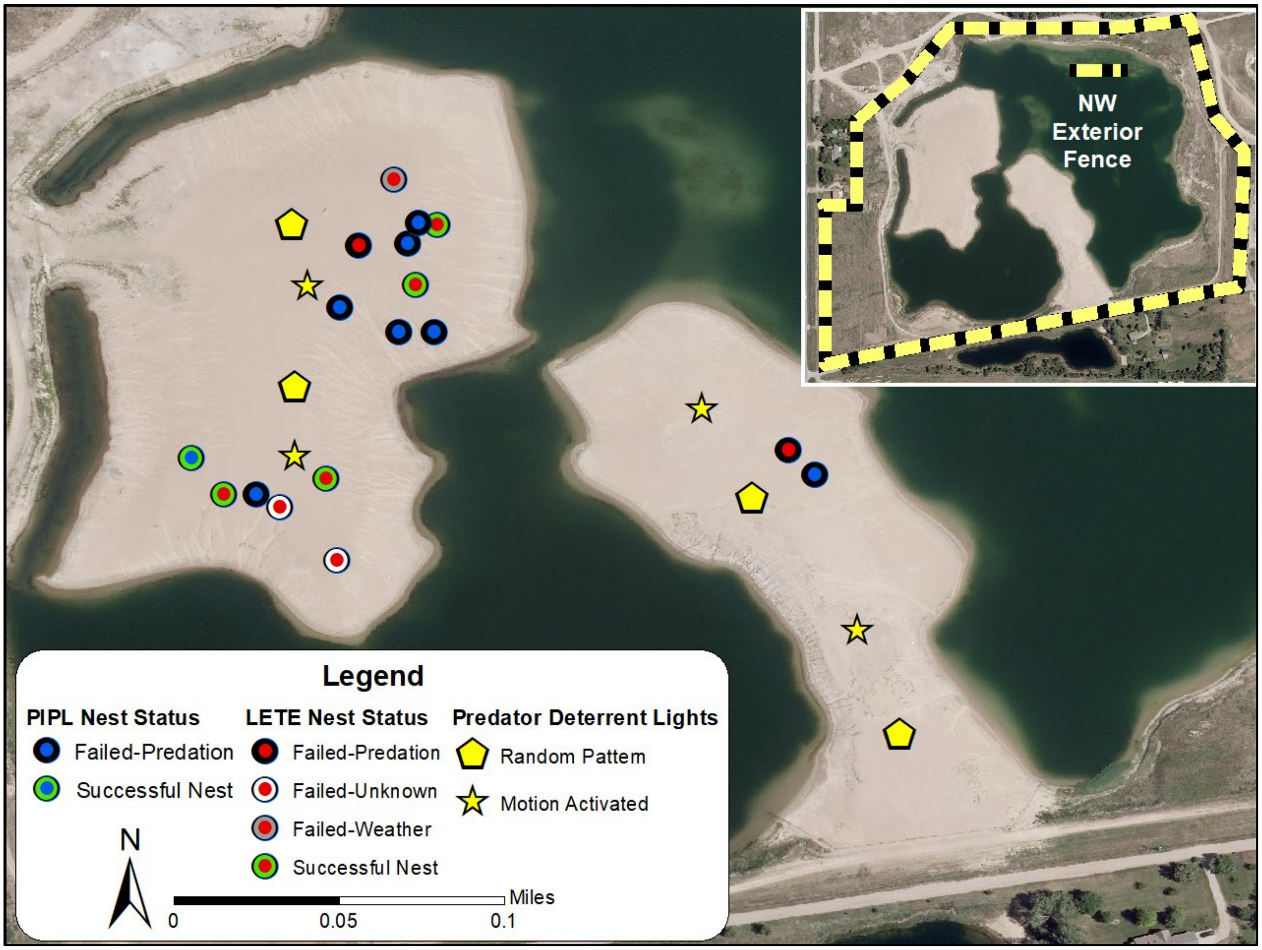

Figure 31. Piping plover (PIPL, blue inner dot) and least tern (LETE, red inner dot) nest locations and additional management setup at the Newark West OCSW site. The exterior predator exclusion fence (black and yellow dashed line) was deployed outside the moat, random pattern lights (yellow hexagon) and motion activated lights (yellow stars) were deployed in sets and evenly distributed. Final nest status is denoted by colored outer rings. Failed-predation is black, failed-unknown is white, failed-weather is gray, and successful nests are green.

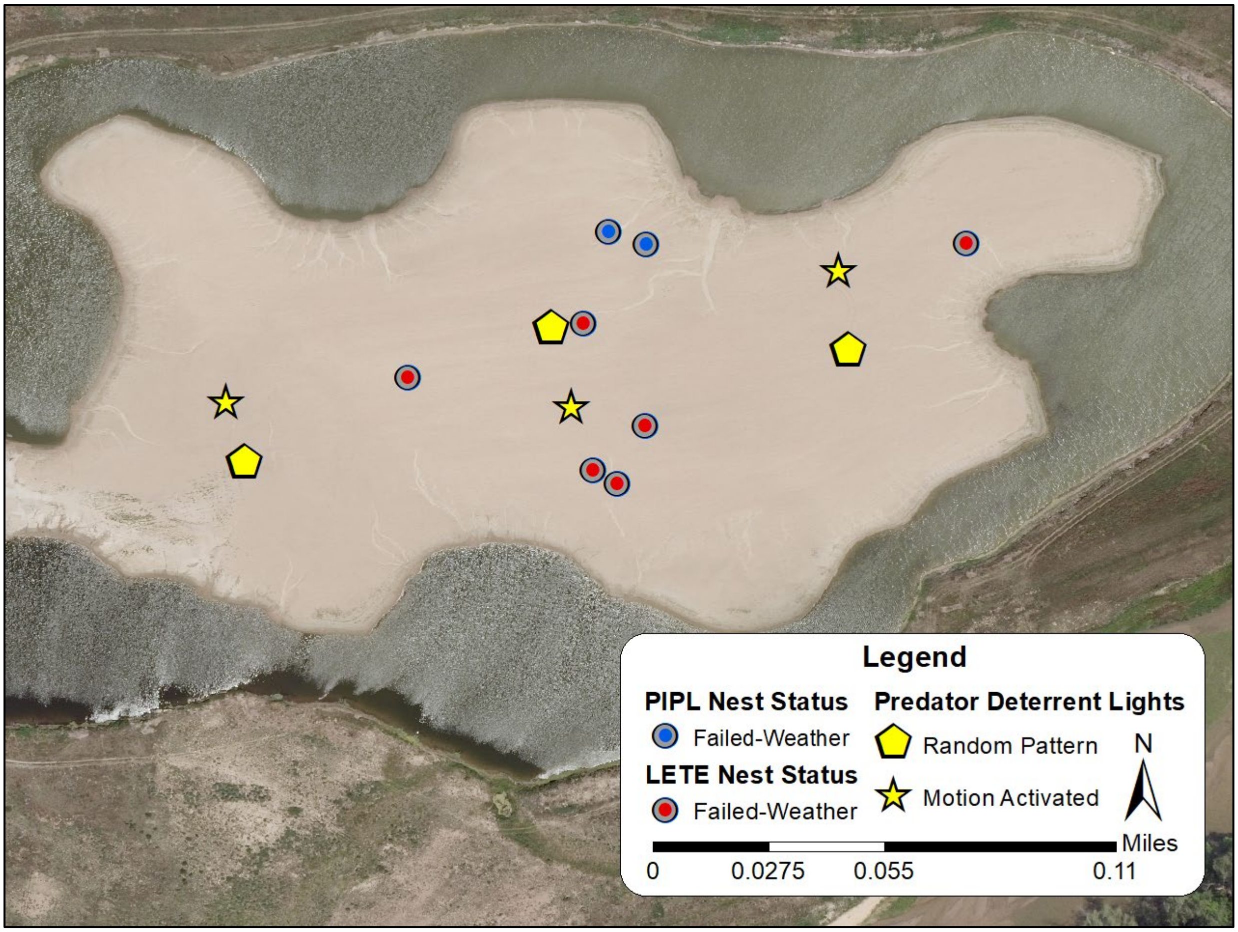

Figure 32. Piping plover (PIPL, blue inner dot) and least tern (LETE, red inner dot) nest locations and additional management setup at the Leaman East OCSW site. The random pattern lights (yellow hexagon) and motion activated lights (yellow stars) were deployed in sets and evenly distributed. Final nest status denoted by colored outer rings, with failed-weather represented by gray.

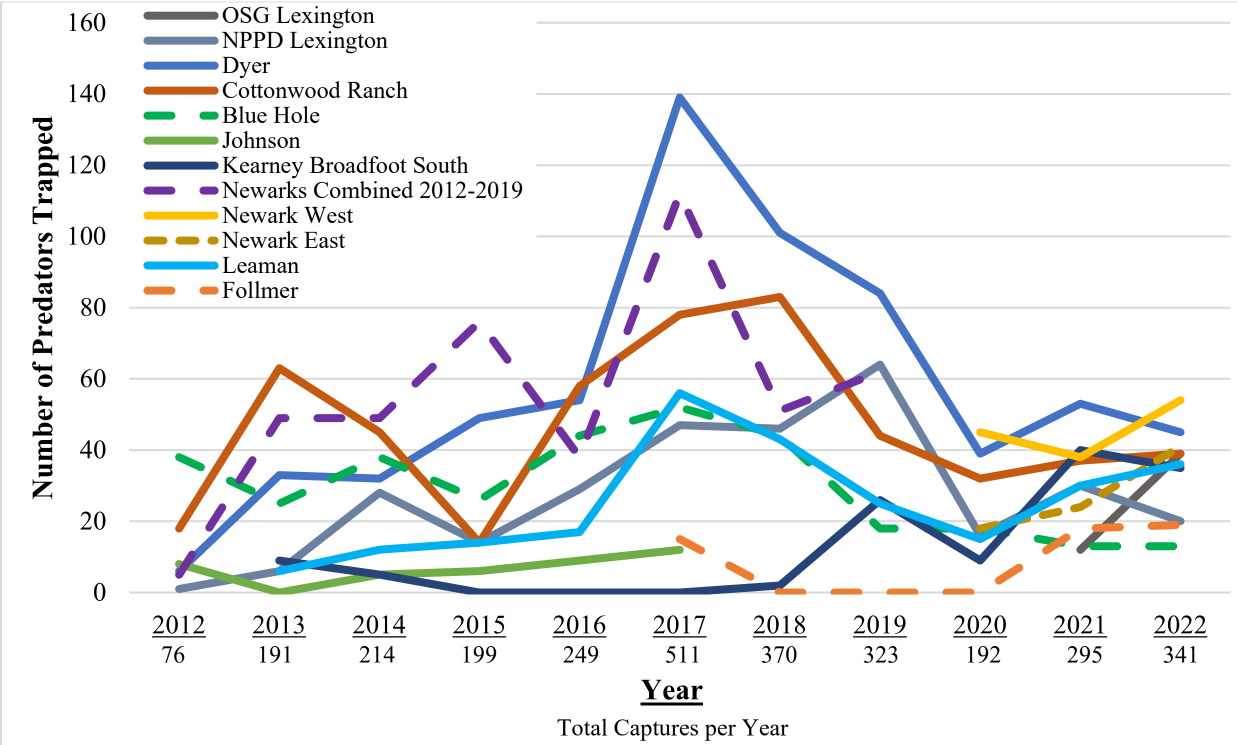

Figure 33. Numbers of predators trapped at Nebraska Public Power District and Program-managed off-channel nesting sites during 2012–2022. Predator trapping efforts at off-channel sites increased substantially in 2017. Trapping did not occur at Kearney Broadfoot South during 2012. Captures only occurred at Follmer in 2017, and 2021-2022 despite trapping effort from 2017-2022. 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.

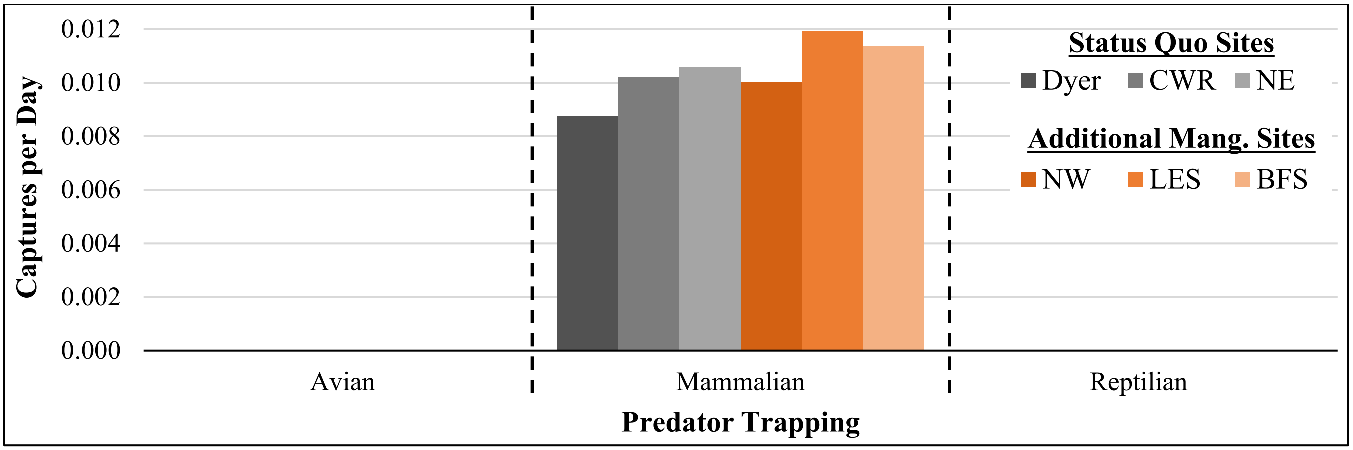

Figure 34. Potential avian, mammalian, and reptilian predators captured per day at six off-channel nesting sites with status quo (grey bars) or additional predator management (orange bars) as registered by daily trapping. The number of unique predators trapped at a site was divided by the number of total trap days for that site. This was done to facilitate comparisons of potential predator presence across sites while controlling for monitoring effort. Status quo sites were Dyer, Cottonwood Ranch (CWR), and Newark East (NE). Additional management sites were Newark West (NW), Leaman (LES), and Kearney Broadfoot South (BFS).

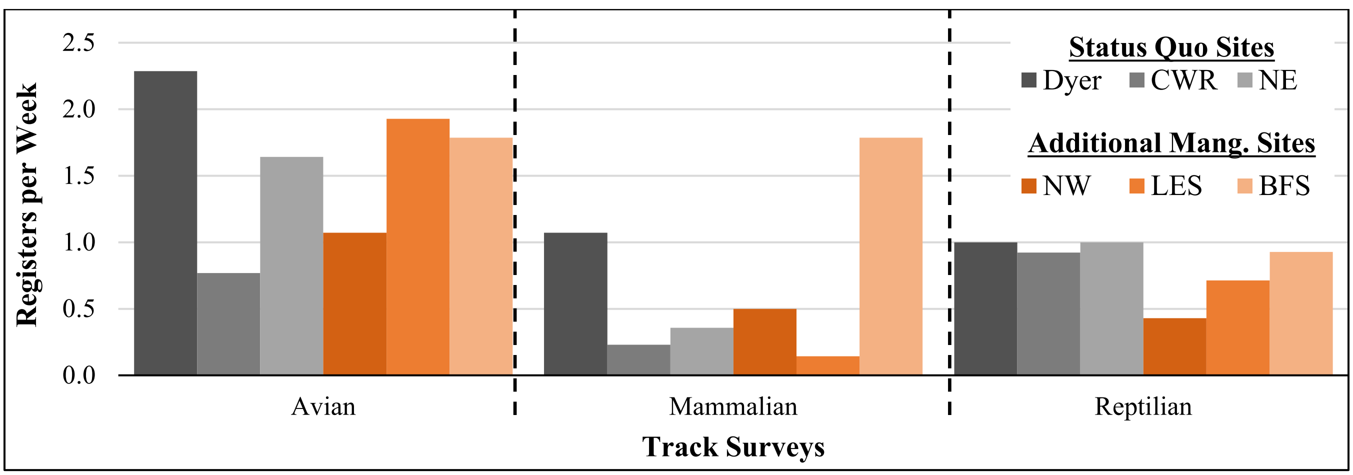

Figure 35. Potential avian, mammalian, and reptilian predators registered per week at six off-channel nesting sites with status quo (grey bars) or additional predator management (orange bars) as registered by weekly track surveys. The number of unique potential predator tracks at a site was divided by the number of total weekly track surveys for that site. This was done to facilitate comparisons of potential predator presence across sites while controlling for monitoring effort. Status quo sites were Dyer, Cottonwood Ranch (CWR), and Newark East (NE). Additional management sites were Newark West (NW), Leaman (LES), and Kearney Broadfoot South (BFS).

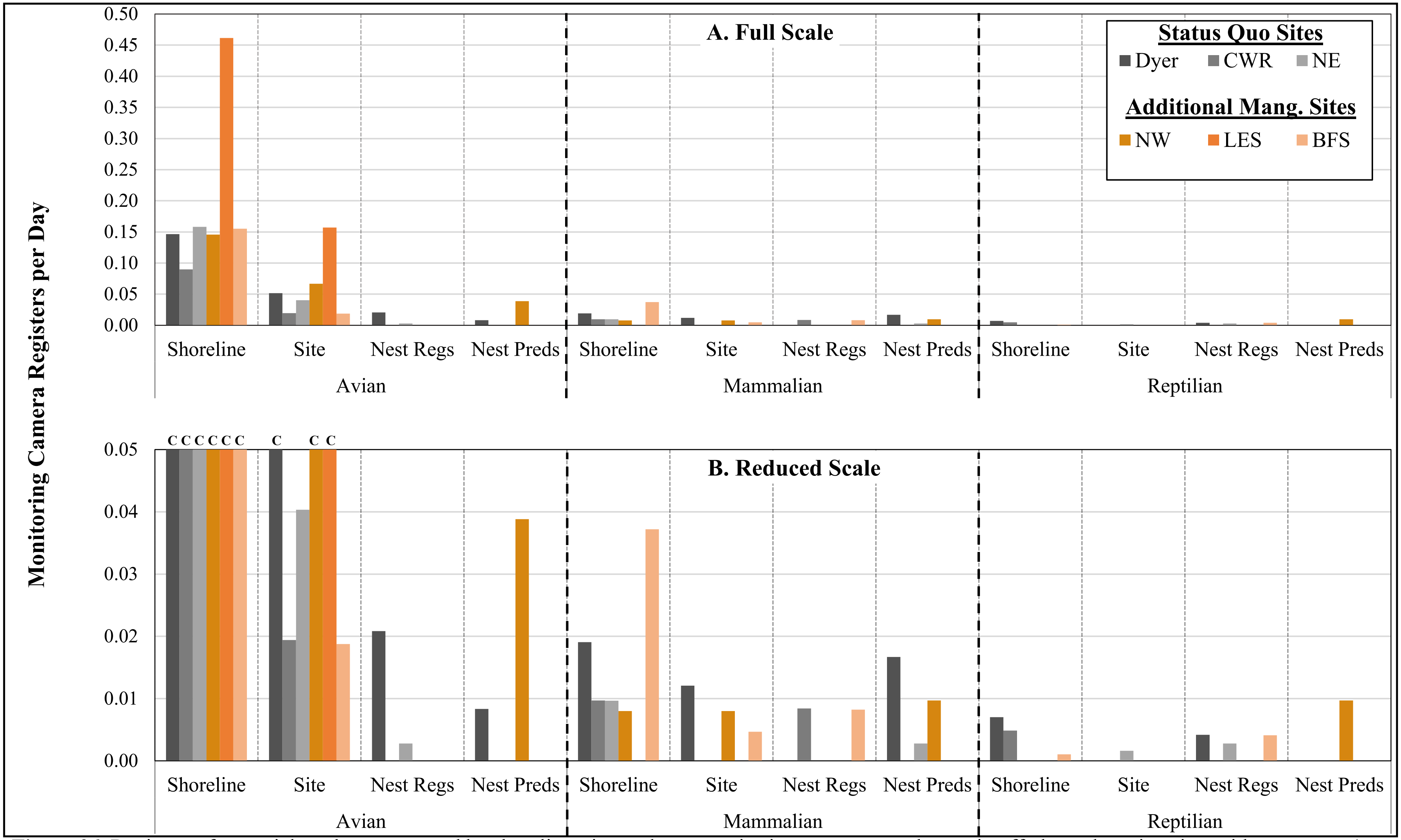

Figure 36. Registers of potential predators captured by shoreline, site, and nest monitoring cameras per day at six off-channel nesting sites with status quo (grey bars) or additional predator management (orange bars) at (A) full y-axis scale, and (B) reduced y-axis scale to show greater detail. The number of unique potential predator registers observed at a site via the indicated monitoring method was divided by the number of total camera days dedicated to the indicated monitoring effort at that site. This was done to facilitate comparisons of potential predator presence across sites while controlling for monitoring effort. Sites defined in text.

[C]Registers surpass y-axis scale. Refer to Figure A (above) for full scale.

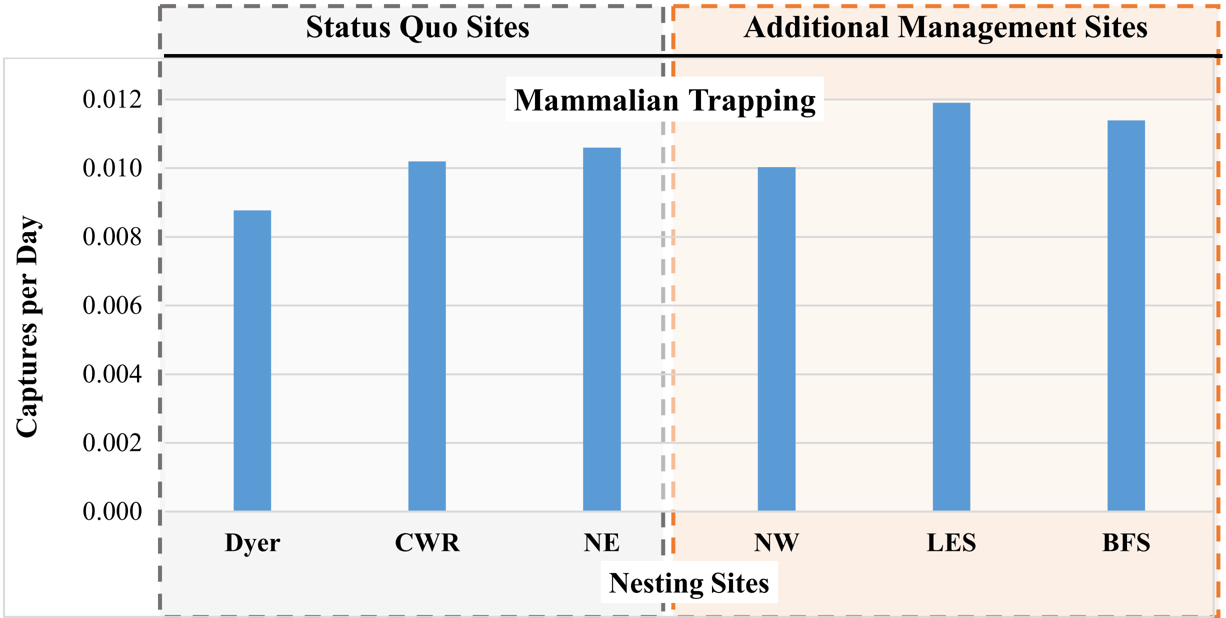

Figure 37. Potential mammalian predators captured per day at six off-channel nesting sites with status quo (to the left with grey background) or additional predator management (to the right with orange background) as registered by daily trapping. The number of unique predators trapped at a site was divided by the number of total trap days for that site. This was done to facilitate comparisons of potential predator presence across sites while controlling for monitoring effort. Nesting site abbreviations are defined in the text.

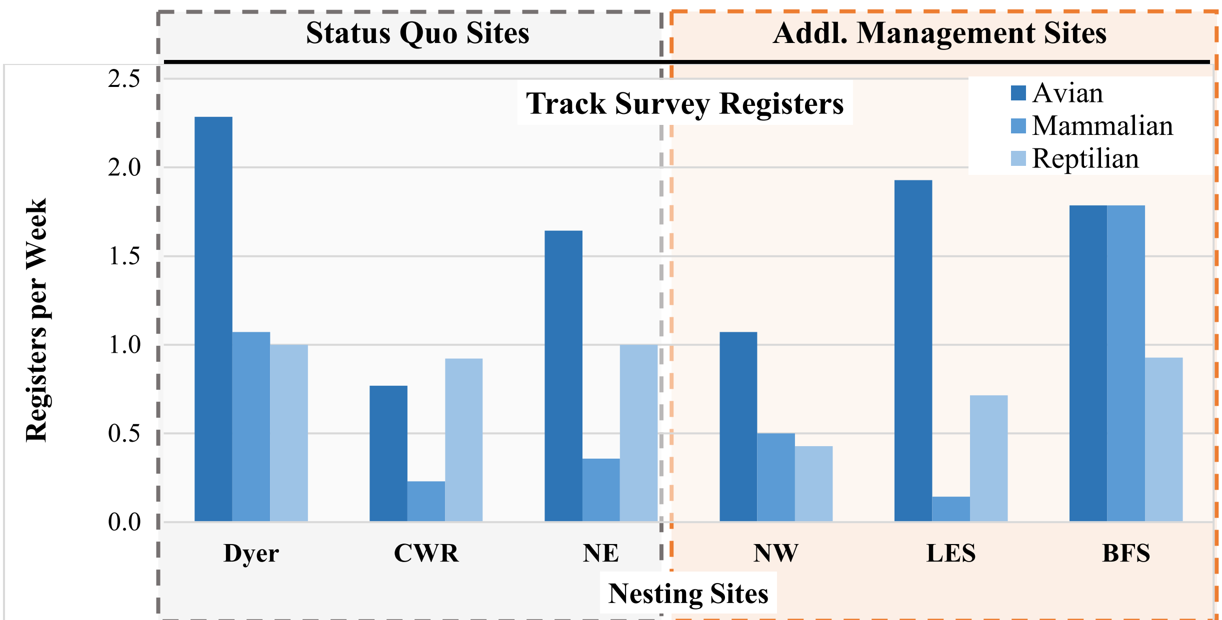

Figure 38. Potential avian, mammalian, and reptilian predators registered by track surveys per week at six off-channel nesting sites with status quo (to the left with grey background) or additional predator management (to the right with orange background). The number of unique potential predator tracks at a site was divided by the number of total weekly track surveys for that site. This was done to facilitate comparisons of potential predator presence across sites while controlling for monitoring effort. Nesting site abbreviations are defined in the text.

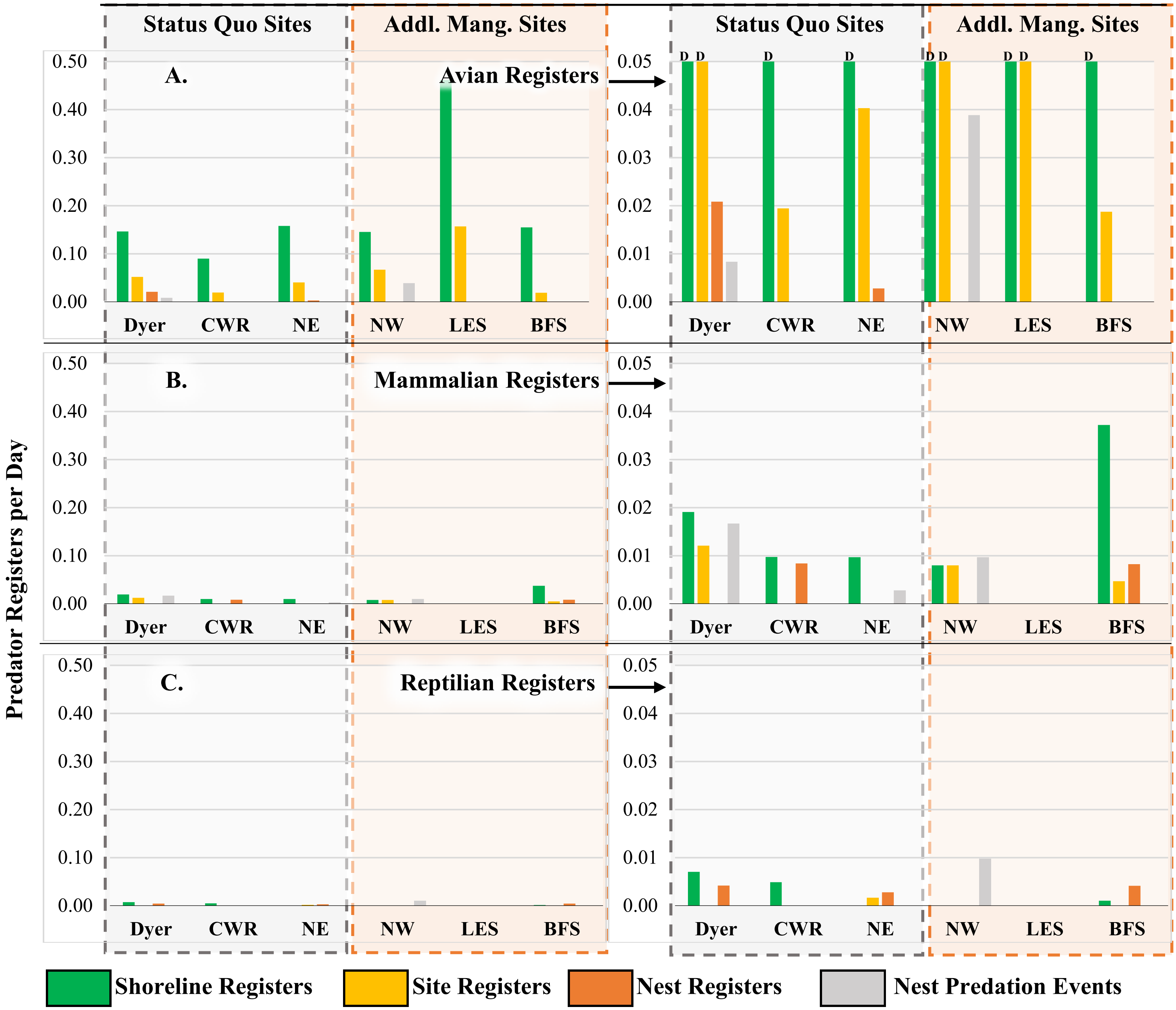

Figure 39. Potential (A) avian, (B) mammalian, and (C) reptilian predators registered by shoreline (green), site (yellow), and nest cameras per day at six off-channel nesting sites at status quo sites (to the left with grey background) and additional predator management sites (to the right with orange background). Potential predators at the nest are denoted with orange and observed predation events at nest are denoted with grey. For A-C, panels on the right are reduced in scale to show greater detail. The number of unique potential predator registers at a site within a given monitoring method was divided by the monitoring effort devoted to that method within each site. Nesting site abbreviations are defined in the text.

[D]Registers surpass y-axis scale. Refer to figure on the left for full scale.

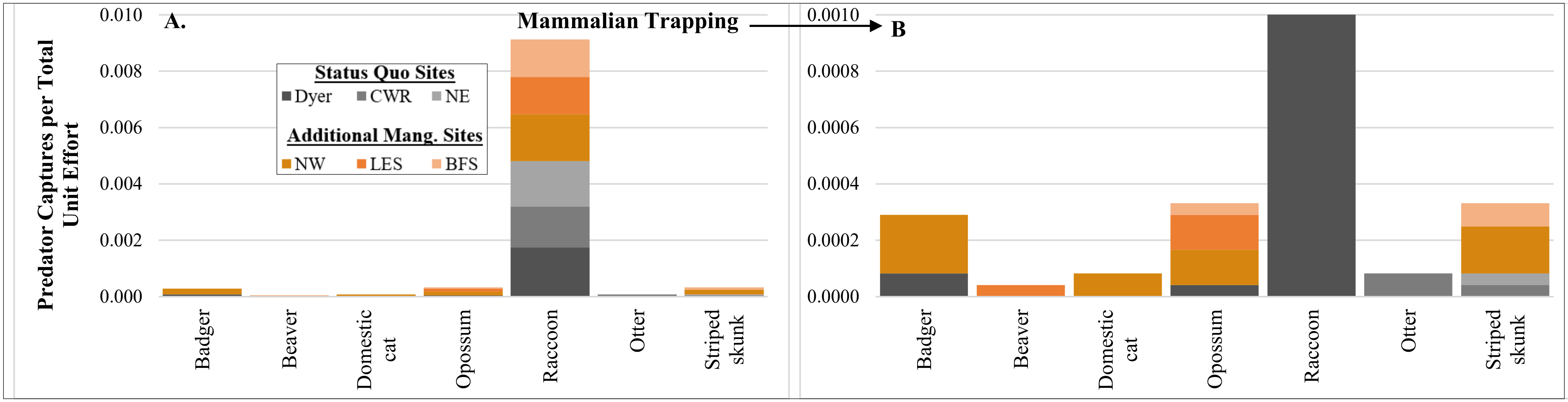

Figure 40. (A) Potential predator species captured in traps per total unit effort across six off-channel nesting sites with status quo (grey bars) or additional predator management (orange bars). (B) Reduced scale to show greater detail. Captures per total unit effort was calculated by taking the total unique captures for each potential predator species at each nesting site obtained through predator trapping divided by the sum of trapping days across all sites. Nesting site abbreviations are defined in the text.

[C]Registers surpass y-axis scale. Refer to figure on the left for full scale.

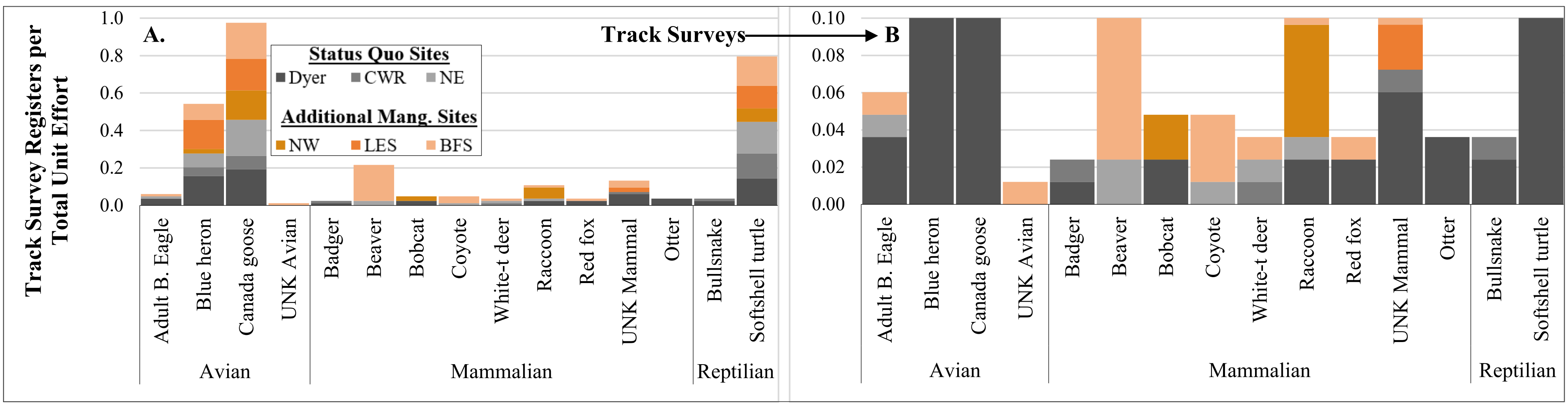

Figure 41. Potential predator species track registers per total unit effort at six off-channel nesting sites with status quo (grey bars) or additional predator management (orange bars). (B) Reduced scale to show greater detail. Registers per total unit effort was calculated by taking the total unique track registers for each potential predator species at each nesting site obtained through weekly track surveys divided by the sum of track surveys conducted across all sites. Nesting site abbreviations are defined in the text.

[C]Registers surpass y-axis scale. Refer to figure on the left for full scale.

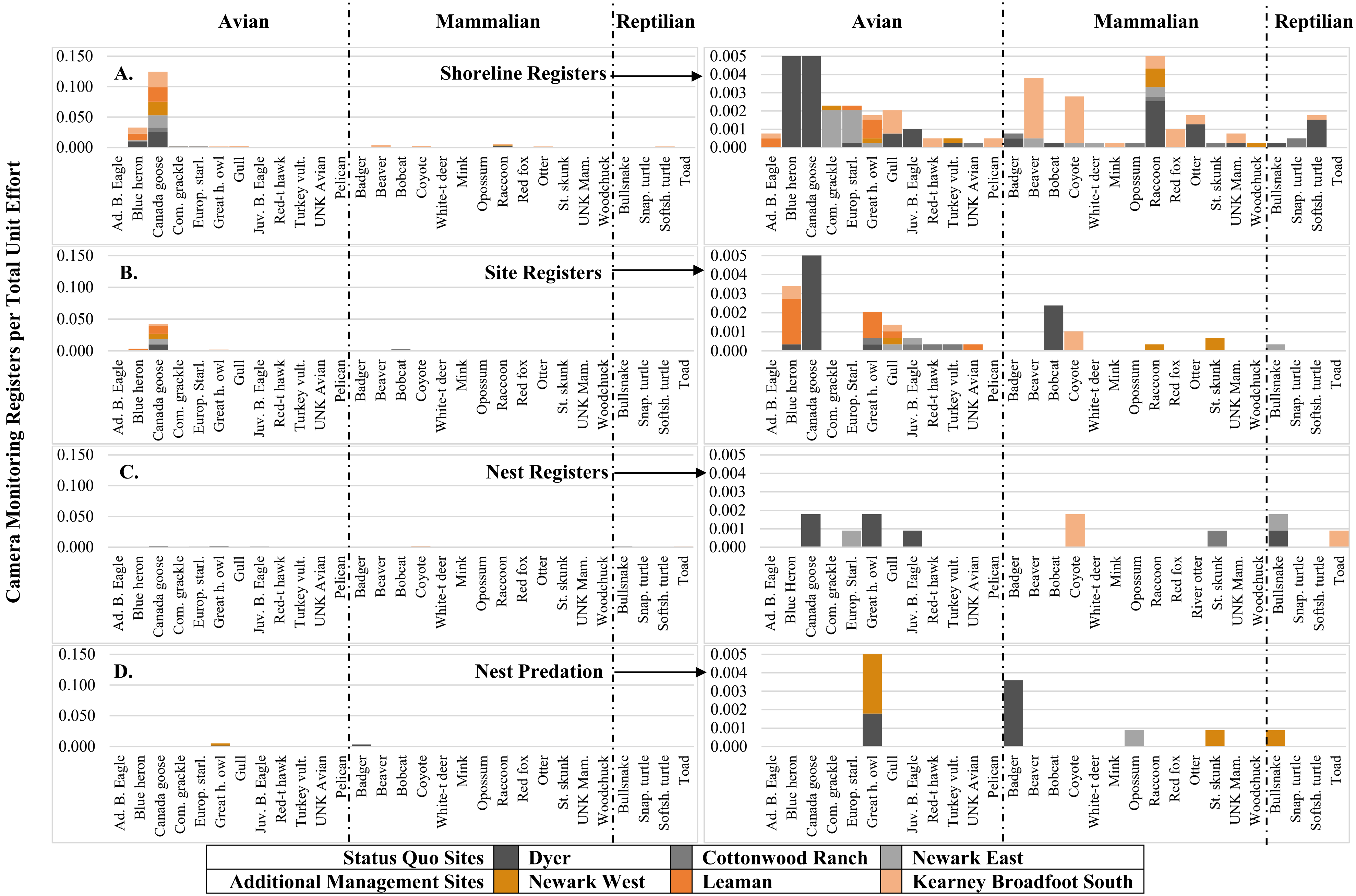

Figure 42. Potential predator species registered at (A) shoreline, (B) nesting site, and (C) nest cameras per total unit effort at six off-channel nesting sites with status quo (grey bars) or additional predator management (orange bars). (D) depicts species observed predating nest documented by nest camera. For Figures A-D, panels on the right are reduced in scale to show greater detail. Registers per total unit effort was calculated by taking the total unique registers for each potential predator species at each nesting site obtained through the specified monitoring method divided by the sum of total effort dedicated to that type of monitoring (camera days) across all sites. Nesting site abbreviations are defined in the text.

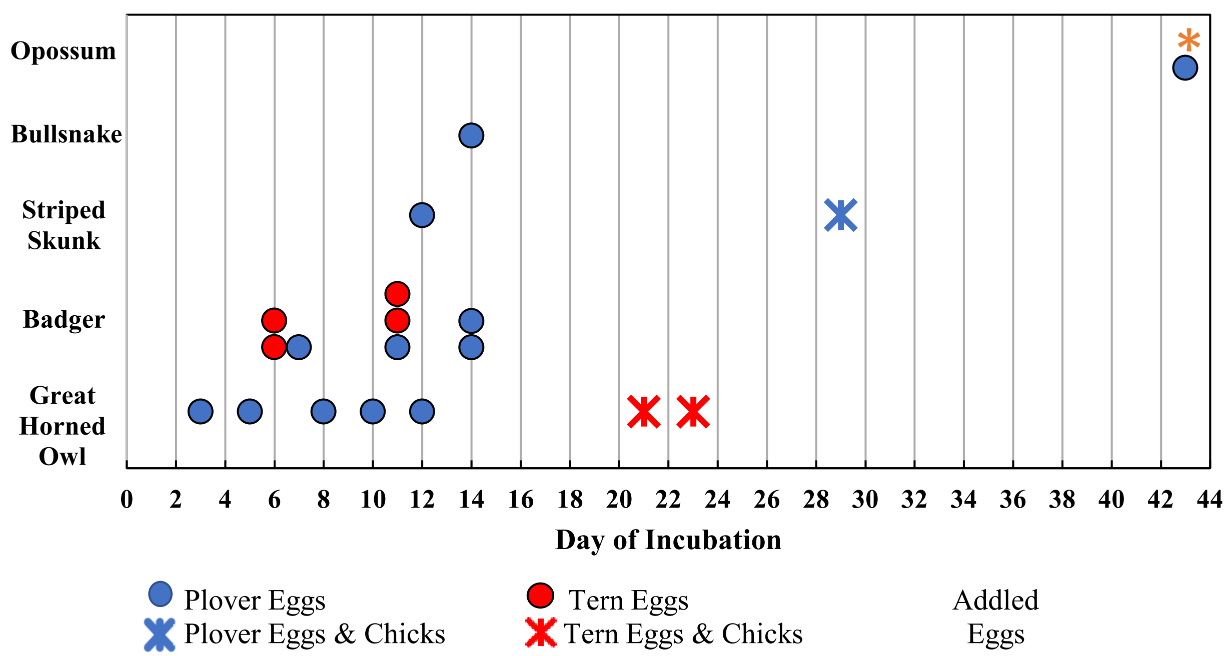

Figure 43. Incubation timeline for nests indicating the day predation occurred on piping plover nests (blue) and least tern nests (red) by Virginia opossum, bullsnake, striped skunk, badger, and great horned owl. Data from all nest monitoring sources (i.e., outside/inside observers; nest, site, and shoreline camera data; and track surveys) were used to determine nest fates. All nests contained eggs, and one plover (X) and two tern nests (X) had newly hatched chicks present when predation occurred. Based on the nest initiation date, one plover nest likely contained addled eggs (*) when predation occurred.

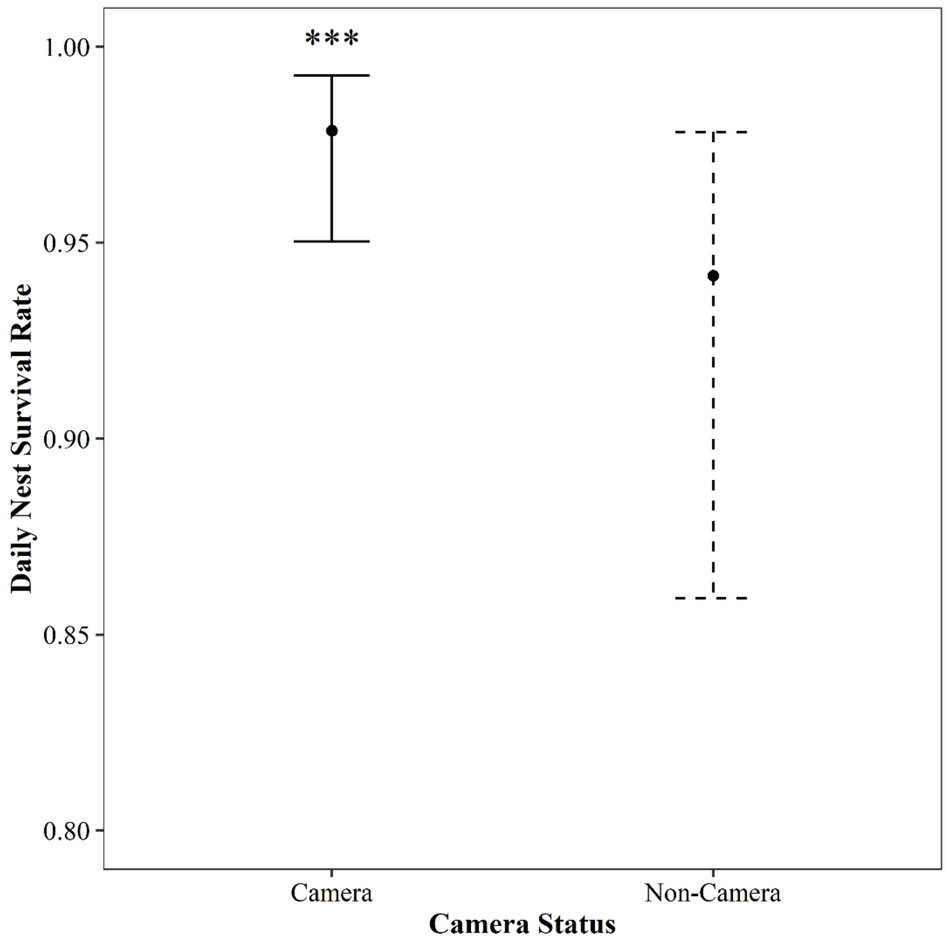

Figure 44. Estimated average daily survival rates of plover and tern nests with a nest camera present (Camera, solid line = 95% CI) or absent (Non-Camera, dashed line = 95% CI) at six off-channel nesting sites in 2022. Average daily nest survival rates were significantly higher for nests with cameras than nests without cameras [$z(1, N = 134) = 3.47$; $p < 0.001$***].

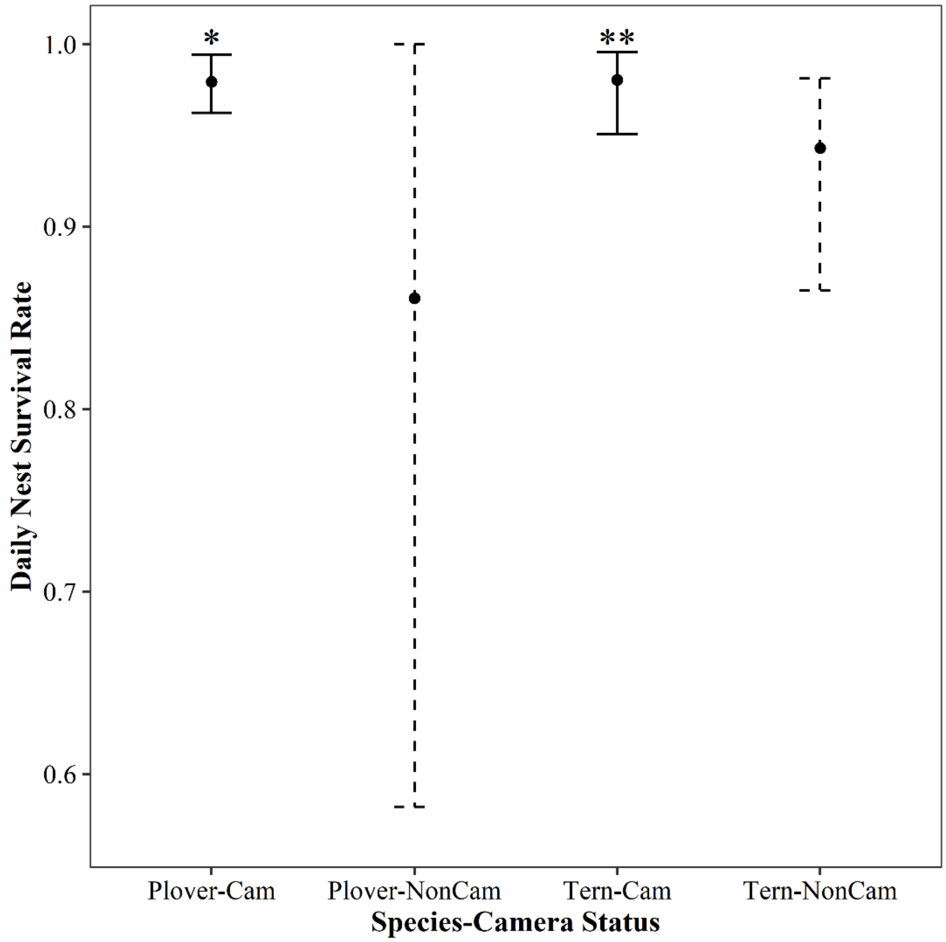

Figure 45. Species-specific average daily survival rates of plover and tern nests with a nest camera present (Cam, solid line = 95% CI) or absent (NonCam, dashed line = 95% CI) at off-channel nesting sites that had nests both with and without cameras in 2022. Average daily nest survival rates were significantly higher for nests with cameras than nests without cameras for plovers [z(1, N = 21) = 2.38; p = 0.02*] and terns [z(1, N = 95) = 2.94; p = 0.003**]. For plover comparisons, only Dyer and Kearney Broadfoot South had plover nests both with and without cameras, so comparisons were limited to plover nests at those two sites. Only three plover nests without cameras were observed at Dyer (one nest) and Kearney Broadfoot South (two nests) and their survival variability created a 95% confidence interval wider than other species and camera status categories with more nests.

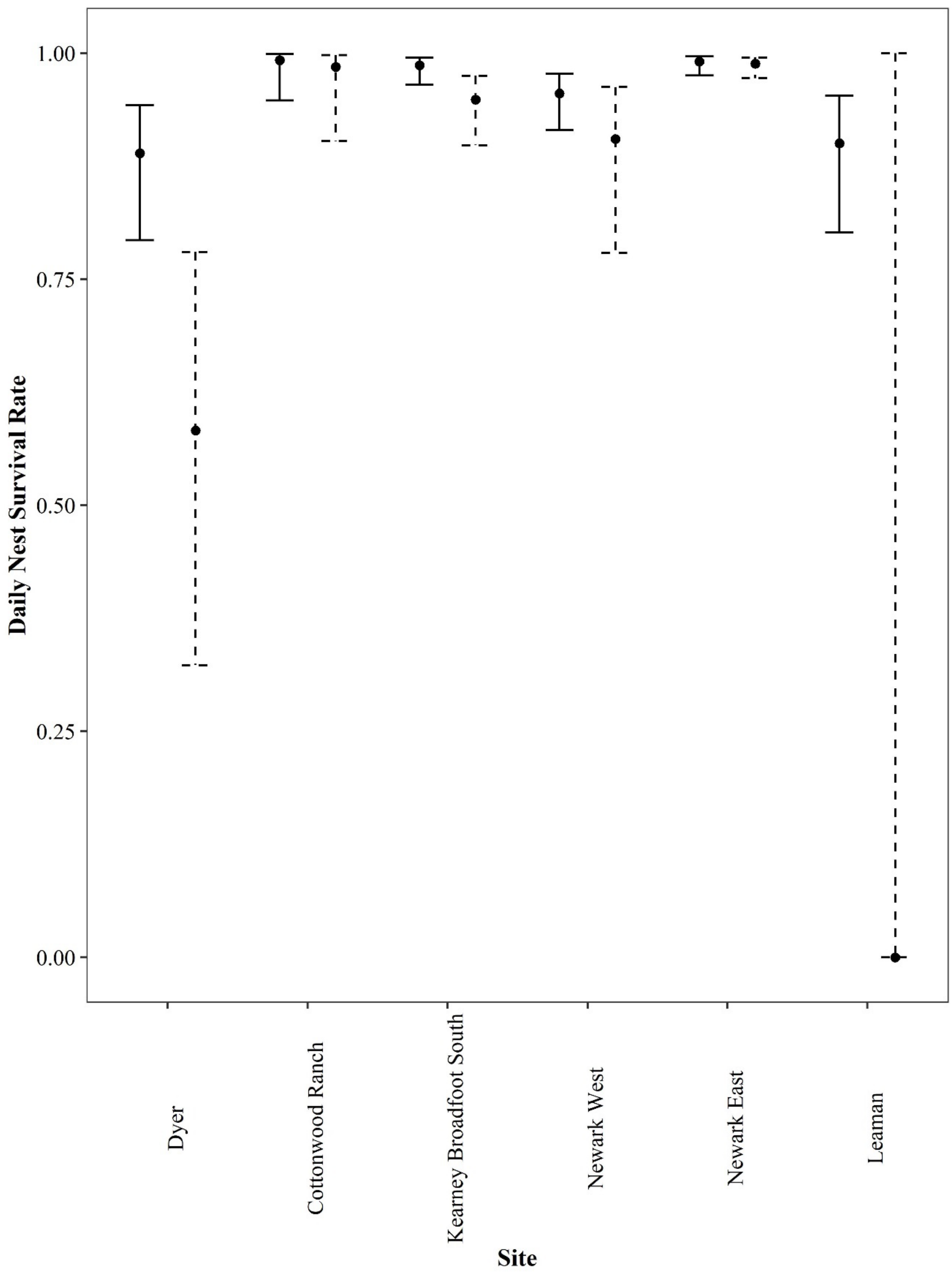

Figure 46. Estimated site-level average daily survival rates of plover and tern nests with nest cameras present (solid line = 95% CI) or absent (dashed line = 95% CI) at six off-channel nesting sites in 2022. All camera-absent nests failed at Leaman (n=2), leading to a 95% confidence interval of 0 to 1 for the site.

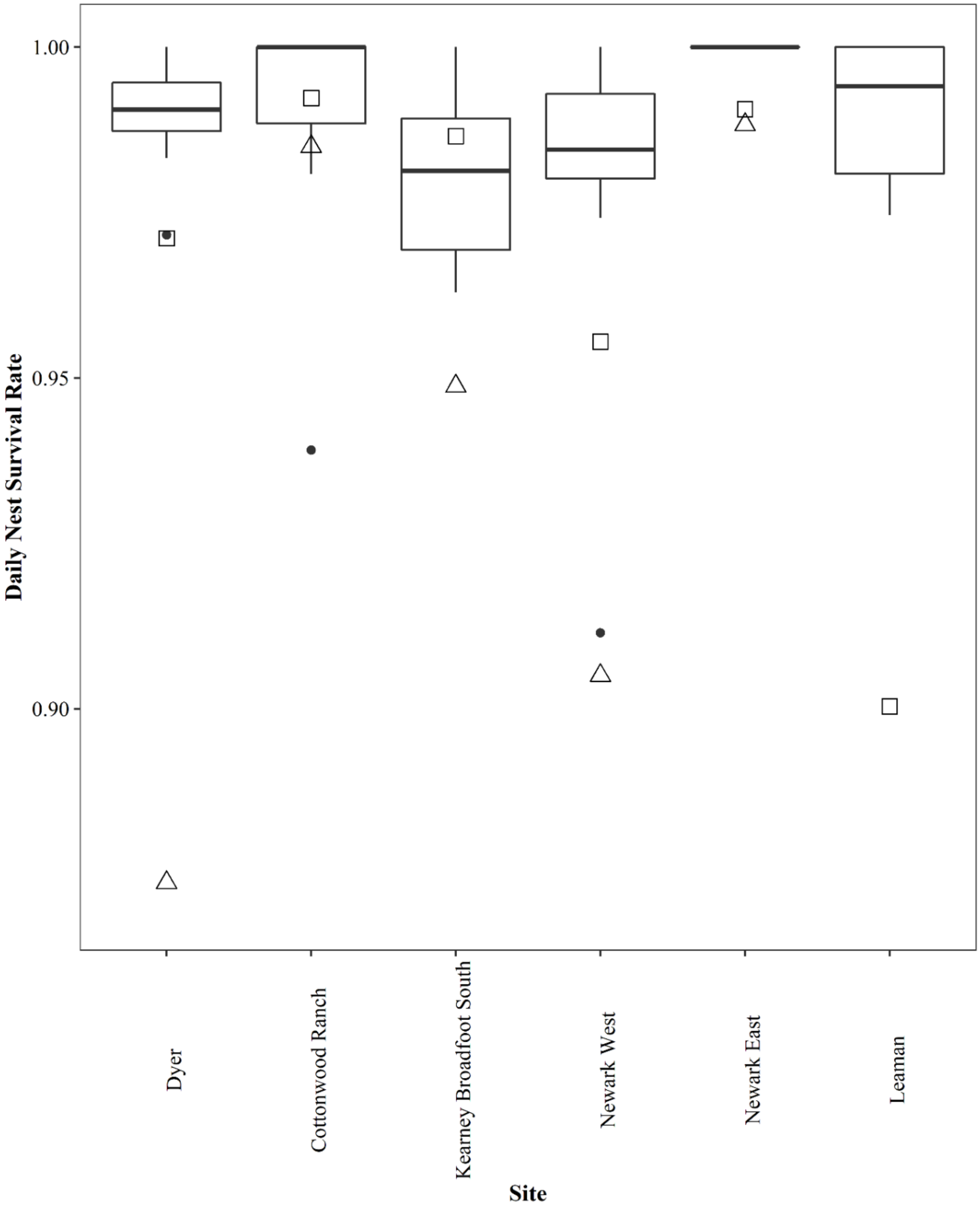

Figure 47. Combined 2022 piping plover and least tern average daily nest survival rates (DSR) of nests with a camera present (hollow square) and absent (hollow triangle) at six off-channel nesting sites compared to the distribution (boxplots) of plover and tern average daily nest survival rates prior to nesting site camera usage with outliers represented as filled circles (2010-2016). Average DSR for nests with and without cameras were lower in 2022 than during 2010-2016 at Dyer, Newark West, Newark East, and Leaman, but average DSR for nests with cameras were at or above camera-absent nest survival rates at all sites in 2022. Points excluded from the figure include the 2022 Leaman site that did not have cameras (DSR = 0) and a Cottonwood Ranch 2010-2016 outlier (DSR = 0).