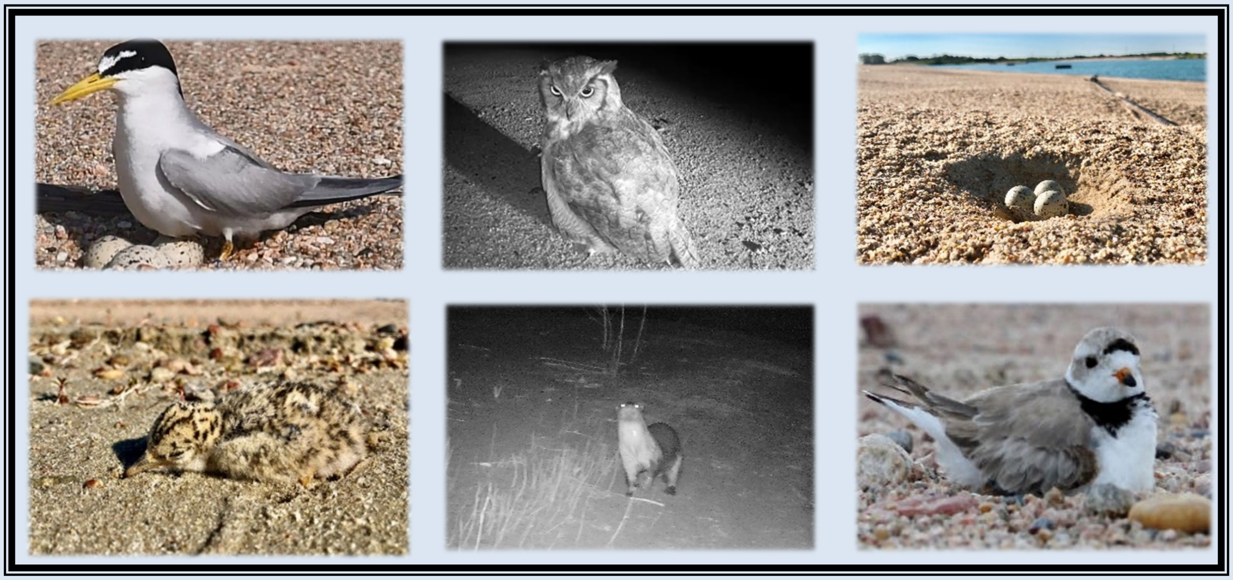
Platte River
Recovery Implementation Program

2021 Piping Plover and Interior Least Tern Monitoring and Research Report, Central Platte River, Nebraska



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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 plovers (plover) and interior least terns (least tern or tern) during 2021. 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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EXECUTIVE SUMMARY

To evaluate progress toward the Platte River Recovery Implementation Program ("Program" or "PRRIP") management objective of improving productivity on the central Platte River of threatened piping plover (*Charadrius melodus*) and interior least tern (*Sternula antillarum*), the Executive Director's Office (EDO) conducted monitoring of piping plovers and interior least terns along PRRIP's Associated Habitat Reach (AHR) on the central Platte River between Lexington and Chapman, Nebraska. Monitoring took place from 02 May to 12 August 2021. 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 2021 focused on implementing additional predator management actions and remote camera monitoring to quantify the impact of predation on piping plover productivity and the effectiveness of additional predator management at reducing predation pressure and mitigating impacts. This focus was a response to the dip in fledge ratios 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, additional predator management in the form of predator exclusion fencing completely surrounding nesting peninsulas and predator deterrent lights were also deployed at three Program managed sites, Broadfoot-South Kearney, Newark West, and Leaman East, 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 all Program managed OCSW sites. 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 2021 season, the number of breeding pairs observed peaked at 36 pairs for plovers and 84 pairs for terns, resulting in a fledge ratio of 0.97 fledges per breeding pair for plovers and a fledge ratio of 1.21 for terns. The Program has observed an overall positive species' response in reproductive output to habitat creation, rehabilitation, and management from 2001-2021. 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 (2010-2021), nest success has remained relatively stable for both species. However, chick success for plovers shows a slight decrease over time, while tern chick success has remained in a stable range. The 2021 fledge ratio for plovers was lower than in 2020 (1.22 in 2020 vs. 0.97 in 2021), but higher than the lows observed in 2018 and 2019 (0.62 in 2018 and 0.67 in 2019). Fledge ratios for terns usually stay within a relatively stable range, though they

also experienced a low in 2019 (0.75). Least tern fledge ratios were marginally higher in 2020 (1.27) than in 2021(1.21), but both numbers are similar to, if not slightly better than, previous years. Piping plover and least tern 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, Broadfoot-South Kearney (Broadfoot), Blue Hole, and Leaman East (Leaman) continued to have poor plover nest and brood survival. No tern nesting occurred on Leaman, however Broadfoot and Blue Hole had poor nest and brood survival for terns as well. Remote camera monitoring conducted on the two Program monitored sites, Broadfoot and Leaman, indicate that predation was responsible for nest loss. Broadfoot and Blue Hole are two sites that have had documented problems with predation in the past and this continued in 2021.

With the exception of 2010 for terns, the highest proportion of loss for both species from 2010-2020 could not be attributed to a known cause (fated as failed-unknown), as there was a lack of sufficient evidence to fate those nests and broods. Losses due to predation (failed-predation) were typically the next highest. In some cases, this is due to evidence not being visible to observers outside the site, but lack of physical evidence in and around the nest bowls is often contributed to by adults who will remove eggshells and other evidence from the area after the event; predator species who are too light to leave clear or lasting tracks in loose sand, including some avian predators; weather events; and several other possible variables. 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. For plovers, the proportion of losses assigned to failed-unknown causes decreased compared to 2020, and part of the reason was likely due to increased monitoring effort. The highest proportion of loss for terns was still the failed-unknown category, with predation as the second. However, remote camera monitoring effort was centered on plovers, so tern nest monitoring likely did not experience as large of a benefit.

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, 1 by an American Crow, and 1 by a badger. There was also one tern nest at Broadfoot-Kearney South that was predated but the camera malfunctioned and did not register the individual predator or the predation event. However, the nest was determined predated because it was inactive and damaged tern eggs were found nearby the nest. The nest was determined predated by an unknown species. 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.

Most potential avian predators were not deterred from occupying nesting peninsulas or predating nests by the deterrent lighting or exclosure fencing. However, the interior predator exclusion fence deployed on Broadfoot-South Kearney did seem to reduce movement onto the interior of the peninsula and nesting area by other avian species that rely more prominently on terrestrial locomotion once they arrive on the peninsula, such as great blue herons and Canada geese. Both of these species present a risk to plovers and terns due to predation or trampling of the eggs or young chicks. This season, heron and geese were infrequently registered at individual nests at Broadfoot but were registered by track surveys and cameras along the shorelines, posing a risk to chicks as they move away from the nest bowl and to the shorelines.

Added predator deterrents did seem to decrease potential terrestrial predator presence with fewer terrestrial predators being registered as moving across barriers from outside the nesting area into the nesting area. A larger number of potential predator registers at a nest and site level, as well as the single observed mammalian predation event, occurred on sites without additional management. Data from track surveys combined with shoreline cameras reveal a more diverse and numerous predator community capable of making it onto nesting sites, though site-level cameras did not document presence of many of these species. Site-level cameras set up higher from the ground to give a wider field of view and capture triggers from avian predators may have created a "blind spot" at this level of monitoring.

Though minor changes to site-level camera setup may be necessary moving forward, the Program plans to continue implementation of additional management and monitoring of results, to further quantify the impact of predation and determine 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 Program is responsible for implementing certain aspects of the threatened piping plover (plover) and the recently delisted interior least tern (least tern or tern) recovery plan.

The northern Great Plains population of piping plovers was listed as threatened on January 10, 1986. The least tern was listed as endangered on June 27, 1985; however, on February 12, 2021, the US Fish and Wildlife Service removed the interior least tern from the federal list of Endangered Species. The interior least 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 interior least tern provided by these Acts and will continue to manage for interior least tern consistent with ongoing piping plover management. Though not required for ESA compliance, the Program's Governance Committee directed EDO staff in 2021 to continue to monitor the species following the same monitoring protocol for least terns as it did prior to the federal delisting. Moving forward, the Governance Committee may direct monitoring of interior least 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 and terns. The management objectives for piping plover and interior least tern as defined in the First Increment Adaptive Management Plan (AMP) (PRRIP 2021b) are:

1) Improve production of piping plovers and least terns along the central Platte River.

a) Increase number of fledged plover and tern chicks

i) Increase breeding pairs (indicator is nesting pairs)

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

b) Reduce adult mortality

i) Reduce predation (indicator is nesting pairs)

PRIORITY HYPOTHESES AND BIG QUESTIONS

During development of the Program's AMP in the early 2000's, there was substantial disagreement about the appropriate management strategy to achieve the management objective. Program participants developed a number of priority hypotheses that reflected piping plover and interior least tern related uncertainties. In 2010, those hypotheses were sequenced to develop a smaller set of Tier 1 hypotheses to receive focused attention during the First Increment of the Program (2007-2019) (PRRIP 2021c) including:

- **P1 & T1:** Additional bare sand habitat will increase the number of adult plovers and terns.
- **P2:** Plover productivity is related to the number of suitable macroinvertebrates and macroinvertebrates limit plover production below 800 cfs from May-Sep.
- **T2:** Tern productivity is related to the number of prey fish (<3 in) and fish numbers limit tern production below 800 cfs from May-Sep.
    - **T2a:** Flow rates influence the number and species diversity in tern prey base (fish).
- **TP1:** Interaction of river and sandpit habitat.
- **TP2:** The central Platte River may act as a source or sink for plovers and terns.
- **TP4d:** Correlation between river island habitat and flow.
- **TP5:** Use of riverine islands by plovers and terns will increase with active channel width.

As a means of better linking science learning to Program decision-making, priority hypotheses were further refined into a set of "Big Questions" that provided a template for linking specific hypotheses and performance measures to management objectives and overall Program goals.

The four "Big Questions" that relate directly to plovers and terns include (PRRIP 2020):

- **Big Question #6 –** Does availability of suitable nesting habitat limit plover and tern use and reproductive success on the central Platte River?
- **Big Question #7** – Are both suitable in-channel and off-channel nesting habitats required to maintain central Platte River plover and tern populations?
- **Big Question #8** – Does forage availability limit plover and tern productivity on the central Platte River?

- **Big Question #10** – Do Program management actions in the central Platte River contribute to plover and tern habitat and their use of the Associated Habitats?

Monitoring protocols were developed and implemented to obtain data for the above key indicators to provide the data necessary to test the Tier 1 plover and tern hypotheses, evaluate learning related to plover and tern Big Questions, and ultimately assess progress toward meeting the management objective. Many of these hypotheses and questions have been addressed over the course of the First Increment (PRRIP 2015, PRRIP 2020). 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 piping plover and interior least tern use and productivity on mid-channel sandbars and created or rehabilitated off-channel sand and water (OCSW) nesting sites; and 2) identify and document factors that are believed to influence nest site selection and nest and brood success along the central Platte River between Lexington and Chapman, Nebraska.

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 2021. Monitoring and research during 2021 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 (2008−2021) 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. Piping 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. Least 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 least 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.

2021 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 piping plover and least tern nesting sites within the region has been dependent upon construction and vegetation management efforts.

Other than at the start and end of the season, daily flows at the Kearney gage (USGS gage 06770200, USGS 2021) in 2021 were similar or higher overall across the nesting season than the median daily flows from 2001-2020 (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; then again at the end of the season in late July and early August, when many birds have already fledged and migrated to the river or moved out of the area. The peak flow for this gage was 2,450 cubic feet per second (cfs) on 29 May. This high discharge occurred before the first observed nesting peaks of either species. Slightly lower peaks, that were still above the 20-year median, occurred between 10 June and 6 July during and after the height of the nesting season as result of EA flow releases. During these peaks most 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 during these peaks and the vegetation growth on other sandbars are shown in the pictures below.

The lowest flow this gage experienced during the nesting season of 2021 was 92.7 cfs on 03 August. At this time, some of the stretches of the main channel that are typically monitored during river surveys were completely dry. One of these stretches was over 12 miles long and included the southern channels of the river from approximately 2 miles west of the Minden bridge to 2 ½ miles east of the Gibbon bridge. Included in this was the Rowe property between the Minden and Gibbon bridges. This stretch of river 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.

Shoemaker property with low flow and exposed sandbars on 01 May 2021.

Shoemaker property at peak flow and inundated sandbars on 29 May 2021.

Kearney Diversion with low flow and exposed sandbars on 01 May 2021.

Kearney Diversion 29 May 2021 during peak discharge.

Vegetated sandbar at Hostetler property on 16 June 2021

Dry section of the southern channel, east of the Gibbon bridge on 06 August 2021

MANAGEMENT

Management actions designed to increase nesting habitat (bare sand) and productivity of piping plovers and least terns were taken at on- and off-channel sites during fall 2020 and spring 2021. Management activities were site specific and included: mechanical actions to create nesting habitat (dozers, scrapers, and backhoes), mechanical actions to improve nesting conditions and remove vegetative cover (disking, tree removal, and nest furniture distribution); chemical application to kill or prevent emergence of vegetation (spring or fall herbicide application); and predator control (trapping, fencing, and predator deterrent lights).

SUMMARY OF HABITAT AVAILABILITY, 2007−2021

OFF-CHANNEL MECHANICAL HABITAT CREATION AND MAINTENANCE

OSG Lexington from June 2021 during nesting season.

Approximately 48 acres of managed off-channel nesting habitat were present in the AHR at the beginning of the First Increment (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 2009−2021 as the Program constructed and/or restored acres of habitat. Habitat availability increased in 2021 due mostly to the construction of new habitat from active mining at established sites and habitat restoration at new sites. The most notable gain in habitat, was the restoration of the newly acquired OSG Lexington site. There were 36 acres of habitat that became available for nesting at this site in 2021. The nesting area available can be seen in the picture above inside the red outline, as well as pictures of drone footage taken in April 2021 to the left, after the rehabilitation of the site.

OSG Lexington drone photos taken on 23 April 2021 after rehabilitation occurred.

Due to the completion of mining activities at Newark East, 6.7 more acres of habitat were available in 2021. We also saw an increase of 3.7 acres at Follmer-Alda as mining there progressed and the new peninsula became available. Mining activities at Follmer-Alda and the OSG Lexington OCSW site are still underway, and we expect additional habitat will become available for the 2022 nesting season. 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.

OCSW SITES:

Eleven of the seventeen off-channel sites monitored during 2021 were actively managed to increase piping plover and least 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 – Mechanical rehabilitation of this site included removal of junkpiles and trees on the nesting area, removal of sand and gravel piles, leveling low areas, and improving the slope and shorelines by making them more gradual. A pre-emergent herbicide was applied during spring 2021 after the mechanical rehabilitation took place. A permanent 4-foot-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, A temporary 4-foot-high electrified predator fence was also installed across the east entrance to the nesting area and predator trapping occurred during the 2021 nesting season. Sand and gravel mining occurred to the east of the habitat.

^{MG}2 NPPD Lexington – A pre-emergent herbicide was applied during spring 2021, 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 2021 nesting season. No sand and gravel mining occurred during 2021.

^{PMG}3 Dyer – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2020. A pre-emergent herbicide was applied during spring 2021. Permanent 4-foot-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 2021 nesting season. 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 2020, a pre-emergent herbicide was applied spring 2021, and predator trapping occurred during 2021. A permanent 4-foot-high woven wire predator fence with offset electric wires and top wire was maintained in 2021. No sand and gravel mining occurred.

^{MG}5 Blue Hole – A pre-emergent herbicide was applied during spring 2021, a permanent 4-foot-high fence was maintained along the west edge of the peninsula, and predator trapping occurred during 2021. Sand and gravel mining did not occur during 2021; however, the area west of this OCSW site is a high traffic area for loading and unloading equipment.

^{MG}6 Johnson – A pre-emergent herbicide was applied during spring 2021, and the woven-wire predator fence with offset electric wires along the west side of the nesting area was maintained. No sand and gravel mining occurred during 2021.

[G] 7 ***Ed Broadfoot and Sons*** – Not managed. Sand and gravel mining occurred during 2021.

[PMG]8 ***Broadfoot-South Kearney*** – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2020 and a pre-emergent herbicide was applied to the nesting area during spring 2021. A permanent 4-foot-high woven wire predator fence with offset electric wires and top wire was maintained across the east end of the main peninsula, and predator trapping occurred during 2021. Predator deterrent lights were installed on the site for the 2021 nesting season as a part of our additional predator management study, as well as a permanent interior 4-foot-high woven wire fence with an electrified top wire present to prevent avian perching. Prior to the installation of the interior fence, mechanical improvements were made to areas with deep washouts. Sand and gravel mining took place north of the main peninsula during 2021.

Habitat availability at Non-Access Broadfoot South Non-Access Islands, July 2021.

[PMG]9 ***Broadfoot-South Kearney—Non-Access Islands*** – A 4-foot-high hog-panel fence with chicken wire was placed across the land-bridge extending to one of the non-access islands located northwest of the main peninsula. Sand and gravel mining occurred directly east of the islands during 2021. The area where this mining is occurring is unvegetated; however, it is not suitable for nesting due to the activity in the area and changing terrain. There were 10 acres of unmanaged, suboptimal habitat available on these islands for piping plover or least tern nesting and foraging this season. This can be seen in the picture above. Most of these areas are partially or heavily vegetated, including large portions of the shorelines. Also due to the active mining, the area of this site varies year to year.

[PMG]10 ***Newark West*** – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2020. A pre-emergent herbicide was applied during spring 2021, permanent 4-foot-high woven wire predator fences with offset electric wires and a top wire were maintained across the ends of each peninsula. The entire perimeter of the site is enclosed with a permanent 4-foot-high woven wire fence with an offset electric wire. Predator trapping inside the perimeter fence, but outside the nesting peninsula, occurred during 2021. Predator deterrent lights were also installed on the nesting site during spring 2021 as part our additional predator management. No sand and gravel mining occurred during 2021.

[PMG]11 ***Newark East*** – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2020. A pre-emergent herbicide was applied during spring 2021. The permanent 4-foot-high woven wire predator fence with offset electric wires and electrified top wire was maintained across the west peninsula and a temporary 4-foot-high electrified predator fence was installed across the east peninsula. Predator trapping occurred in 2021 as well as sand and gravel mining east of the nesting areas. There were 23 acres available for piping plover and least tern nesting and foraging in 2021, which was an increase of about 6.7 acres from 2020.

[PMC]*12 Leaman East* – A contact herbicide was applied to kill existing vegetation along the waterline during fall 2020. A pre-emergent herbicide was applied to the nesting area during spring and predator trapping occurred during 2021. A permanent, 4-foot-high woven wire predator fence with an electrified top wire and offset electric wires was maintained in 2021. Predator deterrent lights were installed on the nesting site during spring 2021 as part of our additional predator management. No sand and gravel mining occurred.

[MG]*13 Trust Wild Rose East* – The nesting area was disked in the spring of 2021. No sand and gravel mining occurred.

[PMG]*14 Follmer-Alda* – A contact herbicide was applied to kill existing vegetation along the waterline during fall 2020. A pre-emergent herbicide was applied to the nesting area during spring and predator trapping occurred during 2021. Sand and gravel mining occurred east of the main peninsula and west of the new peninsula during 2021. Mechanical improvements were done to level out low areas and improve the slope of shorelines to create 3.7 new acres of habitat available for nesting on the east peninsula. More habitat is expected to become available in 2022.

[G]*15 DeWeese-Alda* – Not managed. Sand and gravel mining occurred during 2021.

[G]*16 Hooker Brothers - GI Southeast* – Not managed. Sand and gravel mining occurred during 2021.

[G]*17 Hooker Brothers - GI East* – Not managed. Sand and gravel mining occurred during 2021.

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. 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. 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. 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 2017-2021.

In preparation for the 2021 season, on-channel maintenance on Program properties occurred in the form of pre-emergent weed spraying and disking. This management 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 piping plovers and least 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 2021 were collected following the 2017 monitoring protocol.

The current report includes a synthesis of data collected from 2001-2021 to provide a look at piping plover and least 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 include:

- Brood survival rates changed from a 15-day success interval for both species, to a fledging age of 21 days for least terns and 28 days for piping plovers, which created a higher benchmark of fledging success
- River surveys increased from 3 to 7 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 7 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 17 Program owned or partnered OCSW sites along the reach to document adults, breeding pairs, nests, chicks, and fledglings during 2021 (Figure 5). River surveys were conducted along the central Platte River between Chapman and Lexington, Nebraska.

Semi-monthly OCSW Surveys

We conducted 7 semi-monthly surveys from outside the nesting colony at 17 OCSW Program owned or partnered sites (Figure 5) to count individual birds and document piping plover and least 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 2-4 and 7 May; 14-17 May; 1 June; 14-15 and 19 June; 30 June-2 July; 15-16 July; and 27 July-02 August during 2021. Program staff and personnel from NPPD conducted the semi-monthly OCSW surveys during 2021.

Semi-monthly River Surveys

Program staff conducted semi-monthly river surveys between the J2 Return and the Chapman Bridge. Each of the surveys took 2-3 days to complete. Semi-monthly river surveys were conducted on 4-5 May; 12-13 May; 2-3 June; 16-17 June; 29-30 June; 13 and 15 July; 3, 6, and 9 August during 2021. 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 piping plover and least tern adults, breeding pairs, nests, chicks, and fledglings located within this reach of river. On the 1 August survey some channels and sections were not completed due to a lack of flow in the channel. The bridge segment stretches that were not completed in their entirety include the Kearney to Minden, Minden to Gibbon, Gibbon to Shelton, and Hwy 281 to South Locust.

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 17 OCSW sites monitored semi-monthly in 2021 (Figure 5); 11 of these sites had observed nesting by either 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 2021.

Outside Monitoring

Outside surveys 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 piping plover and least 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. 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 piping plover and least tern breeding pair estimates (BPE) according to the methods described by Baasch et al. (2015). Briefly, we estimated piping plover and least 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 piping plover breeding pair counts by assuming: 1) piping plover nests did not hatch within 28 days of being initiated; 2) piping plovers did not re-nest within 5 days of losing a nest or brood or fledging chicks; 3) piping plover chicks fledged at 28 days of age (fledging age 2010−2021); 4) piping plover chicks that survived to 15 days of age (fledging age 2007−2009) also fledged. We obtained least tern breeding pair estimates by assuming: 1) least tern nests did not hatch within 21 days of being initiated; 2) least terns did not re-nest within 5 days of losing a nest or brood; 3) least tern chicks fledged at 21 days of age (fledging age 2010−2021); 4) least tern chicks that survived to 15 days of age (fledging age 2007−2009) also fledged; and 5) least 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 7 snapshots of the numbers observed during the 2021 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 (Tables 1-2 and 12-13). Thus, peak breeding pair estimates are associated with a specific peak date. A site peak is reported in Tables 3 and 14 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 15-16. 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 in the RStudio program (R Core Team 2017). We included nests located on OCSW sites that were monitored during 2021 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 least terns and piping 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 (least tern) or <28 days (piping 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 piping plover nest was observed to be active and intact 12 days after it was initiated, and then was found to be empty (no eggs) 4 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 2 observation periods) and assigned a "failed" status to the nest as it likely did not hatch within 16 days of initiation. If, however, a piping plover nest with an unknown fate was last observed to be active 25 days after it was initiated, but then 4 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 2 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 least tern and piping 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 (least terns) or 28 days (piping 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 least tern or piping plover chicks, respectively, and a successful status to the brood otherwise.

RESULTS:

PIPING PLOVERS

2021 Seasonal Summary

An overall positive response to Program habitat creation, rehabilitation, and management has been observed in plovers across the AHR (Tables 1-2) when comparing data from 2001-2021.However, reproductive success varies across sites every year (Table 3).

Piping plover adult and eggs.

- Throughout the AHR, 250 acres of habitat were available in 2021; all of which was off-channel.
- Nesting occurred at 10 of the 17 OCSW sites.
- AHR plover breeding pairs peaked at 36, leading to a fledge ratio of 0.97.
- Fledge ratios observed in 2021 were lower than those in 2020, but are still higher than the low fledge ratios observed in 2018 and 2019.
- Newark East had high success with the highest fledge ratio among sites.
- Blue Hole and Broadfoot-South Kearney had high investment, but low fledge ratios.
- Remote camera monitoring reduced the number of failed fates due to unknown causes.

Off- vs. On-Channel Productivity

<u>Semi-monthly OCSW Surveys</u>- Similar to past years, piping plover breeding pairs, nests, and chicks were observed on OCSW sites (Table 4 vs. Table 5). Beginning in 2017, all documented piping plover reproduction has occurred on OCSW sites. Though monitoring effort changed from 3 surveys a season in 2001-2009 (Figure 6), to 7 surveys a season in 2010-2021 (Figure 7), patterns of peak adult counts remain consistent. In 2021 adult counts for piping plovers (52) 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, all the way back to 2001 (Figures 6-7). OCSW survey breeding pairs also peaked on the 15 June survey on the off-channel sites, with 34 (Table 6). The highest OCSW survey nest count was 1 June for piping plovers (24). The highest chick count occurred 15 June (34); for fledglings this occurred on 1 July (10).

<u>Semi-monthly River Surveys</u> - No nests or chicks were observed on-channel during 2021 (Tables 5 and 7), as 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 2001-2021 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 2021 surveys, the highest number of adult piping plovers (8) was observed on the river during the 15 July survey (Table 7, Figure 9). This followed the previous three seasons' patterns of adult counts on the river peaking in mid to late summer (Figure 9). Fledges were first observed on the river during the 15 July survey when the highest numbers of piping plover fledglings (7)

were recorded. All fledglings were presumed to have come from OCSW sites as no nests or chicks were observed on-channel, and the locations observed and highest fledgling count dates were similar to the nearby OCSW sites (Tables 6 and 7).

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

Piping plover nesting was observed at 10 of the 17 OCSW sites as a result of semi-monthly monitoring in 2021. Nests and broods at these 10 OCSW sites were then monitored on a semi-weekly basis (Table 3, Figure 11).

Breeding Pairs- During the 2021 season, the number of piping plover breeding pairs peaked on 10 June at 36 pairs. Piping 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 2001-2021, 0.17 more plover breeding pairs (95% CI: 0.12 - 0.21 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.

Nests- 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 50 piping plover nests were observed and monitored at 10 of the 17 off-channel sites during 2021 (Tables 2-3, 4, Figures 11-12,14). The first plover nest was observed on 6 May 2021 and the last nest was first observed on 6 July 2021. Plover nests had an apparent nest success of 60% (30/50) (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 2021, average daily survival rate of piping plover nests over all monitored sites was 0.9783 (range = 0.9396–1; Table 8). Significant difference in average daily nest survival were observed among sites [$\chi 2(5, N=42) = 18.00; p=0.003$] with nest survival rates being low at Broadfoot-South Kearney, Blue Hole, and Leaman East. Average survival rate over the 28-day incubation period over all the monitored sites during 2021 was 0.5412 (range = 0.1749–1; Table 8).

We tested for an effect of ownership (i.e., Program or non-Program) on daily nest survival rates during 2021. Average daily nest survival rate of piping plovers at Program owned and/or managed nesting sites was 0.9789 (95% CI: 0.9647 – 0.9875) and 0.9767 (95% CI: 0.0.9492 – 0.9895) at non-Program sites (Table 9), but this difference was not statistically significant [$\chi 2(1, N=42) = 0.04$; $p = 0.84$]. Average survival rate over the 28-day incubation period across all Program sites was 0.5508 (95% CI: 0.3660 - 0.7028), compared to 0.5173 (95% CI: 0.2322 – 0.7444) 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 been generally increasing from 2001-2021 (Figure 12). The first observation of a plover chick occurred on 04 June 2021, and the last nest known to hatch occurred on 09 July 2021. The 30 successful nests in 2021 resulted in 99 chicks and an overall hatch ratio of 1.98 chicks/nest or 2.75 chicks/breeding pair (99 chicks/36 breeding pairs) (Table 2). The proportion of success of chicks (fledged chicks/total chicks) was 35% (35/99) in 2021 (Table 2, Figure 15). This proportion seems to be decreasing for this species overall even within the 2010-2021 time period when monitoring protocols and age at fledging were comparable. Care must be used when comparing current numbers using a higher benchmark (fledge age) for success and relying upon increased monitoring effort to those numbers observed under a different protocol from before 2010. This gradual decrease in the successful number of chicks despite the increase in brood counts is one of the indicators that prompted the Program to investigate possible causes and management solutions.

When comparing daily brood survival rates from the start of the Program to the present, the rate has remained stable (Tables 1-2). Brooding-period survival rates are more variable from year to year, but two of the lowest rates occurred in 2018 and 2019. Looking at current rates, average daily survival rates for piping plover broods across all sites during 2021 was 0.9759 (range = 0 –1.000; Table 10). We found a statistically significant difference between at least 2 sites after removal of sites with no variability associated survival rate estimates [$\chi 2(5, N=21) = 13.78$; $p= 0.001$; Table 10]. Average survival rate over the 28-day brooding period over all monitored sites was 0.5054 (range = 0–1).

Young piping plover chick.

When testing for the effect of ownership, average daily survival rate of piping plover broods at Program owned and/or managed nesting sites was 0.9771 (95% CI: 0.9566 – 0.9881) and 0.9714 (95% CI: 0.9151 – 0.9908) at non-Program sites (Table 11), but this difference was not statistically significant [$\chi 2(1, N=21) = 0.11$; $p = 0.74$]. Average survival rate over the 28-day brooding period across all Program sites was 0.5231 (95% CI: 0.2889 – 0.7143), compared to 0.4440 (95% CI: 0.0834 – 0.771) at non-Program sites (Table 11).

Fledges- During the 2021 season, we first observed a piping plover fledgling on 30 June and the last known piping plover chick to fledge did so on 02 August. The apparent nest-based fledge rate for plovers was 0.70 (35 fledglings/50 nests) and there was a pair-based fledging rate of 0.97 (35 fledglings/36 breeding pairs) at all sites monitored during 2021 (Table 2). This pair-based fledge ratio was lower than in 2020, but better than the dip in ratios in 2018 and 2019 (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. Piping plover fledge ratios dropped after that, and we saw very low numbers in 2018 and 2019 which helped to prompt the investigation into possible causes, specifically the impact of predation. In 2020, the numbers went back up to a more acceptable range.

Mortality- 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 piping plovers in 2021. Across the entire AHR, Program and non-Program sites, there was no documented research related mortality in 2021, and no nests or broods that were determined to be abandoned. There were 2 piping plover nests (4% of total plover nests) and 1 brood (3% of total piping plover broods) lost to weather. Failed-predated losses accounted for 14 plover nests (28%) and 2 plover broods (7%). In 2021, 3 plover nests (6%) 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. Nine piping plover broods (30%) were also assigned a failed-unknown fate. There were 1 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 the last couple of seasons.

Plover mortality events from 2021. Predated plover eggs (top) and adult plover mortality (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. Consistently, the largest number of losses each year have been 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. The second most common reason for nest and brood loss from 2010-2021 was due to predation (failed-predated), a cause which likely also accounts for a portion of our failed-unknown losses during this time-period. In 2020-2021, remote camera monitoring was deployed in order to reduce this uncertainty, identify causes, and narrow down the timing of loss. Information gathered will be used to inform management decisions to reduce losses and improve piping plover reproductive success along the AHR.

Conclusions

The Program has observed an overall positive response in piping plover reproductive outputs to habitat creation, rehabilitation, and management. Increases have been seen in 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 been generally increasing 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 (2010-2021). In this same time period from 2010-2021, the proportion of successful chicks has remained relatively stable as well but has been slightly decreasing over time. 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 this date are not comparable. There was a peak in plover fledge ratios from 2010-2014, after which numbers gradually decreased, leading to very low fledge ratios in 2018 and 2019. Numbers in 2020 and 2021 did however return 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, sites with high reproductive investment, but low reproductive output were Broadfoot-South Kearney and Leaman East, two Program sites, and Blue Hole, a non-Program site (Table 3). Broadfoot-South Kearney had the highest initial investment, but poor nest and brood survival as well as low nest success and fledge ratio. This site has historically had low reproductive success and previously documented problems with predation. Leaman East produced only plover nests in 2021, all of which failed due to great horned owl predation. This site has also experienced poor reproductive success in recent years. Blue Hole also suffered losses due to predation, losing at least three of the seven nests, and has historically dealt with consistent predation problems. 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. With the additional evidence collected with cameras and track surveys, most of our losses in 2021 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 avian predation impacts, as well as enforced the importance of improving our monitoring to further reduce our failed-unknown losses by accurately fating them.

LEAST TERNS

2021 Seasonal Summary

Terns have also shown an overall positive response to Program habitat creation, rehabilitation, and management along the AHR (Tables 12-13) from 2001-2021. However, reproductive success does vary by site, year to year (Table 14).

Least tern adult and chick.

- Throughout the AHR, 250 acres of habitat were available in 2021; all of which was off-channel.
- Nesting occurred at 8 of the 17 OCSW sites.
- The peak AHR breeding pair estimate for terns was 84, leading to a fledge ratio of 1.21.
- Fledge ratios observed in 2021 were slightly lower than in 2020, but within the range observed since 2010, and were much higher than the low fledge ratio observed in 2019.
- Dyer had the highest reproductive success (fledge ratio), followed closely by Newark East.
- Broadfoot-South Kearney had high investment by terns, but low success.
- Remote camera monitoring reduced the number of failed fates due to unknown causes.

Off- vs. On-Channel Productivity

Semi-monthly OCSW Surveys- Similar to past years, most least tern breeding pairs, nests, and chicks were observed on OCSW sites (Table 15 vs. 16). Adult count peak dates on OCSW sites have remained relatively consistent from 2001-2021, with a mid-season peak being typical in this area (Figures 18-19). In 2021, adult counts for least terns (128) peaked on off-channel sites on the 15 June survey (Table 17, Figure 19). Breeding pairs peaked on the 15 June survey on the off-channel sites, with 80 for least terns (Table 17). The highest OCSW survey nest counts were on 15 June for least terns (73). The highest chick counts occurred on 1 July for terns (82); for fledges this occurred on 15 July for least terns with 27 fledglings observed.

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). The highest number of adults for least terns (51) were observed on the river during the 15 July survey (Table 18, Figure 21). This followed the previous five seasons' patterns of least tern adult counts on the river peaking late season (Figure 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. No nests or chicks were observed on-channel during 2021. No nesting has been observed on-channel since 2016 (Table 16). As with the plovers, tern fledglings were first observed on the river during the 15 July survey; this was when the highest numbers of least tern fledglings (31) were recorded (Table 18). All fledglings were presumed to have come from OCSW sites as no nests or chicks were observed on-channel, and the locations observed and highest fledgling count dates were similar to that of OCSW sites (Tables 17 vs. 18).

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 declined and most nesting occurred on OCSW sites (Table 15 vs. Table 16, Figure 22).

Semi-Weekly Nest and Brood Monitoring

Least terns were observed nesting on 8 of the 17 OCSW sites during semi-monthly monitoring, and these sites with reproductive activity were then monitored on a semi-weekly basis (Table 14, Figure 23).

Least tern breeding pair. Adult bringing fish back for incubating mate.

Breeding pairs- Least tern breeding pair estimates peaked at 84 pairs (Table 13) on 23 June 2021. Though there were some variations in counts year to year, least tern breeding pairs have been generally increasing since 2001, which marks the start of the Program's available monitoring data set along the AHR (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 these additions of OCSW habitat (Table 15, Figure 25). For every acre of habitat increase, 0.35 more LETE breeding pairs (95% CI: 0.20 - 0.50 breeding pairs) were present in the AHR. This is the first of several pieces of evidence indicating that least 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 99 least tern nests were observed and monitored at 8 of the 17 off-channel sites during 2021 (Tables 13-15, Figure 23). The first observation of a least tern nest was on 18 May 2021 and the last nest was first observed on 12 July 2021. In 2021, at least 1 egg from 65% (64/99) of least tern nests hatched (Table 13). The proportion of successful nests, or apparent nest success, was lower than in 2020. However, it is still within the relatively stable range that these numbers have remained in since the Program began adding habitat and increased monitoring efforts (Table 13, Figure 27). All of these were located on off-channel sites and no nesting was observed on-channel during 2021 (Tables 15 vs. 16, 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.

Terns have seen both an increase in counts of nests and a relatively stable success proportion as the Program has made additions to habitat and increased monitoring effort (Figures 24 and 27). Across the reach, they have also experienced stable daily nest survival rates over the life of the Program, but incubation-period survival rates have varied more year to year across sites (Tables 12-13). Average daily survival rate of least tern nests in 2021 over all monitored sites was 0.9800 (range =0.9351-0.9916; Table 19). A statistically significant difference in average daily nest survival was observed between at least 2 sites [$\chi 2(7, N=99) = 15.67$; $p = 0.03$; Table 19]. Average survival rate over the 21-day incubation period over all the monitored sites during 2021 was 0.6548 (range = 0.2445–0.8374; Table 19).

When effect of ownership (i.e., Program or other) on nest survival rates was tested average daily survival rate of least tern nests at Program owned and/or managed nesting sites was 0.9807 (95% CI: 0.9711– 0.9871) and 0.9786 (95% CI: 0.9618 – 0.9881) at non-Program sites, but this difference was not statistically significant [$\chi 2(1, N=99) = 1.29$; $p = 0.26$; Table 20]. Average survival rate over the 21-day incubation period across all Program sites was 0.6637 (95% CI: 0.5399 – 0.7617), compared to 0.6348 (95% CI: 0.4410 – 0.7778) at non-Program sites (Table 20).

Least tern chick eating small fish adult brought back.

Broods- Brood counts have also been increasing over time, likely in response to the increase in the other related reproductive metrics and the factors that affected them (Figure 24). The 64 nests that hatched resulted in 158 chicks, a hatch ratio of 1.60 chicks/nest, and a ratio of 1.88 chicks/breeding pair (158 chicks/84 breeding pairs) during 2021 (Table 13). The first observation of a least tern chick occurred on 1 June 2021, and the last nest known to hatch occurred on 30 July 2021. When looking at the proportion of successful chicks (102 fledged chicks/ 158 total chicks) for 2021, it is similar but slightly lower than in 2020. 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).

Brood counts have also responded positively over the course of the First Increment and Extension, with an increase in counts and a stable success proportions for both nests and chicks. This is also reflected in daily brood survival rates (Table 13). Brooding-period survival rates showed more variability over the years, but are generally more stable than those for plovers, having never reached the very low rates like the one seen by plovers in 2018 (Tables 12-13). Average daily survival rates for least tern broods across all sites during 2021 was 0.9875 (range = 0.9582–0.9968; Table 21). Average survival rate over the 21-day brooding period over all monitored sites during

2021 was 0.7677 (range = 0.3621–0.9340; Table 21). We found a statistically significant difference in average daily brood survival between at least 2 sites [$\chi 2(6, N=64) = 13.09$; $p = 0.04$; Table 21].

When testing Program vs. non-Program, average daily survival rate of least tern broods at Program owned and/or managed nesting sites was 0.9921 (95% CI: 0.9826 – 0.9965) and 0.9747 (95% CI: 0.9478 – 0.9879) at non-Program sites (Table 22), and this difference was statistically significant [$\chi 2(1, N=64) = 4.37$; $p = 0.04$]. Average survival rate over the 21-day brooding period across all Program sites was 0.8472 (95% CI: 0.6918 – 0.9283), compared to 0.5835 (95% CI: 0.3247 – 0.7741) at non-Program sites (Table 22).

<u>Fledges</u>- We observed the first least tern fledgling on 6 July 2021 and the last known least tern chick to fledge did so on 12 August 2021. Apparent fledge success at all sites monitored was 1.03 fledglings/nest (102 fledglings/99 nests) or 1.21 fledglings/breeding pair (102 fledglings/84 breeding pairs) (Table 13). The fledge ratio for least terns was slightly lower than in 2020, but it was still higher than the dip in 2019 of 0.75 (Table 13 and Figure 28). Fledgling counts have increased since 2001 with the additions of habitat and increased monitoring effort (Tables 12-13). Both fledgling counts and fledge ratios, which are used as an indicator of success by the Program, have remained within a similar range with some yearly variation (Table 13 and Figure 28) during periods with comparable protocols, 2010-2021.

<u>Mortality</u>- 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 least terns on Program sites in 2021. For the entire AHR, Program and non-Program sites, there was no documented research related mortality in 2021, and no nests or broods were determined to be abandoned. There were 5 least tern nests (5% of total least tern nests) lost to weather. Ten tern nests (10%) and two tern broods (3%) were lost to predation. In 2021, 18 tern nest losses (18%) were fated as failed-unknown due to unknown causes. These losses occur when loss stage is known, but there is not enough evidence to assign a specific fate. Eleven least tern broods (17%) were assigned a failed-unknown fate. There were two unknown tern nest/brood losses (2%). The nests were known to have failed overall; however, it is uncertain whether they had hatched before failing so the failure could not be assigned to either the nest or brood stage. 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 the last couple of seasons.

Much like with the plovers, collecting sufficient evidence to accurately fate tern nests and determine the causes of reproductive losses has 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. This information will inform future management decisions in an attempt to reduce least tern reproductive losses and improve productivity along the AHR.

Conclusions

The Program has observed an overall positive response in least tern reproductive output to habitat creation, rehabilitation, and management. Breeding pairs 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 (2010-2021). Though we saw a dip in fledge ratio in 2019, the numbers have since returned to within a more typically seen stable range. Although we see a variation year to year in reproductive success for least 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 interior least terns nesting outside the AHR. For example, fledge ratios for least 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).

Fledge ratios at Blue Hole and Broadfoot-South Kearney were the lowest among the seven OCSW sites utilized by terns this year with successful nesting. Both had low daily and incubation-period nest survival. Broadfoot-South Kearney was once again the site with the highest initial reproductive investment, but poor nest and brood survival. Blue Hole also had poor nest survival, but had better brood survival than Broadfoot-South Kearney. The site that with the lowest daily brood survival and brooding period survival rates was Hooker Brothers- GI Southeast, which is an unmanaged site with active mining taking place.

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, most losses for terns in 2021 still fall into the failed-unknown category. Due to the delisting of least terns, piping 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 fate five tern nests failed due to predation, the second highest category of reproductive loss for terns

PREDATOR MANAGEMENT AND MONITORING

In 2021 the Program employed additional monitoring 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. This caused the Program to begin looking into possible causes and management 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 piping 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 has implemented several long-term management strategies to reduce the risk of predation at OCSW sites. Off-channel nesting sites are peninsulas that are surrounded by water to provide a ≥100 ft wide barrier to terrestrial predators. Nesting site entrances are protected by installing permanent and temporary electrified fences across the entrance of each nesting area. Non-electrified fence-panel wings are positioned on the ends of the electrified fence and extend 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 are removed, avian spikes are placed on all potential, non-removable perches, and the Program actively traps and removes 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 2021 season, the design and implementation were refined and various combinations of additional management were deployed on three Program monitored and managed sites: Broadfoot- South Kearney, Newark West, and Leaman East. This management included predator exclusion fences and predator deterrent lights. The Program will continue implementing these additional management strategies until 2024 to provide a long-term 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 Wildlife Services (Wildlife Services) on Program and NPPD off-channel nesting sites in 2021 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 (dog proof traps), and body hold snares (snares; Table 23). 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 247 traps were set during the 2021 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, time, site, date, and trap type 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/time of site exit to current visit date/time of site exit 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), traps 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 Wildlife Services trapping efforts and possibly adjust trapping methods to better meet management objectives for off-channel plover and least tern nesting sites.

Predator Exclosure Fencing

Interior predator exclusion fence at Broadfoot-South Kearney.

In addition to our pre-existing predator exclusion fences that are deployed across nesting peninsula entrances, this season additional predator exclusion fencing that completely surrounded our nesting areas was tested on two OCSW sites, Broadfoot-South Kearney 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 Broadfoot-South Kearney 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 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 Broadfoot-South Kearney, 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 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 an 8- 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). The third site was Leaman East. This site's additional management consisted only of predator deterrent lights, with three sets of motion activated and random pattern lights distributed across the site (Figure 32).

Random pattern Foxlight.

Blinking Risoon solar strobe light.

Motion activated Luposwiten solar light.

ADDITIONAL PREDATOR MONITORING

During the 2021 plover and tern nesting season, the Program monitored predator presence and predation events at six plover and tern nesting sites: Dyer, Cottonwood Ranch, Broadfoot-South Kearney, Newark West, Newark East, and Leaman East. 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, as well as remote cameras placed to monitor individual nests.

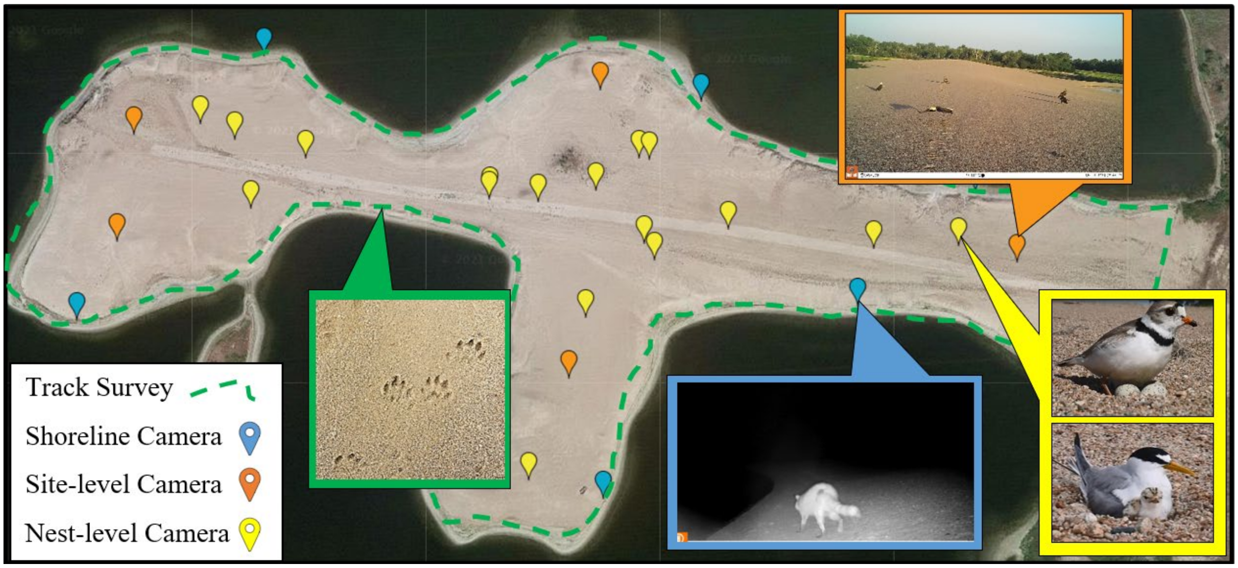
METHODS

Terrestrial mammal trapping

We took advantage of the daily trapping logs to 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 predator present at the site as well as the frequency of capture 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 2021 predator monitoring efforts and their field of view represented in the color-coded callouts. Broadfoot-South Kearney is being used as an example.

Example of an animal dig at the predator fence

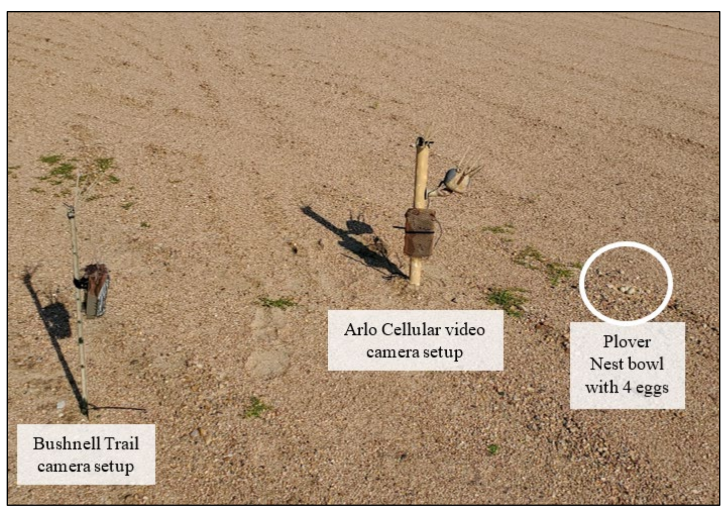
Animal tracks, animal digs (i.e., disturbed sand under a fence due to animal digging, see figure to the right), fence turn backs (i.e., the animal walked to the fence and retreated), and owl pellets detected for a given species during a single survey over an entire nesting peninsula were recorded as 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 were not recorded during these surveys due to the ubiquitous nature of their tracks and the inability to distinguish them as a unique register from one survey to another.

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 placed every 1,200 linear feet along the shorelines of the six nesting sites to document potential predator presence. 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 5 – 6 ft-tall PVC pipes with avian spikes placed on top to prevent avian predator perching. Site-level cameras were placed at each of the six nesting sites every 4 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 shoreline methods.

Nest-level cellular video and trail cameras (represented in yellow in the figure above) 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 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 2 acres (4-13 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



Example of a trail camera and cellular video camera setup

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 to 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. 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 or an actual predation event 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 2021 nesting season.

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 (Tables 24-31). To 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), 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 monitored sites (Figure 33 (A-F)). For example, the number of unique registers of great-horned owl by nest cameras at Leaman were divided by the total nest camera days of effort over all six sites to represent Leaman's relative contribution to total great-horned owl registers given the total nest camera monitoring effort over all sites.

To test whether cameras placed at a plover or tern nests negatively impacted nest survival, we ran a mixed effect nest fate logistic exposure model to calculate daily survival rate (DSR) at sites with camera and non-camera nests. Combined plover and tern nest survival information was used from four sites (Dyer, Broadfoot – South Kearney, Newark West, Newark East). Cottonwood Ranch and Leaman East also had cameras placed at nests but were excluded from these comparisons due to all nests having cameras at each site. 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. We also made a fourth site-specific comparison between DSR of nests with cameras in 2021 to average DSR of all nests at a given site from 2010-2016 prior to any camera usage at sites. For example, the average DSR of all nests with cameras at Broadfoot-South Kearney in 2021 was compared to the average DSR of all nests monitored at Broadfoot-South Kearney from 2010-2016. These comparisons were made to examine whether nest camera placement had a negative impact overall (regardless of site or species), is specific to plovers or terns, or impacts nest survival at some sites more than others.

RESULTS

Two-hundred and ninety-six terrestrial animals were captured and removed from 10 nesting sites representing 10 different species (Tables 24 and Figures 33A and 34) using 247 traps over 26,560 traps days during the 2021 plover and tern nesting season (Table 24). Two hundred and seventy-three raccoons were captured and constituted the greatest captures per unit effort at every site (Tables 25-26, Figure 33A).

Track surveys documented a total of 152 unique registers (Table 27) over 80 surveys of the six Program nesting sites. Across all Program sites, turtles were the most common animal track registered and had the highest number of registers per unit total effort (.750) (Figure 33B).

Shoreline cameras registered 498 unique potential predator registers. Site-level cameras registered 66 unique potential predator registers. No predation events were documented by shoreline or site-level cameras over 2,598 and 2,439 camera days (respectively) of monitoring across all six nesting sites (Tables 28 and 29). Across all Program sites Canada goose was the species registered most often at the shoreline (.099 registers/total effort) and site-level (.011 registers/total effort) (Figures 33C and 33D).

Crow predating plover eggs at Newark East.

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, 42 nest cameras monitored 56 nests (30 plover nests and 26 tern nests) for a combined effort of 668 camera days across all sites (Table 30). A total of 36 unique potential predator presence/predation events were documented on nest cameras. Of these 36 unique events, 15 were predation events where the predator was captured on camera consuming or destroying eggs or chicks in the nest bowl, i.e., 14 by great horned owls and 1 by an American crow. In addition to the 15 predation events captured on camera, 2 additional camera-monitored nests were determined as predated though the actual predation event was not captured by the nest camera. One camera-monitored nest at Dyer was determined predated by a badger because the badger was registered on the nest camera and the nest was damaged and inactive the following monitoring visit. There was also one camera-monitored nest at Broadfoot-Kearney South that was determined predated by an unknown species because damaged eggs were found nearby the nest and the nest was inactive. However, the camera malfunctioned and did not register the individual predator or the predation event. In total, camera-monitored nests suffered 17 predation events, 15 of those events were captured on

Tern egg predated at Broadfoot-South Kearney. Predation occurred at nest with camera, but the individual predator or predation event was not captured due to camera malfunction

camera. Great-horned owl was the predator species with the highest number of registers per unit total effort for nest registers (.007) and nest predation events (.021) (Figures 33E and 33F). Two of these predation events occurred at successful nests (i.e., chicks and eggs present in the nest bowl) and 14 events occurred at active nests (i.e., only eggs present in the nest bowl) (Tables 31-32). When combining data from all monitoring sources (outside/inside observers, nest, site, and shoreline camera data, and track surveys), a total of 5 tern nests, 12 plover nests, 15 tern eggs, 42 plover eggs, and 5 plover chicks were depredated during the 2021 nesting season (Table 32). Because of this detailed data, we were able to determine the fate for 78% of eggs laid (i.e., failed or hatched) and the fate for 92% of chicks (i.e., failed or successfully left the nest bowl with adults). 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. Piping plover nest predation occurred when nests averaged 63% developed and least tern nest predation occurred when nests averaged 92% developed (Table 33, Figure 35). Of the plover nest predations, two were predated twice on two separate occasions, O-LES-04-21 and O-LES-05-21. All four of these predation events were counted in the frequency plot because predation occurred at each nest at different developmental stages, but only counted once for the total number of plover nests that experienced some level of predation (12).

To test for a possible negative impact on daily survival rates of placing cameras at nests, 96 nests were observed at Dyer, Broadfoot-South Kearney, Newark West, Newark East in 2021, where some nests had cameras and others did not. Of those 96 nests, 30 were plover nests and 66 were tern nests. Approximately half of those nests had cameras placed to observe activity and determine nest fate. Seventy percent of all camera nests and 65% of all non-camera nests successfully hatched chicks. Seventy-five percent of plover camera nests hatched compared to 50% of non-camera plover nests. Sixty-five percent of tern camera nests hatched compared to 68% of non-camera tern nests. Plover average daily survival rate (DSR) was significantly higher for nests with cameras compared to nests without cameras, but DSR for tern nests with cameras was not different from nests without (Tables 34, Figure 36). Combining data for both species to look for overall effects of cameras on daily nest survival rate (DSR), we found no difference between nests monitored with cameras and those that were not (Figure 37). 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, as there were no differences in DSR between camera-monitored nests and those not monitored by cameras at any of the four sites for which both conditions existed (Figure 38). Combined 2021 plover and tern average daily nest survival rates of nests with a camera present at the four off-channel sites was within the range of daily survival rates observed at each site prior to use of cameras on nesting sites at all sites besides Broadfoot-South Kearney (2010-2016, Figure 39). Broadfoot – South Kearney nest camera DSR was lower than site DSR observed prior to camera use. Two off-channel nesting sites monitored with remote nest cameras were not included in the analysis because the few nests that occurred were all monitored by cameras. At Cottonwood Ranch DSR for the single plover nest that occurred was 1. At Leaman DSR for the 5 plover nests that occurred was 0.9396.

DISCUSSION

Predator monitoring helped us identify predators responsible for nest predation, learn about predator communities at each nesting site, quantify predator presence, and begin to evaluate effectiveness of predator management actions. In 2021 potential avian predators were responsible for 94% of documented predation events, resulting in losses of both eggs and chicks. Potential avian predators were registered with greater frequency at more sites than were potential mammalian predators, drawing attention to the important role they may play in limiting piping plover and least tern productivity at off-channel nesting sites. The ubiquitous distribution of avian registers from shorelines to individual nests demonstrates the ineffectiveness of current predator deterrents and the need to develop management tools that are specifically tailored to avian predators.


Great horned owl predating eggs.

Trapping data showed that raccoons were the most common terrestrial predator trapped across all sites on the outside of nesting peninsulas. Dog proof traps were the most efficient trapping type to capture raccoons in 2021 and should remain deployed across sites in the future. Snares were also effective at capturing raccoons and additional species not captured by other trapping methods. Snares can be an effective trap type to increase captures of several potential predator species at sites where they can be installed in dig-outs under exterior exclusion fencing (e.g., Newark West). While current trap types focus of non-canid mesopredators, trap types to capture fox and coyotes should be considered if predator monitoring reveals these species are present on nesting sites and negatively impacting plover breeding success.

Raccoons were also registered across all sites by track surveys. Though USDA/APHIS removes hundreds of racoons each year from around nesting peninsulas, populations are likely high enough that some still wind up on nesting peninsulas, as track surveys document. However, raccoon was not a common potential predator registered on shoreline, site, or nest-level cameras. This may be due to the tendency of raccoons to move predominantly along the shoreline (as documented in track surveys) but may also be partially due to lower overall detection probabilities of site-level cameras due to low installation density and the height at which site-level cameras were installed. Raccoons were detected at the nest level but only at Dyer and without any documented predation by this species.

Track surveys together with shoreline cameras were helpful at showing which species were able to cross water-filled moats and/or breach fences to arrive at shorelines utilized by plovers for foraging. Even with these barriers in place, track surveys combined with shoreline cameras reveal that we still have a diverse mammalian and avian community present on the shoreline of nesting sites. Canada goose and great blue heron were present at all sites along the shoreline and were the most frequently registered by shoreline cameras. Great blue heron is one potential predator suspected of having an impact on plover brood success. Canada geese present in large numbers may trample and dislocate plovers foraging along shorelines. Interestingly, neither of these potential avian predators were registered often at the nest level (i.e., Canada goose had four unique registers and great blue heron had zero). Fewer mammals than expected were registered on shoreline cameras based on track survey data, emphasizing the importance of utilizing both sources of information for complete documentation of shoreline predator communities.

Site-level cameras were able to capture potential avian predators but did not prove effective in documenting the mammalian community, making this a "blind spot" hindering our ability to evaluate the effectiveness of interior fencing and predator deterrent lighting. Site-level cameras were positioned at a greater height than cameras at the shoreline and nest level providing a higher and wider field of view (catching more avian predators) but reducing triggers from low to the ground mammalian predators. The height of the cameras was determined by past predator studies (Table 35; Keldsen 2021) where site level cameras were most useful when they were positioned higher in the air to cover the interior of the nesting peninsulas due to the topography of each individual nesting peninsula.

Imagery from nest cameras provided evidence to fate nests that were successful or to fate failed nests due to either predation, weather, or hatching, reducing the number of failed unknown outcome fates. The nests with cameras that were fated as failed unknown (4) were due to camera malfunction and the lack of evidence available for outside observers to determine the nest's true fate (i.e., newly hatched chicks, weather event, physical predation evidence at the nest). The fate of failed due to predation could only be assigned to nests with cameras because of the direct evidence they captured. Nests without cameras that were fated as failed due to unknown causes likely failed due to predation but had to be fated as failed-unknown due to lack of evidence. Nest cameras showed us that great-horned owls were the greatest threat to nesting plovers and terns during the 2021 season. Great-horned owls were the most common predator present at nests and responsible for 88% (14/16) of nest predation events where evidence to identify the predator was captured on nest cameras and 82% (14/17) of total predation events on nest-monitored cameras. Nest cameras also provided important detail about great-horned owl predatory behavior. Owls depredating nests earlier in incubation were less likely to consume all eggs in the nest, whereas owls depredating nests further along in incubation or with newly hatched chicks usually consumed all eggs and chicks in the nest bowl. This tendency of great-horned owls to depredate nests later during incubation makes their impact on productivity even greater, given the reduced probability of successfully renesting after a loss to a predator later in the season (Swift et al. 2020).

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 in 2021 were within the distribution observed at these same sites prior to the use of remote cameras, except at Broadfoot – South Kearney. Broadfoot – South Kearney experienced lower daily nest survival than the other compared sites from 2010-2016. Several low annual average daily nests survival rates at Broadfoot – South Kearney were only slightly higher than those of 2021 camera nests at the site. We conclude Broadfoot – South Kearney daily nest survival was also not negatively impacted by nest cameras due to low daily nest survival rates being observed prior to camera usage. The use of remote cameras to identify potential predators and predation events at plover and tern nests does not bias nest success and 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 (Figures 30-32). 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:

A kestrel observed at a plover nest on Cottonwood Ranch. Kestrels are an example of a predator that typically leaves few, if any, tracks or other evidence.

The additional monitoring deployed on Program managed sites used a combination of trapping results, track surveys, and remote cameras to improve our monitoring accuracy by providing more detailed nesting information, reduce our unknown fates, increase our understanding of the impacts of predation on our species, and help quantify the success of our additional management. No harm to or avoidance by our species was observed in response to the additional monitoring or management. Of the nests with cameras deployed, 78% of the eggs laid and 92% of the chicks were fated. Nest cameras collected evidence to identify the predator responsible for 16 out of 17 total predation events that occurred at camera-monitored nests. Of the 16 events with the predator captured on camera, 15 (94%) of these were attributed to avian predators. 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. Avian predation typically occurred late in nest incubation or very early during brood incubation. 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 remained unknown whether the nest had hatched or not prior to loss. These nests were ultimately fated as unknown even though the reproductive attempt was an overall failure, and in some cases a known cause of that failure was determined. This was due to lack of evidence regarding stage of loss, and an inability to assign the loss to either the nest (eggs) or brood (chicks) stage. The timing of the predation events observed in 2021 is also concerning as most occurred later during incubation, after significant investment has already been made, and when the probability of renesting is lower (Swift et al. 2020), thus amplifying impact.

The predator species with the highest impact in 2021 was the great-horned owl. It accounted for 14 of the 16 (88%) predation events where the predator was captured on nest cameras. An American crow was responsible for 1(6%) event and a badger accounted for a single event (6%). High numbers of registers per unit effort of avian predators on the nest cameras at Broadfoot-South Kearney and Leaman suggested that the success of our species at these sites was more heavily affected by avian predation than at other sites. It was precisely because of repeatedly low success rates linked to predation at these two sites that they were chosen for testing additional predator management.

Monitoring predator presence both from the outside of nesting peninsulas to inside nesting areas and at individual nests helped to evaluate the effectiveness of predator management. Potential avian predators were present across all levels of monitoring. This, combined with heavy nest predation by avian predators at sites with additional management, seems to indicate that predator deterrent lighting was ineffective in reducing presence or predation by avian predators.

However, on all Program managed sites, a decrease in terrestrial predator registers was seen as predators encountered existing barriers moving from outside the site, down to the nest level. Additional management deployed on three of the Program managed sites appeared to be effective in reducing terrestrial predation and potential predator registers even farther. Most site and nest level registers of terrestrial predators in 2021 occurred on sites without additional management, and the single mammalian predation event also occurred on a site without additional lighting or fencing. The interior predator exclusion fencing at Broadfoot-South Kearney was also effective at reducing great blue heron and Canada goose presence within nesting areas. Both of these species present a risk to plover and tern nests through predation or trampling of the eggs or young chicks. Their continued presence along shorelines suggest they remain a threat to mobile chicks that spend a large amount of time foraging there after leaving the nest bowl.

Moving forward the Program will continue to implement additional predator management and monitoring to gather information on the predator community, their impact on plover and tern productivity, and evaluate effectiveness of predator management over time. Trapping data, track surveys and trail cameras identified potential predator communities present at nesting sites. Nest cameras documented predation events, provided limited information on hatch success, and allowed us to accurately fate nests and reduced the number of failed-unknown fates. Cellular nest video cameras captured the same type of information but provided more detail on predatory behavior and provided quantitative evidence of losses and timing of losses due to predation by avian species, highlighting the importance of using what we have learned for the development of options for mitigating this threat.

PAST RESEARCH SYNTHESIS

Piping plover and least 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 was 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 that were expounded upon in past annual reports are located in Table 35.

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

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
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)	----[A]	----	----	----	----	----	----	----	----
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, 2010–2021. 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**
Max Adult Counts	96	71	73	94	108	99	108	77	74	88	71	67
Peak Breeding Pair Estimate (BPE)	20	28	30	27	30	40	43	40	37	45	32	36
Total Nests Observed	35	34	46	31	43	54	60	50	47	60	49	50
Successful Nests (≥1 egg hatched)	21	27	32	23	34	34	40	30	35	31	28	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
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
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
Chicks Observed (<15D)	76	88	99	80	116	119	120	92	95	94	98	99
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
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
Chicks (≥15D)	50	61	68	43	67	73	70	53	36	42	52	45
Fledglings (28D)	41	46	59	28	55	52	55	47	23	30	39	35
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
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
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
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
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
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

Table 3. Site-specific numbers of adults, nests, chicks, and fledglings observed while monitoring OCSW nesting sites for piping plover reproduction during 2021. Chick and fledgling counts represent numbers documented as being produced 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				PIPL											
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 D	Chicks 15-21 D	Fledglings	Apparent Nest Success	Fledge Ratio (AHR peak date[B])	Fledge Ratio (Site peak date[C])
1. OSG Lexington	FPT	22	23	1	1	2	1	1	0	0	0	1.00	0.00	0.00
2. NPPD Lexington	FPT	39	55	5	5	8	5	4	14	8	7	0.80	1.40	1.40
3. Dyer	FHPT	27	31	7	7	12	8	7	26	17	9	0.88	1.29	1.29
4. Cottonwood Ranch	FHPT	19	11	1	1	2	1	1	4	0	0	1.00	0.00	0.00
5. Blue Hole	FPT	35	53	2	4	10	7	2	3	1	1	0.29	0.50	0.25
6. Johnson	FP	9	5	0	0	1	0	0	0	0	0	---[D]	---	---
7. Ed Broadfoot and Sons	N	26	11	0	0	0	0	0	0	0	0	---	---	---
8. Broadfoot-South Kearney (BFS)	FHILPT	27	28	8	8	11	13	6	19	2	2	0.46	0.25	0.25
9. BFS Non-Access Islands	T	26	12	1	1	2	1	1	3	0	0	1.00	0.00	0.00
10. Newark West	EFHLPT	26	15	3	3	5	4	3	11	5	4	0.75	1.33	1.33
11. Newark East	FHPT	25	17	5	5	7	5	5	19	12	12	1.00	2.40	2.40
12. Leaman East	FHLPT	26	15	3	3	6	5	0	0	0	0	0.00	0.00	0.00
13. Trust Wild Rose East	D	7	4	0	0	0	0	0	0	0	0	---	---	---
14. Follmer-Alda	HPT	7	4	0	0	0	0	0	0	0	0	---	---	---
15. DeWeese-Alda	N	7	14	0	0	0	0	0	0	0	0	---	---	---
16. Hooker Bros-GI Southeast	N	24	14	0	0	1	0	0	0	0	0	---	---	---
17. Hooker Bros-GI East	N	7	4	0	0	0	0	0	0	0	0	---	---	---

[A] Management actions applied to each site: disking (D), exterior predator fencing (E), peninsula entry predator fencing (F), fall 2020 herbicide (H), interior predator fencing (I), predator deterrent lights (L), no management (N), spring 2021 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. 16 of this report) on 10 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] "----" Cannot be calculated.

Table 4. Piping plover OCSW total nesting incidence and productivity by year, 2001−2021.

Year	Piping Plover Off-Channel Peak BPE[A]	Nests	Succ Nests	Fledglings[B]	Fledglings Per Peak BPE[B]
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
Mean	**24.14**	**31.62**	**21.14**	**32.71**	**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. Piping plover on-channel total nesting incidence and productivity by year, 2001−2021.

Year	On-Channel Peak BPE[A]	Piping Plover Nests	Succ Nests	Fledglings[B]	Fledglings Per Peak BPE[B]
2001	0	0	0	0	---[C]
2002	0	0	0	0	---
2003	0	0	0	0	---
2004	0	0	0	0	---
2005	0	0	0	0	---
2006	0	0	0	0	---
2007	4	4	2	7	1.75
2008	3	5	1	3	1.00
2009	2	2	1	1	0.50
2010	5	13	18	10	2.00
2011	0	0	0	0	---
2012	1	1	1	4	4.00
2013	0	0	0	0	---
2014	2	2	1	4	2.00
2015	6	7	1	1	0.17
2016	1	2	1	1	1.00
2017	0	0	0	0	---
2018	0	0	0	0	---
2019	0	0	0	0	---
2020	0	0	0	0	---
2021	0	0	0	0	---
Mean	**1.14**	**1.71**	**1.24**	**1.48**	**1.55**[C]

[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] "---" 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 surveys in 2021.

	Piping Plover				
Survey	**Adults**	**BPE[A]**	**Nests**	**Chicks**	**Fledglings**
1-May	30	0	0	0	0
15-May	41	19	15	0	0
1-Jun	47	33	24	0	0
15-Jun	52	34	15	34	0
1-Jul	42	31	10	29	10
15-Jul	3	16	0	6	8
1-Aug	0	2	0	0	2

[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. 16). 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 2021.

	Piping Plover				
Survey	**Adults**	**BPE[A]**	**Nests**	**Chicks**	**Fledglings**
1-May	2	0	0	0	0
15-May	1	0	0	0	0
1-Jun	4	0	0	0	0
15-Jun	0	0	0	0	0
1-Jul	0	0	0	0	0
15-Jul	8	0	0	0	7
1-Aug[B]	1	0	0	0	1

[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. 16). 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) for piping plover nests monitored on OCSW sites during 2021. Incubation-period nest survival rate = (daily nest survival rate)^28.

Site	Management[A]	# Nests	# Nests Lost	Exposure Days	Daily Nest Survival Rate**	Daily Nest Survival SE	Daily Nest Survival Rate 95% CI Lower	Daily Nest Survival Rate 95% CI Upper	Incubation Period Survival Rate	Incubation Period Survival Rate 95% CI Lower	Incubation Period Survival Rate 95% CI Upper
OSG Lexington	FPT	1	0	27.0	1	0	1	1	1	1	1
NPPD Lexington	FPT	5	1	125.0	0.9920	0.0079	0.9456	0.9989	0.7993	0.2091	0.9691
Dyer	FHPT	8	1	156.0	0.9936	0.0064	0.9561	0.9991	0.8357	0.2843	0.9751
Cottonwood Ranch OCSW	FHPT	1	0	22.0	1	0	1	1	1	1	1
Blue Hole	FPT	7	5	121.0	0.9595	0.0178	0.9063	0.9830	0.3140	0.0636	0.6194
Broadfoot-South Kearney	FHILPT	13	7	198.0	0.9652	0.0129	0.9289	0.9833	0.3714	0.1268	0.6248
Non-Access Islands Broadfoot-South Kearney	T	1	0	9.0	1	0	1	1	1	0.9988	1
Newark West	EFHLPT	4	1	75.0	0.9868	0.0132	0.9119	0.9981	0.6884	0.0757	0.9491
Newark East	FHPT	5	0	99.0	1	0	1	1	1	1	1
Leaman East OCSW	FHLPT	5	5	80.5	0.9396	0.0262	0.8629	0.9747	0.1749	0.0161	0.4876
All Sites		50	20	912.5	0.9783	0.0048	0.9666	0.9860	0.5412	0.3866	0.6732

[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), spring 2021 pre-emergent herbicide (P), or predator trapping (T).

**Significant difference in average daily nest survival was observed between at least two sites [$\chi2(5, N = 42) = 18.00$; $p = 0.003$]

Table 9. Daily and incubation-period survival rates (RMark estimates) for piping plover nests monitored on Program and non-Program sites during 2021. 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 Lower	Daily Nest Survival Rate 95% CI Upper	Incubation Period Survival Rate	Incubation Period Survival Rate 95% CI Lower	Incubation Period Survival Rate 95% CI Upper
Program[A]	37	14	657.5	0.9789	0.0056	0.9647	0.9875	0.5508	0.3660	0.7028
Non-Program[B]	13	6	255.0	0.9767	0.0094	0.9492	0.9895	0.5173	0.2322	0.7444
All Sites	50	20	912.5	0.9783	0.0048	0.9666	0.9860	0.5412	0.3866	0.6732

[A]Program sites: OSG Lexington, Dyer, Cottonwood Ranch OCSW, Broadfoot-South Kearney, Newark West, Newark East, Leaman East OCSW

[B]Non-Program sites: NPPD Lexington, Blue Hole, Non-Access Islands Broadfoot-South Kearney

Table 10. Daily and brooding-period survival rates (RMark estimates) for observed piping plover broods (1 or more chicks) monitored on OCSW sites during 2021. Brooding-period survival rate = (daily brood survival rate)^28.

Site	Management[A]	# 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
OSG Lexington	FPT	1	1	0.5	0	0	0	0	0	0	0
NPPD Lexington	FPT	4	1	75.0	0.9868	0.0132	0.9119	0.9981	0.6884	0.0757	0.9491
Dyer	FHPT	7	0	186.0	1	0	1	1	1	1	1
Cottonwood Ranch OCSW	FHPT	1	1	12.5	0.9228	0.0744	0.6072	0.9893	0.1053	0	0.7396
Blue Hole	FPT	2	1	27.0	0.9636	0.0357	0.7824	0.9949	0.3543	0.0010	0.8667
Broadfoot-South Kearney	FHILPT	6	5	46.0	0.8963	0.0440	0.7736	0.9563	0.0467	0	0.2862
Non-Access Islands Broadfoot- South Kearney	T	1	1	1.5	0	0	0	0	0	0	0
Newark West	EFHLPT	3	1	48.5	0.9796	0.0202	0.8689	0.9971	0.5614	0.0195	0.9227
Newark East	FHPT	5	1	95.5	0.9896	0.0104	0.9298	0.9985	0.7459	0.1302	0.9598
All Sites		30	12	492.5	0.9759	0.0069	0.9581	0.9863	0.5054	0.3015	0.6792

[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), spring 2021 pre-emergent herbicide (P), or predator trapping (T).
***Significant difference in average daily brood survival rate was observed between at least two sites [$\chi2(5, N = 21) = 13.78$; $p < 0.001$].

Table 11. Daily and brooding-period survival rates (RMark estimates) for piping plover broods (1 or more chicks) monitored on Program and non-Program sites during 2021. 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]	23	9	389.0	0.9771	0.0075	0.9566	0.9881	0.5231	0.2889	0.7143
Non-Program[B]	7	3	103.5	0.9714	0.0163	0.9151	0.9908	0.4440	0.0834	0.7710
All Sites	30	12	492.5	0.9759	0.0069	0.9581	0.9863	0.5054	0.3015	0.6792

[A]Program sites: OSG Lexington, Dyer, Cottonwood Ranch OCSW, Broadfoot-South Kearney, Newark West, Newark East

[B]Non-Program sites: NPPD Lexington, Blue Hole, Non-Access Islands Broadfoot-South Kearney

Table 12. 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**
Adult Count	45	117	105	133	184	122	133	145	114
Peak Breeding Pair Estimate (BPE)	22	33	38	39	45	33	38	36	42
Total 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]
Chicks Observed (<15D)	42	65	62	72	73	38	49	59	68
Hatch Ratio (<15D Chicks/Total Nests)	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/Total	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] "-----" years for which indicated data were not collected.

[C] Does not include reproductive information from Dinan Island.

Table 13. Summary of least tern reproductive success at OCSW and river-island sites on the central Platte River in Nebraska, 2010–2021. 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**
Max Adult Count	170	150	137	197	260	262	200	159	174	169	158	166
Peak Breeding Pair Estimate (BPE)	53	62	66	65	94	141	88	77	88	95	84	84
Total Nests Observed	76	90	88	96	146	187	122	118	112	132	105	99
Successful Nests (≥1 egg hatched)	48	52	63	51	82	116	77	63	79	67	74	64
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
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
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
Chicks Observed (<15D)	122	125	144	118	180	258	170	129	168	137	160	158
Hatch Ratio (<15D Chicks/Total Nests)	1.61	1.39	1.64	1.23	1.23	1.38	1.39	1.09	1.50	1.04	1.52	1.60
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
Chicks (≥15D)	76	101	95	70	104	158	91	78	117	74	107	100
Fledglings (21D)	75	96	84	64	91	146	80	76	117	71	107	102
Historic Fledge Ratio (≥15D Chicks/Total Nests)	1.00	1.12	1.08	0.73	0.71	0.84	0.75	0.66	1.04	0.56	1.02	1.01
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
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
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
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
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

Table 14. Site-specific numbers of adults, nests, chicks, and fledglings observed while monitoring OCSW nesting sites for least tern reproduction during 2021. Chick and fledgling counts represent numbers documented as being produced 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				LETE											
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 D	Chicks 15-21 D	Fledglings	Apparent Nest Success	Fledge Ratio (AHR peak date[B])	Fledge Ratio (Site peak date[C])
1. OSG Lexington	FPT	22	23	0	1	4	1	0	0	0	0	0.00	---[D]	---
2. NPPD Lexington	FPT	39	55	8	9	18	10	6	15	9	7	0.60	0.88	0.78
3. Dyer	FHPT	27	31	17	17	28	19	16	42	32	32	0.84	1.88	1.88
4. Cottonwood Ranch	FHPT	19	11	0	0	1	0	0	0	0	0	---	---	---
5. Blue Hole	FPT	35	53	9	9	18	10	4	6	4	4	0.40	0.44	0.44
6. Johnson	FPT	9	5	0	0	2	0	0	0	0	0	---	---	---
7. Ed Broadfoot and Sons	N	26	11	0	0	0	0	0	0	0	0	---	---	---
8. Broadfoot-South Kearney (BFS)	FHILPT	27	28	15	16	25	20	7	18	6	6	0.35	0.40	0.38
9. BFS Non-Access Islands	T	26	12	0	0	2	0	0	0	0	0	---	---	---
10. Newark West	EFHLPT	26	15	9	9	20	9	6	16	11	11	0.67	1.22	1.22
11. Newark East	FHPT	25	17	17	18	27	18	15	40	32	33	0.83	1.94	1.83
12. Leaman East	FHLPT	26	15	0	0	4	0	0	0	0	0	---	---	---
13. Trust Wild Rose East	D	7	4	0	0	0	0	0	0	0	0	---	---	---
14. Follmer-Alda	HPT	7	4	0	0	0	0	0	0	0	0	---	---	---
15. DeWeese-Alda	N	7	14	0	0	0	0	0	0	0	0	---	---	---
16. Hooker Bros GI Southeast	N	24	14	9	10	17	12	10	21	6	9	0.83	1.00	0.90
17. Hooker Bros GI East	N	7	4	0	0	0	0	0	0	0	0	---	---	---

[A] Management actions applied to each site: disking (D), exterior predator fencing (E), peninsula entry predator fencing (F), fall 2020 herbicide (H), interior predator fencing (I), predator deterrent lights (L), no management (N), spring 2021 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. 16 of this report) on 23 June 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] "----" Cannot be calculated.

Table 15. Least tern OCSW total nesting incidence and productivity by year, 2001−2021.

Year	Least Tern Off-Channel Peak BPE[A]	Nests	Succ Nests	Fledglings[B]	Fledglings Per Peak BPE[B]
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
Mean	**61.48**	**82.62**	**50.62**	**72.95**	**1.26**

[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 16. Least tern on-channel total nesting incidence and productivity by year, 2001−2021.

Year	Least Tern				
	On-Channel Peak BPE[A]	Nests	Succ Nests	Fledglings[B]	Fledglings Per Peak BPE[B]
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	---
2015	8	14	3	0	0.00
2016	2	2	0	0	---
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	---
Mean	**1.86**	**2.81**	**0.86**	**0.71**	**0.44[C]**

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

Table 17. Number of least tern adults, estimated breeding pairs (BPE), nests, chicks, and fledglings documented from outside the nesting area during semi-monthly OCSW surveys in 2021.

	Least Terns				
Survey	**Adults**	**BPE[A]**	**Nests**	**Chicks**	**Fledglings**
1-May	0	0	0	0	0
15-May	4	0	0	0	0
1-Jun	96	53	42	0	0
15-Jun	128	80	73	6	0
1-Jul	106	73	14	82	0
15-Jul	72	61	4	17	27
1-Aug	10	54	0	2	5

[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. 16). 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 18. 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 2021.

	Least Tern				
Survey	**Adults**	**BPE[A]**	**Nests**	**Chicks**	**Fledglings**
1-May	0	0	0	0	0
15-May	14	0	0	0	0
1-Jun	19	0	0	0	0
15-Jun	5	0	0	0	0
1-Jul	13	0	0	0	0
15-Jul	51	0	0	0	31
1-Aug[B]	18	0	0	0	15

[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. 16). 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 19. Daily and incubation-period survival rates (RMark estimates) for least tern nests monitored on OCSW sites during 2021. Incubation-period nest survival rate = (daily nest survival rate)^21.

Site	Management[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	FPT	1	1	15.0	0.9351	0.0629	0.6538	0.9910	0.2445	0.0000	0.8270
NPPD Lexington	FPT	10	3	179.5	0.9834	0.0095	0.9499	0.9946	0.7040	0.3396	0.8934
Dyer	FHPT	19	3	355.0	0.9916	0.0048	0.9742	0.9973	0.8374	0.5781	0.9445
Blue Hole	FPT	10	6	133.0	0.9558	0.0176	0.9051	0.9800	0.3873	0.1233	0.6547
Broadfoot-South Kearney	FHILPT	20	13	322.0	0.9604	0.0108	0.9330	0.9769	0.4280	0.2330	0.6118
Newark West	EFHLPT	9	3	176.0	0.9831	0.0097	0.9489	0.9945	0.6991	0.3325	0.8914
Newark East	FHPT	18	3	310.5	0.9904	0.0055	0.9706	0.9969	0.8163	0.5346	0.9368
Hooker Brothers - Southeast	N	12	2	196.0	0.9898	0.0071	0.9603	0.9975	0.8071	0.4274	0.9480
All Sites		99	34	1687.0	0.9800	0.0034	0.9722	0.9857	0.6548	0.5531	0.7391

[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), no management (N), spring 2021 pre-emergent herbicide (P), or predator trapping (T).
*Significant difference in average daily nest survival was observed between at least two sites [$\chi2(7, N = 99) = 15.67; p = 0.03$]

Table 20. Daily and incubation-period survival rates (RMark estimates) for least tern nests monitored on Program and non-Program sites during 2021. Incubation-period nest survival rate = (daily nest survival rate)^21.

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]	67	23	1178.5	0.9807	0.0040	0.9711	0.9871	0.6637	0.5399	0.7617
Non-Program[B]	32	11	508.5	0.9786	0.0064	0.9618	0.9881	0.6348	0.4410	0.7778
All Sites	99	34	1687.0	0.9800	0.0034	0.9722	0.9857	0.6548	0.5531	0.7391

[A]Program sites: OSG Lexington, Dyer, Broadfoot – South Kearney, Newark West, Newark East

[B]Non-Program sites: NPPD Lexington, Blue Hole, Hooker Brothers – Southeast

Table 21. Daily and brooding-period survival rates (RMark estimates) for observed least tern broods (1 or more chicks) monitored on OCSW sites during 2021. Brooding-period brood survival rate = (daily brood survival rate)^21.

Site	Management[A]	# Broods	# Broods Lost	Exposure Days	Daily Brood Survival Rate*	Daily Brood Survival SE	Daily Brood Survival Rate 95% CI Lower	Daily Brood Survival Rate 95% CI Upper	Brooding Period Survival Rate	Brooding Period Survival Rate 95% CI Lower	Brooding Period Survival Rate 95% CI Upper
NPPD Lexington	FPT	6	1	110.0	0.9910	0.0090	0.9386	0.9987	0.8262	0.2643	0.9736
Dyer	FHPT	16	1	307.5	0.9968	0.0032	0.9773	0.9995	0.9340	0.6178	0.9904
Blue Hole	FPT	4	1	59.5	0.9833	0.0165	0.8910	0.9977	0.7026	0.0885	0.9519
Broadfoot-South Kearney	FHILPT	7	3	101.5	0.9709	0.0166	0.9135	0.9906	0.5374	0.1496	0.8196
Newark West	EFHLPT	6	1	96.5	0.9897	0.0103	0.9305	0.9985	0.8044	0.2202	0.9700
Newark East	FHPT	15	1	254.5	0.9961	0.0039	0.9727	0.9994	0.9208	0.5593	0.9885
Hooker Brothers - South East	N	10	5	103.5	0.9528	0.0206	0.8915	0.9802	0.3621	0.0897	0.6573
All Sites		64	13	1033.0	0.9875	0.0034	0.9786	0.9927	0.7677	0.6346	0.8578

[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), no management (N), spring 2021 pre-emergent herbicide (P), or predator trapping (T).

*Significant difference in average daily brood survival was observed between at least 2 sites [$\chi2(6, N = 64) = 13.09$; $p = 0.04$]

Table 22. Daily and brooding-period survival rates (RMark estimates) for least tern broods (1 or more chicks) monitored on Program and non-Program sites during 2021. 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 Lower	Daily Brood Survival Rate 95% CI Upper	Brooding Period Survival Rate	Brooding Period Survival Rate 95% CI Lower	Brooding Period Survival Rate 95% CI Upper
Program[A]	44	6	760.0	0.9921	0.0032	0.9826	0.9965	0.8472	0.6918	0.9283
Non-Program[B]	20	7	273.0	0.9747	0.0095	0.9478	0.9879	0.5835	0.3247	0.7741
All Sites	64	13	1033.0	0.9875	0.0034	0.9786	0.9927	0.7677	0.6346	0.8578

[A]Program sites: Dyer, Broadfoot – South Kearney, Newark West, Newark East

[B]Non-Program sites: NPPD Lexington, Blue Hole, Hooker Brothers – Southeast

*Significant difference in average daily brood survival was observed between Program and non-Program sites [$\chi2(1, N = 64) = 4.37$; $p = 0.04$]

Table 23. Number of traps by trap type deployed for terrestrial mammal trapping at Program and NPPD owned plover nesting sites in 2021.

	Trap Type			
Species	**Cage trap**	**Dog proof trap**	**Snare**	**Total traps**
OSG-Lexington	8	8		16
NPPD-Lexington	8	12		20
Dyer	16	16		32
Cottonwood Ranch OCSW	15	17		32
Blue Hole	9	12		21
Broadfoot – South Kearney	14	12		26
Newark West	10	10	16	36
Newark East	9	9		18
Leaman East OCSW	15	13		28
Follmer-Alda	8	10		18
Total	112	119	16	247

Table 24. Summary of terrestrial predator trapping activities at Program and NPPD plover and tern nesting sites in 2021.

Nesting Site	**Mgmt[A]**	**Traps deployed**	**Total Trap Days**	**Captures**	**Captures per trap day**
OSG-Lexington	FPT	16	1,402	12	0.0086
NPPD-Lexington	FPT	20	1,418	30	0.0212
Dyer	FHPT	32	4,372	53	0.0121
Cottonwood Ranch	FHPT	32	4,184	37	0.0088
Blue Hole	FPT	21	1,241	13	0.0105
Broadfoot –South Kearney	FHILPT	26	2,917	40	0.0137
Newark West	EFHLPT	36	3,554	38	0.0107
Newark East	FHPT	18	2,281	24	0.0105
Leaman East	FHLPT	28	3,342	30	0.0090
Follmer-Alda	HPT	18	1,849	18	0.0097
Total		**247**	**26,560**	**295**	**0.0111**

[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), no management (N), spring 2021 pre-emergent herbicide (P), or predator trapping (T).

Table 25. Summary of terrestrial mammal trapping captures, effort, and captures per effort at Program and NPPD owned plover nesting sites in 2021.

		Species Captured													
Site	**Mgmt[A]**	**American badger**	**Domestic cat**	**Mouse *(Peromyscus spp.)***	**North American river otter**	**Ord's kangaroo rat**	**Raccoon**	**Red fox**	**Striped skunk**	**Virginia opossum**	**Wood chuck**	**Total**	**Traps set**	**Trap days**	**Captures/ trap day**
OSG-Lexington	FPT						11	1				12	16	1,402	0.0086
NPPD-Lexington	FPT						30					30	20	1,418	0.0212
Dyer	FHPT			1	1	1	49			1		53	32	4,372	0.0121
Cottonwood Ranch OCSW	FHPT						36			1		37	32	4,184	0.0088
Blue Hole	FPT						12		1			13	21	1,241	0.0105
Broadfoot - South Kearney	FHILPT				1		37		1	1		40	26	2,917	0.0137
Newark West	EFHLPT	1	1				27		1	6	2	38	36	3,554	0.0107
Newark East	FHPT						22			2		24	18	2,281	0.0105
Leaman East OCSW	FHLPT						30					30	28	3,342	0.0090
Follmer	HPT						18					18	18	1,849	0.0097
Total		**1**	**1**	**1**	**2**	**1**	**272[B]**	**1**	**3**	**11**	**2**	**295[B]**	**247**	**26,560**	**0.0111**

[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), spring 2021 pre-emergent herbicide (P), or predator trapping (T).
[B]Removed 1 racoon with firearm at Dyer not included in species captured or captures/trap days.

Table 26. Total terrestrial mammal captures by species and trap type at Program and NPPD owned plover off-channel nesting sites in 2021.

	Trap Type				
Species	**Cage trap**	**Dog proof trap**	**Firearm[A]**	**Snare**	**Total captures**
American Badger				1	1
Domestic cat		1			1
Mouse (*Peromyscus spp.*)		1			1
North American river otter	2				2
Ord's kangaroo rat		1			1
Raccoon	91	178	1	3	273
Red fox		1			1
Striped skunk		3			3
Virginia opossum	6	3		2	11
Woodchuck				2	2
Total Captures	**99**	**188**	**1**	**8**	**296**

[A]Opportunistic firearm usage

Table 27. Summary of track surveys conducted at plover and tern nesting sites in 2021.

Nesting Site	**Mgmt[A]**	**Total Track Surveys**	**Total Unique Track Registers**	**Track Registers per Survey**
Dyer	FHPT	14	38	2.7143
Cottonwood Ranch	FHPT	13	19	1.4615
Broadfoot - South Kearney	FHILPT	14	33	2.3571
Newark West	EFHLPT	13	11	0.8462
Newark East	FHPT	12	29	2.4167
Leaman East	FHLPT	14	22	1.5714
Total		**80**	**152**	**1.9000**

[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), no management (N), spring 2021 pre-emergent herbicide (P), or predator trapping (T).

Table 28. Summary of registers of potential plover and tern predators captured by shoreline cameras during the 2021 nesting season.

Nesting Site	Mgmt[A]	# of Shoreline Cameras	Total Shoreline Camera Days	Total Unique Predator Registers	Registers per Camera Day
Dyer	FHPT	6	512	126	0.2461
Cottonwood Ranch	FHPT	3	252	25	0.0992
Broadfoot - South Kearney	FHILPT	7	609	122	0.2003
Newark West	EFHLPT	6	576	58	0.1007
Newark East	FHPT	5	332	89	0.2681
Leaman East	FHLPT	3	317	78	0.2461
Total		**30**	**2598**	**498**	**0.1917**

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

Table 29. Summary of registers of potential plover and tern predators captured by site-level cameras during the 2021 nesting season.

Nesting Site	Mgmt[A]	# of Site Cameras	Total Site-level Camera Days	Total Unique Predator Registers	Registers per Camera Day
Dyer	FHPT	5	508	1	0.0020
Cottonwood Ranch	FHPT	4	336	21	0.0625
Broadfoot – South Kearney	FHILPT	5	485	1	0.0021
Newark West	EFHLPT	3	288	0	0.0000
Newark East	FHPT	5	525	29	0.0552
Leaman East	FHLPT	3	297	14	0.0471
Total		**25**	**2439**	**66**	**0.0271**

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

Table 30. Summary of registers of potential predators and predation events at plover and tern nests captured by nest-level cameras at during the 2021 nesting season.

Nesting Site	Mgmt[A]	# of Nest Cameras Used	Max Number of Nests Monitored	Total Nest Camera Days	Total Unique Predator Registers or Predation Events	Registers per Camera Day
Dyer	FHPT	10	15	185	9	0.0486
Cottonwood Ranch	FHPT	4	1	19	1	0.0000
Broadfoot - South Kearney	FHILPT	8	18	219	12	0.0548
Newark West	EFHLPT	7	8	92	4	0.0435
Newark East	FHPT	8	9	102	2	0.0196
Leaman East	FHLPT	5	5	51	8	0.1569
Total		**42**	**56**	**668**	**36**	**0.3234**

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

Table 31. 2021 plover and tern nest fate comparison for nests that received cameras and nests that did not receive nest cameras. All monitoring sources (i.e., outside/inside observers; nest, site, and shoreline camera data; and track surveys) were used to determine nest fates.

102 Total Nests	# of Nests	# Succ. Nests	# Succ. Nests w/ Pred[A]	# Fail-Pred	# Fail-UNK	# Fail-WEATH
Nests With Cameras	**56 (55%)**	**34 (61%)**	**2 (4%)**	**15 (27%)**	**4 (7%)**	**1 (2%)**
Piping Plover	**30 (54%)**	**17 (57%)**	**2 (7%)**	**10 (33%)**	**0 (0%)**	**1 (3%)**
Broadfoot - South Kearney	10 (33%)	4 (40%)	1 (10%)	4 (40%)		1 (10%)
Cottonwood Ranch	1 (3%)	1 (100%)				
Dyer	6 (20%)	6 (100%)				
Newark West	4 (13%)	2 (50%)	1 (25%)	1 (25%)		
Newark East	4 (13%)	4 (100%)				
Leaman East	5 (17%)			5 (100%)		
Least Tern	**26 (46%)**	**17 (65%)**	**0 (0%)**	**5 (19%)**	**4 (15%)**	**(0%)**
Broadfoot - South Kearney	8 (31%)	1 (13%)		4 (50%)	3 (38%)	
Cottonwood Ranch						
Dyer	9 (35%)	7 (78%)		1 (11%)	1 (11%)	
Newark West	4 (15%)	4 (100%)				
Newark East	5 (19%)	5 (100%)				
Leaman East						
Nests Without Cameras	**46 (45%)**	**30 (65%)**	**0 (0%)**	**0 (0%)**	**14 (30%)**	**2 (4%)**
Piping Plover	**6 (13%)**	**3 (50%)**	**0 (0%)**	**0 (0%)**	**2 (33%)**	**1 (17%)**
Broadfoot - South Kearney	3 (50%)	1 (33%)			1 (33%)	1 (33%)
Cottonwood Ranch						
Dyer	2 (33%)	1 (50%)			1 (50%)	
Newark West						
Newark East	1 (17%)	1 (100%)				
Leaman East						
Least Tern	**40 (87%)**	**27 (68%)**	**0 (0%)**	**0 (0%)**	**12 (30%)**	**1 (3%)**
Broadfoot - South Kearney	12 (30%)	6 (50%)			5 (42%)	1 (8%)
Cottonwood Ranch						
Dyer	10 (25%)	9 (90%)			1 (10%)	
Newark West	5 (13%)	2 (40%)			3 (60%)	
Newark East	13 (33%)	10 (77%)			3 (23%)	
Leaman East						
Grand Total	**102 (100%)**	**64 (63%)**	**2 (2%)**	**15 (15%)**	**18 (18%)**	**3 (3%)**

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

Table 32. Information gained from nests that received nest camera monitoring summarizing plover and tern reproductive effort, success and failure. 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. Broadfoot – South Kearney = BFS, Cottonwood Ranch = CWR, Leaman East = LES, Newark West = NW, Newark East = NE. SUCC = successful, PRED = Predated, UNK = unknown, WX = weather

		NESTS							EGGS					CHICKS			
Species	Nesting Site	# Monitored	# SUCC	# SUCC Nests w/ PRED	# PRED[A]	# Fail-UNK	# Fail-WX	# Nest Camera Days	# Laid	# Hatch	# PRED	# UNK	# Fail-WX	# Left Nest	# PRED	# UNK Left Nest[B]	# Fail-WX
PLOVER	BFS	10	4	1	4		1	163	37	14	16	6	1	5	3	4	2
PLOVER	CWR	1	1					19	4	4				4			
PLOVER	Dyer	6	6					87	24	14		10		14			
PLOVER	LES	5			5			51	20		20						
PLOVER	NW	4	2	1	1			54	16	9	6	1		7	2		
PLOVER	NE	4	4					67	16	11		5		11			
PLOVER	**PLOVER TOTAL**	**30**	**17**	**2**	**10**	**0**	**1**	**441**	**117**	**52**	**42**	**22**	**1**	**41**	**5**	**4**	**2**
TERN	BFS	8	1		4[A]	3		56	22	2	12[A]	8		2			
TERN	CWR																
TERN	Dyer	9	7		1	1		98	28	21	3	4		18		3	
TERN	LES																
TERN	NW	4	4					38	12	7		5		7			
TERN	NE	5	5					35	14	8		6		8			
TERN	**TERN TOTAL**	**26**	**17**	**0**	**5**	**4**	**0**	**227**	**76**	**38**	**15**	**23**	**0**	**35**	**0**	**3**	**0**
GRAND TOTAL		**56[A]**	**34**	**2**	**15[A]**	**4**	**1**	**668**	**193**	**90**	**57**	**45**	**1**	**76**	**5**	**7**	**2**
			61%	4%	27%	7%	2%			47%	30%	23%	1%	84%	6%	8%	2%

[A] *Includes data from nest O-BFS-22-21 where tern nest/eggs were predated but the individual predator or predation event was not captured on camera because the camera malfunctioned (see pg. 34 for evidence).*

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

Table 33. Timing of plover and tern nest predation captured on nest cameras during the 2021 season based on the estimated incubation day the nest was predated by great-horned owls and an American crow.

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	Broadfoot - South Kearney	O-BFS-03-21	Active	Eggs (4)	18	64%	Great-horned owl
Plover	Broadfoot - South Kearney	O-BFS-04-21	Active	Eggs (3)	25	89%	Great-horned owl
Plover	Broadfoot - South Kearney	O-BFS-05-21	Active	**Addled Eggs** (4)	34	100%	Great-horned owl
Tern	Broadfoot - South Kearney	O-BFS-14-21	Active	Eggs (3)	22	100%	Great-horned owl
Tern	Broadfoot - South Kearney	O-BFS-17-21	Active	Eggs (3)	17	81%	Great-horned owl
Plover	Broadfoot - South Kearney	O-BFS-18-21	Active	Eggs (4)	4	14%	Great-horned owl
Tern	Broadfoot - South Kearney	O-BFS-19-21	Active	Eggs (3)	20	95%	Great-horned owl
Plover	Broadfoot - South Kearney	O-BFS-25-21	Hatched	Eggs (1) & Chicks (3)	28	100%	Great-horned owl
Plover	Newark West	O-NW-08-21	Active	Eggs (4)	8	29%	American Crow
Plover	Newark West	O-NW-13-21	Hatched	Eggs (2) & Chicks (2)	29	100%	Great-horned owl
Plover	Leaman East	O-LES-01-21	Active	Eggs (4)	18	64%	Great-horned owl
Plover	Leaman East	O-LES-02-21	Active	Eggs (4)	5	18%	Great-horned owl
Plover	Leaman East	O-LES-03-21	Active	Eggs (4)	19	68%	Great-horned owl
Plover	Leaman East	O-LES-04-21	Active	Eggs (2)	3	11%	Great-horned owl
Plover	Leaman East	O-LES-04-21	Active	Eggs (2)	22	79%	Great-horned owl
Plover	Leaman East	O-LES-05-21	Active	Eggs (1)	16	57%	Great-horned owl
Plover	Leaman East	O-LES-05-21	Active	Eggs (3)	22	79%	Great-horned owl
Average Incubation Completed for Piping Plovers					**18.3**	**63%**	
Average Incubation Completed for Least Terns					**19.7**	**92%**	

Table 34. Nest fate logistic exposure model results for comparison of daily nest survival (DSR) of plover and tern nests with a nest camera present or not present across and within 4 off-channel nesting sites. Model results included model variable, effect size (**β**), standard error (se), z-value (z), and p-value. Cameras placed at nests (Camera) were not found to impact DSR across sites or within sites during the 2021 nesting season.

Model variable	**β**	se	z	p-value[A]
Both Species Across Sites				
Intercept	4.04	0.43	9.38	0.00
Camera	0.39	0.36	1.09	0.28
Plover Only Across Sites				
Intercept	2.59	1.04	2.49	0.01
Camera	2.50	0.80	3.12	0.002**
Tern Only Across Sites				
Intercept	4.15	0.41	10.11	0.00
Camera	-0.11	0.44	-0.25	0.80
Both Species Within Sites				
Intercept[B]	3.23	0.35	9.10	0.00
Camera	0.01	0.46	0.03	0.98
Dyer	1.36	0.79	1.72	0.08
Newark West	0.23	0.68	0.34	0.74
Newark East	1.18	0.68	1.74	0.08
Camera/Dyer	0.44	1.10	0.40	0.69
Camera/Newark West	1.56	1.25	1.25	0.21
Camera/Newark East	15.15	NE[C]	0.02	0.99

[A]Alpha level of significance = 0.05

[B]Broadfoot –South Kearney is the reference site and included with intercept
[C]Non-estimable (NE) due to all camera nests surviving to hatch chicks
**Camera nests had statistically significantly higher daily nest survival rates than non-camera nests

Table 35. Research previously expanded upon in past annual Program tern and plover reports related to plover and tern monitoring and reproductive success.

Study Years	Study Topic	Document Title	Summary	Principle Findings	Citation
2020	Predator monitoring via remote camera	Platte River Recovery Implementation Program 2020 Interior Least Tern and Piping Plover Monitoring and Research Report, Central Platte River, Nebraska ATTN: PREDATOR CAMERA 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.
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.
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, Farrell P, Henry M, Reichart L. 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, Mason P, Farrell P, Reichart L, Ranglack DH, Little A. 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.
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.
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.

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.

2008-2020	Annual piping plover and least tern synthesis reports	PRRIP Tern and Plover Monitoring Reports (2008-2020)	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
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, however. 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.
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.

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.
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.
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

FIGURES

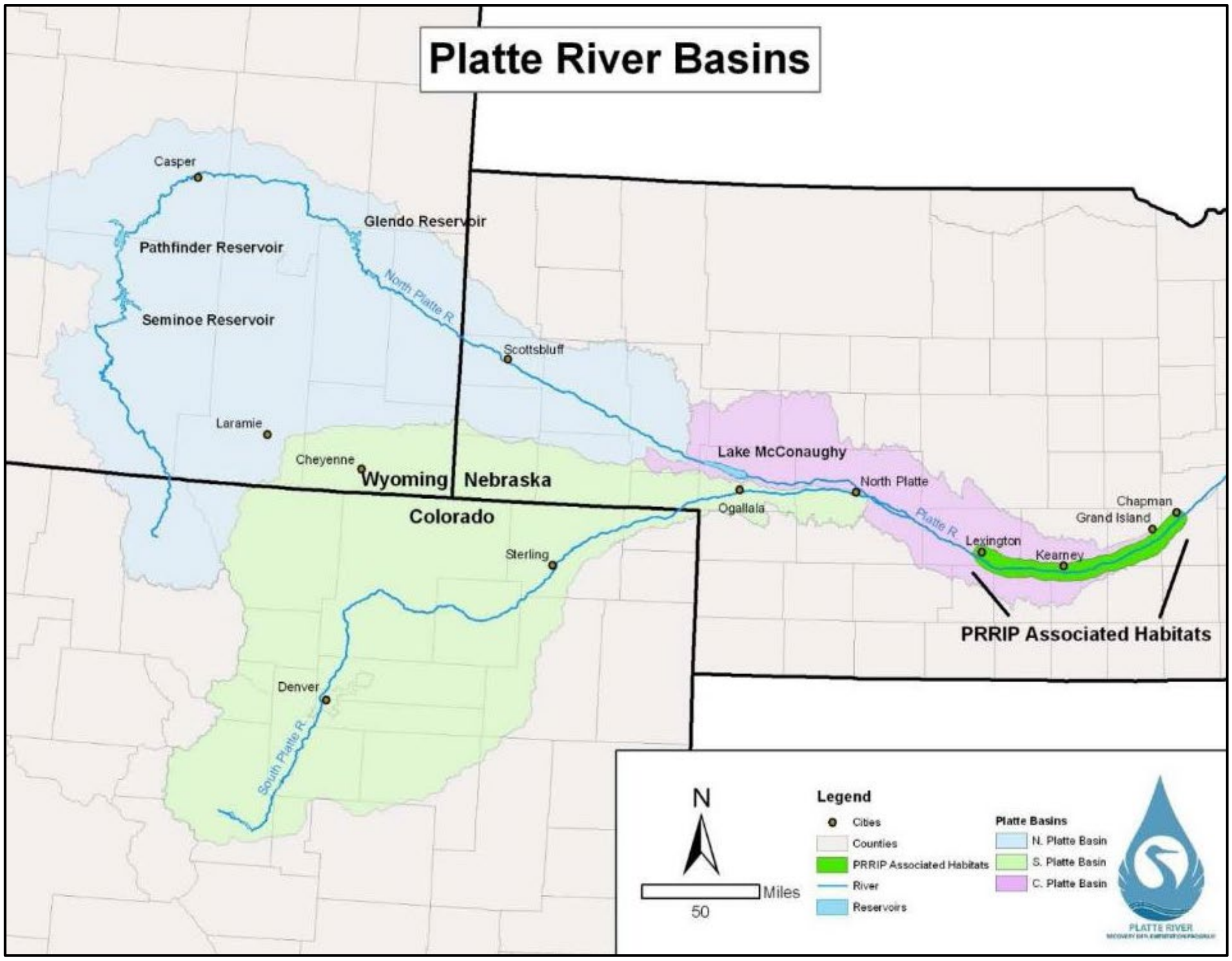

Figure 1. Platte River Basins extending from Colorado and Wyoming through Nebraska. The study area for our piping plover and least tern monitoring and research efforts was the PRRIP Associated Habitat Reach of the Platte River located between Lexington and Chapman, Nebraska (in dark green).

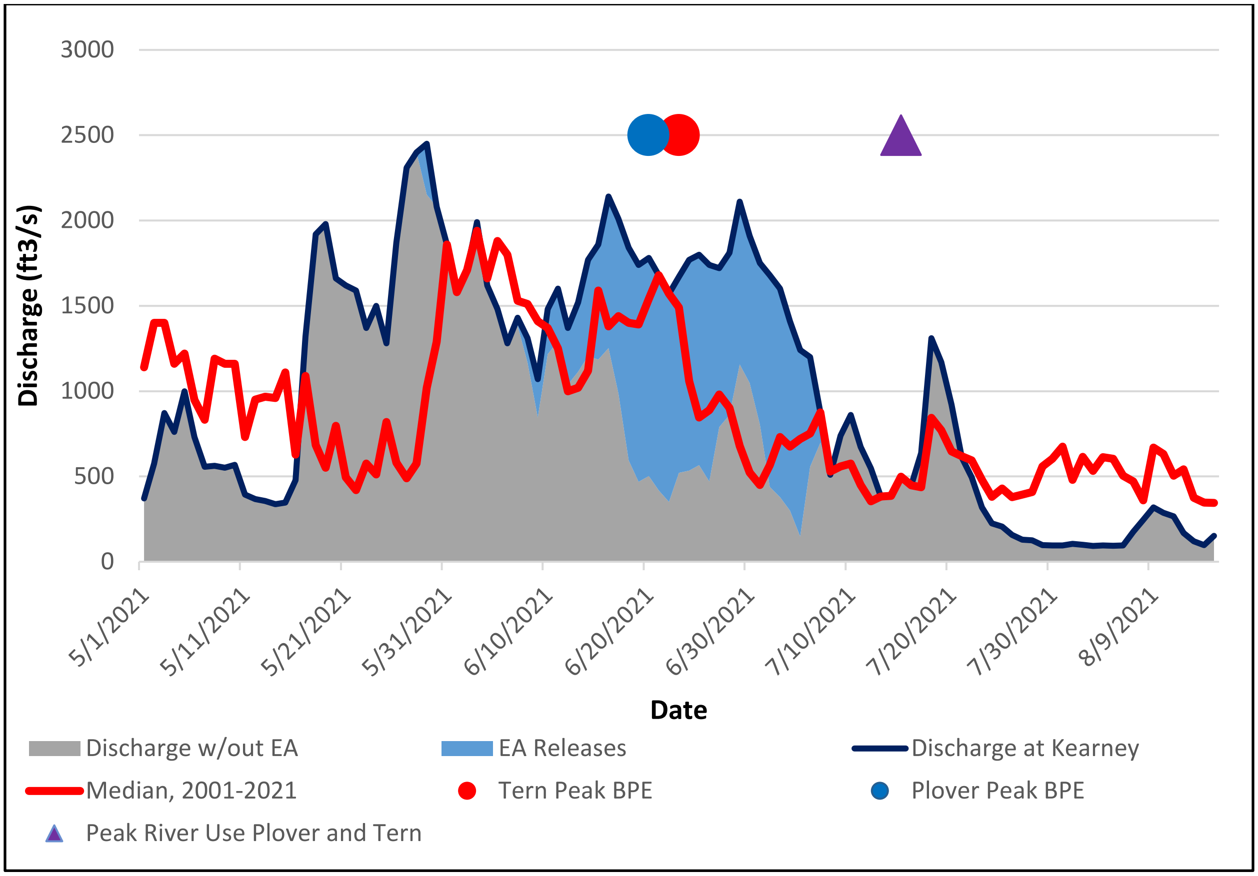

Figure 2. Discharge (ft[3]/second; cfs) at Kearney, Nebraska (USGS gage 06770200) in 2021 (dark blue line) (USGS 2021). Median daily discharge from 2001–2021 at Kearney (USGS gage 06770200) (red line). See Figure 5 for the location of gage stations within our study area. Discharge without the inclusion of the EA releases (gray area). Discharge with EA releases (light blue area). Dates breeding pairs/nesting and river use for both species peaked marked and displayed above discharge. Date plover breeding pairs/nesting peaked at OCSW sites across the AHR (10 June; blue circle), date tern breeding pairs/nesting peaked at OCSW sites across the AHR (23 June; red circle), and date adult counts observed on river survey peaked for both species (15 July; purple triangle).

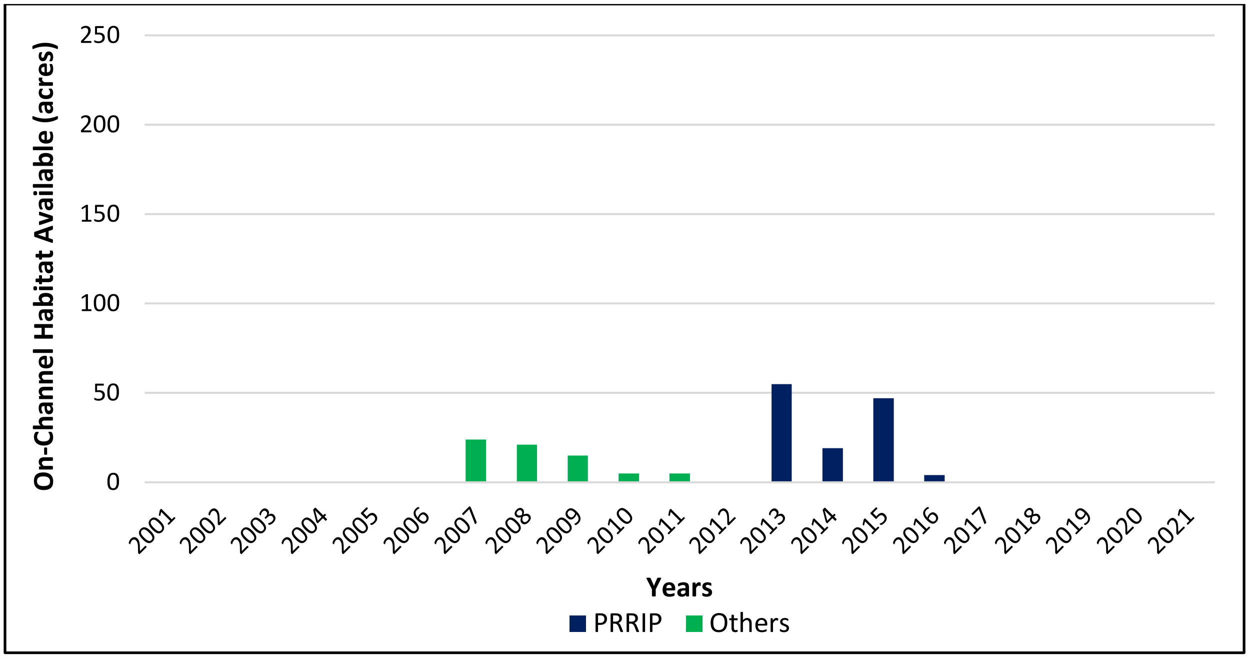

Figure 3. Monitored on-channel nesting habitat along the AHR from 2001-2021 that was created, rehabilitated, and managed by the Program and other organizations and that fits the accepted Program habitat requirements (PRRIP 2015). Available on-channel habitat from 2001-2006 only includes sites that were used in reproductive and survival calculations each year, but no nesting was observed during this time period

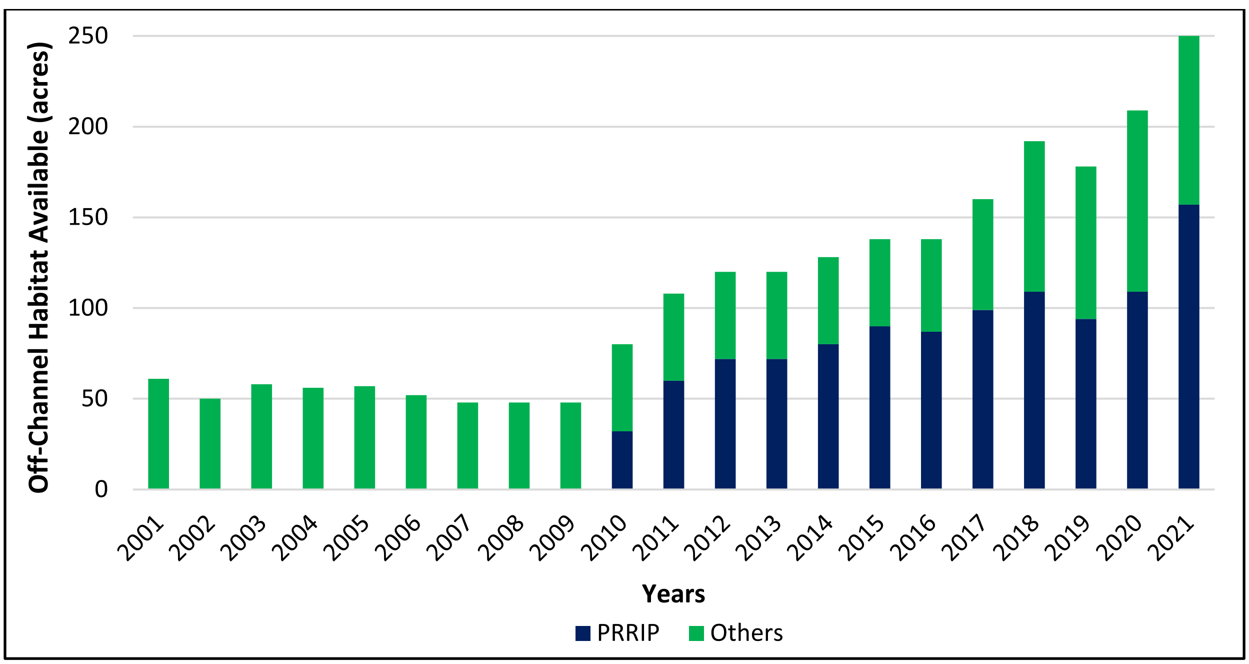

Figure 4. Off-channel nesting habitat along the AHR from 2001-2021 that were monitored by the Program and other organizations and that fits the accepted Program habitat requirements (PRRIP 2015). Due to access restrictions that limited monitoring at some sites, available OCSW habitat from 2001-2009 only includes sites that were used in the reproductive and survival calculations each year.

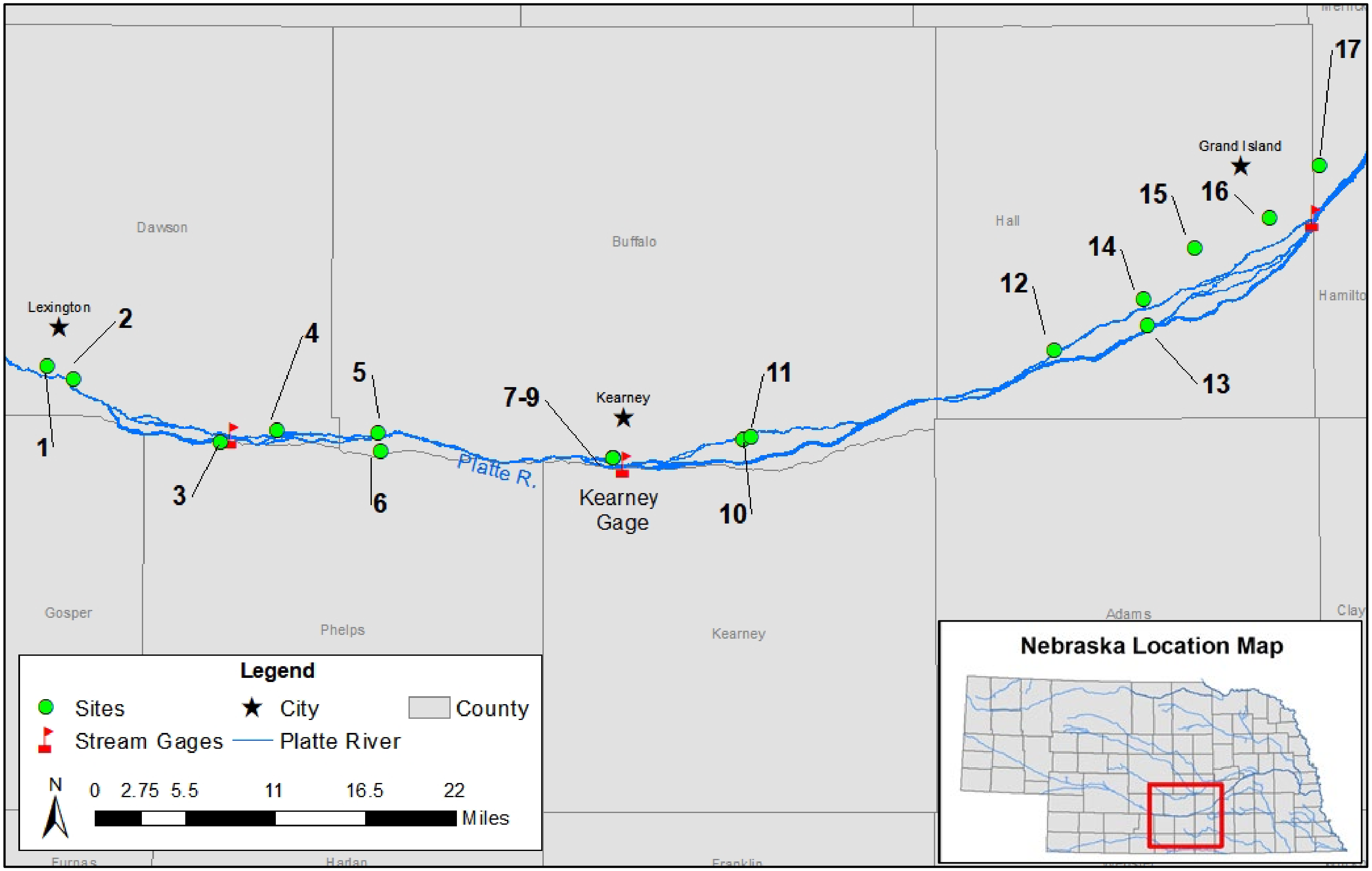

Figure 5. Study area including OCSW nesting sites (green) and river channels (blue) monitored for piping plover and least tern nesting and foraging activities during 2021. River gauge locations are in red. Kearney gage (USGS gage 06770200) location marked (USGS 2021). Names of numbered sites are included in Tables 3 and 14.

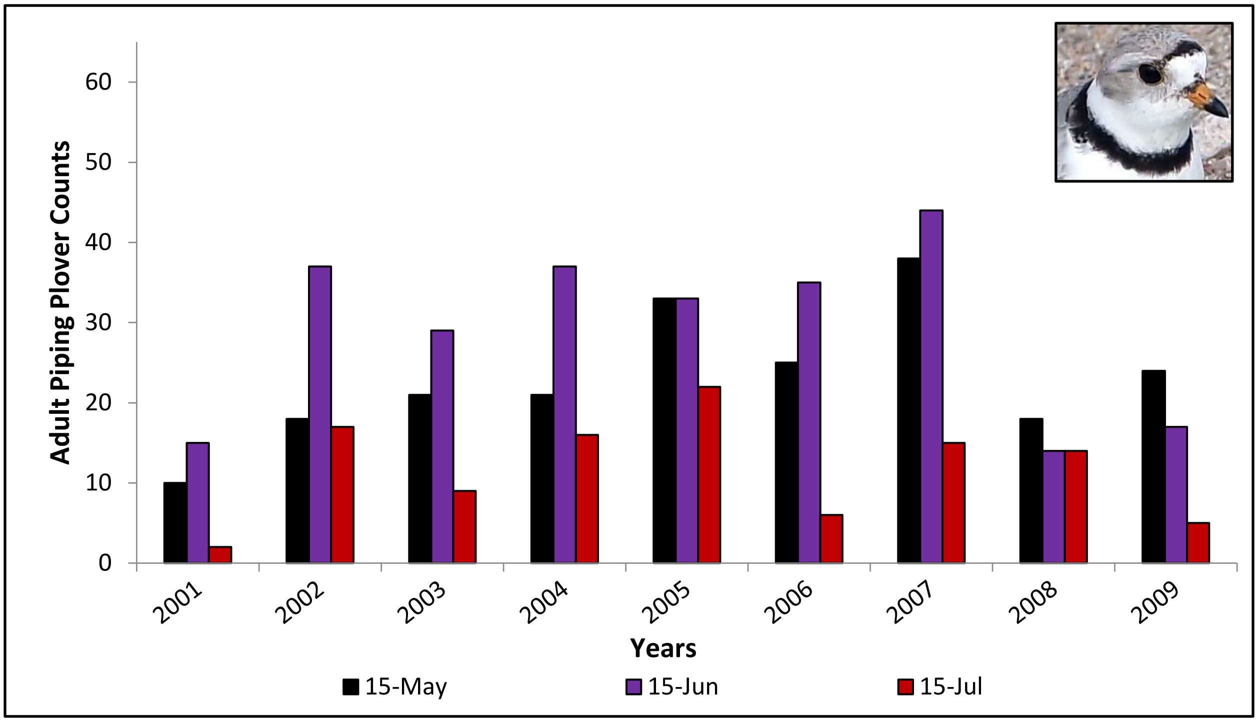

Figure 6. Numbers of piping plover adults observed during 3 semi-monthly surveys of OCSW sites along the Platte River between Lexington and Chapman, Nebraska, 2001–2009.

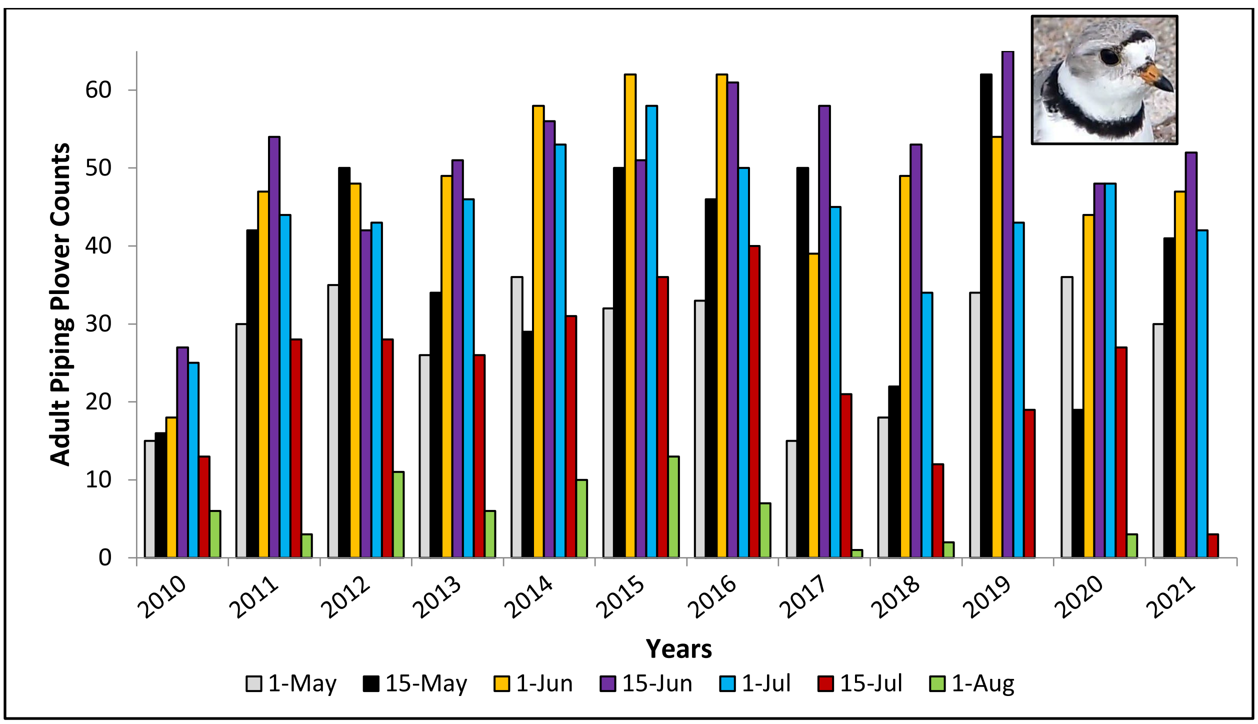

Figure 7. Numbers of piping plover adults observed during 7 semi-monthly surveys of OCSW sites along the Platte River between Lexington and Chapman, Nebraska, 2010–2021.

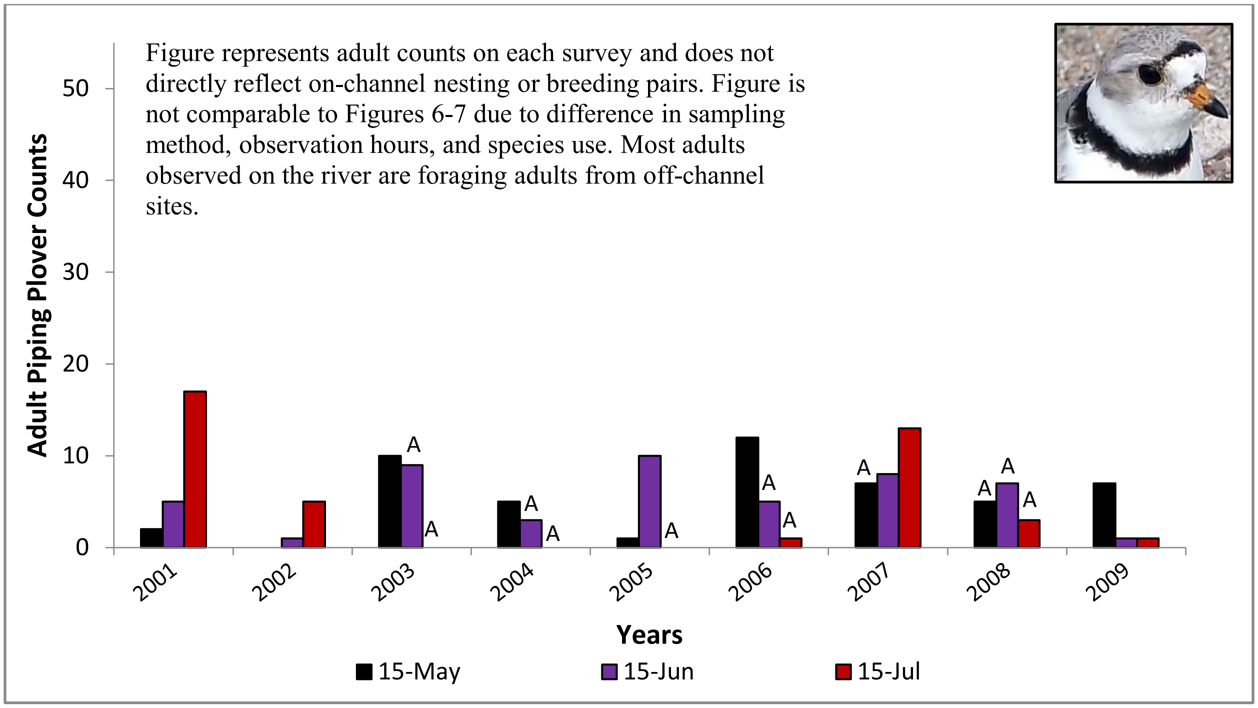

Figure 8. Numbers of piping plover adults observed during 3 semi- monthly surveys of the Platte River between Lexington and Chapman, Nebraska, 2001-2009.
[A]Sample periods for which at least one section of the river was not completed due to a lack of flow in the channel, high flow, or other restrictions.

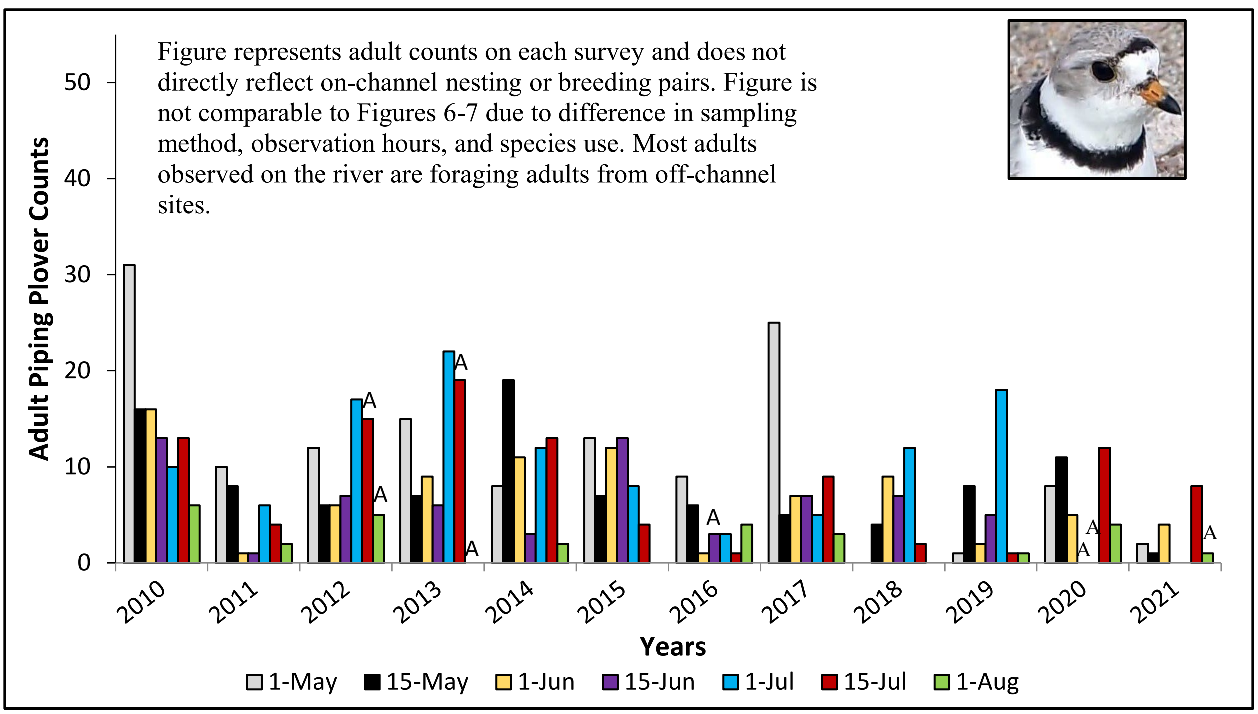

Figure 9. Numbers of piping plover adults observed during 7 semi- monthly surveys of the Platte River between Lexington and Chapman, Nebraska, 2010-2021.
[A]Sample periods for which at least one section of the river was not completed due to a lack of flow in the channel, high flow, or other restrictions.

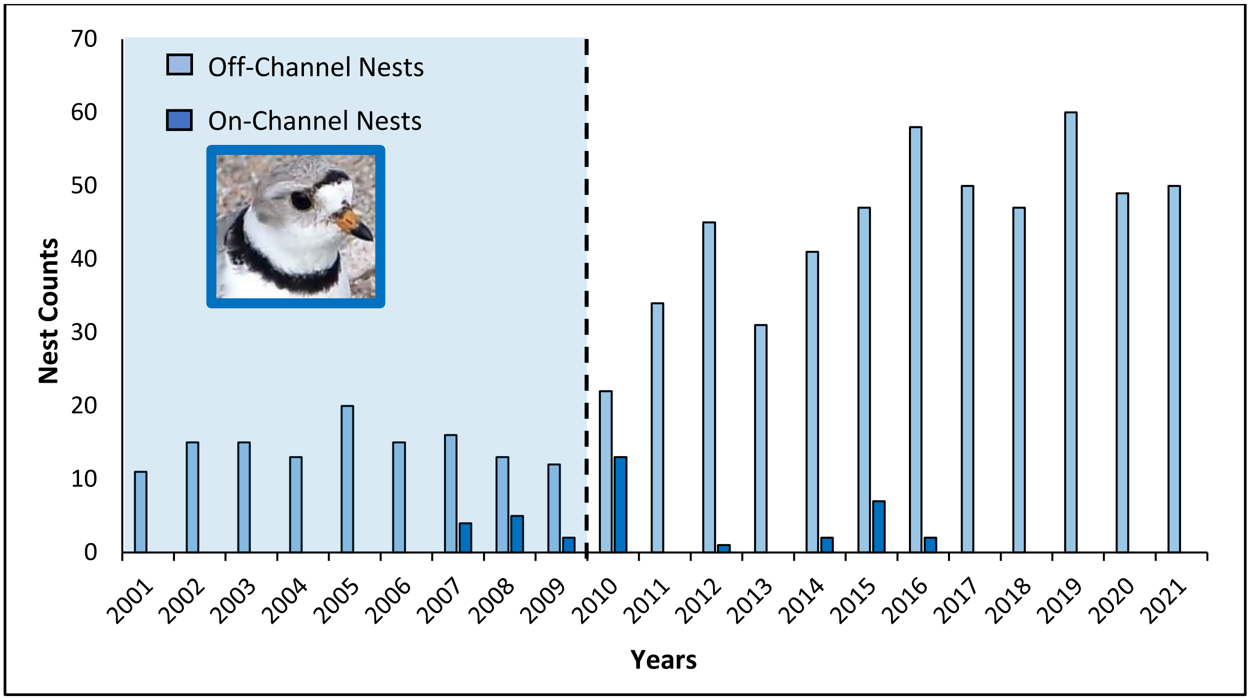

Figure 10. Comparison of piping plover off-channel (light blue bars) and on-channel (dark blue bars) nests within the Program Associated Habitat Reach, 2001-2021. The black dotted line represents changes in protocol, including an increase in monitoring effort, and the shaded area represent years that are not as easily comparable to current protocols.

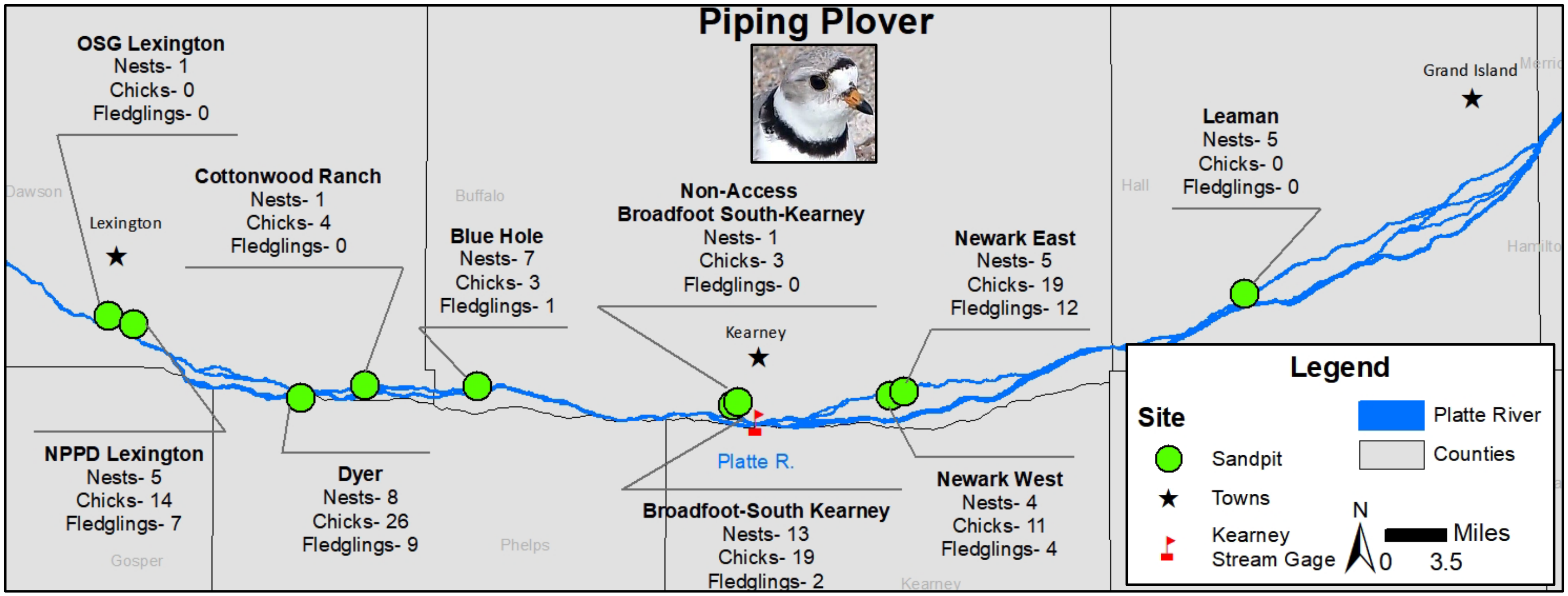

Figure 11. Distribution and numbers of piping plover nests, chicks, and fledglings observed within Program associated habitats during 2021 surveys of sites. Piping plover nests and chicks were observed and monitored at 10 of the 17 off-channel sites monitored during 2021. Kearney stream gage (USGS gage 06770200) marked in red (USGS 2021).

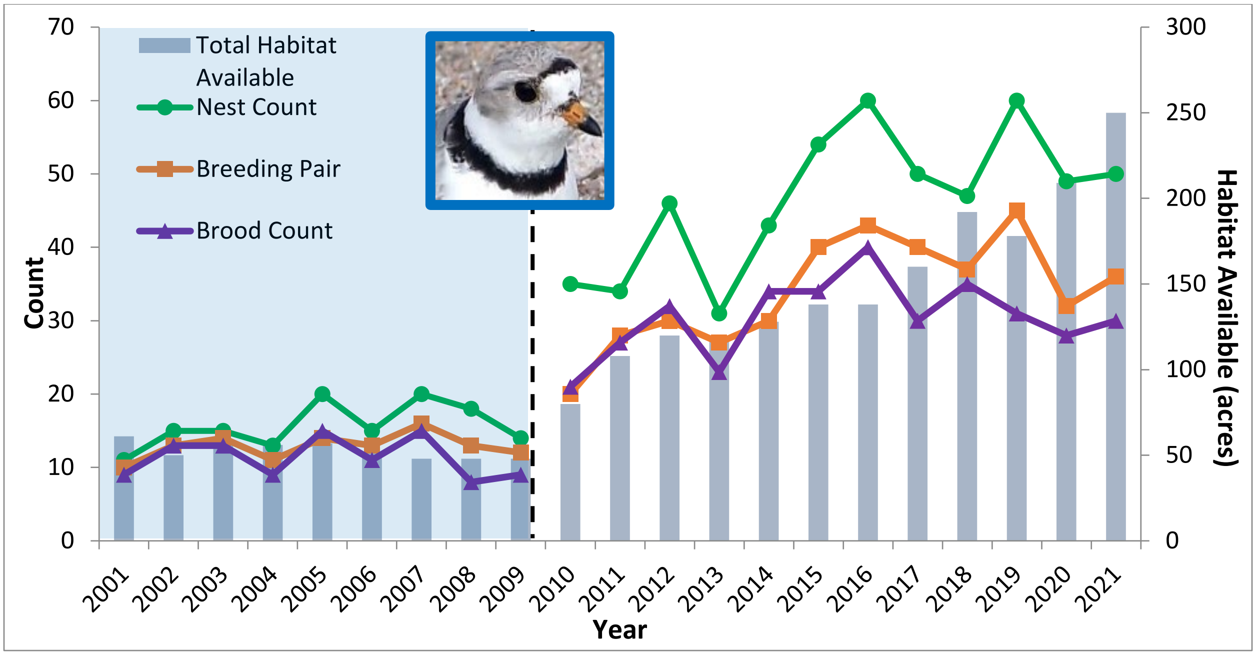

Figure 12. Annual total numbers of piping plover nests (green line), peak breeding pairs (orange line), brood counts (purple line), and total on- and off-channel habitat available (blue bars) observed within the Program Associated Habitat Reach, 2001-2021. The black dotted line represents changes in 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.

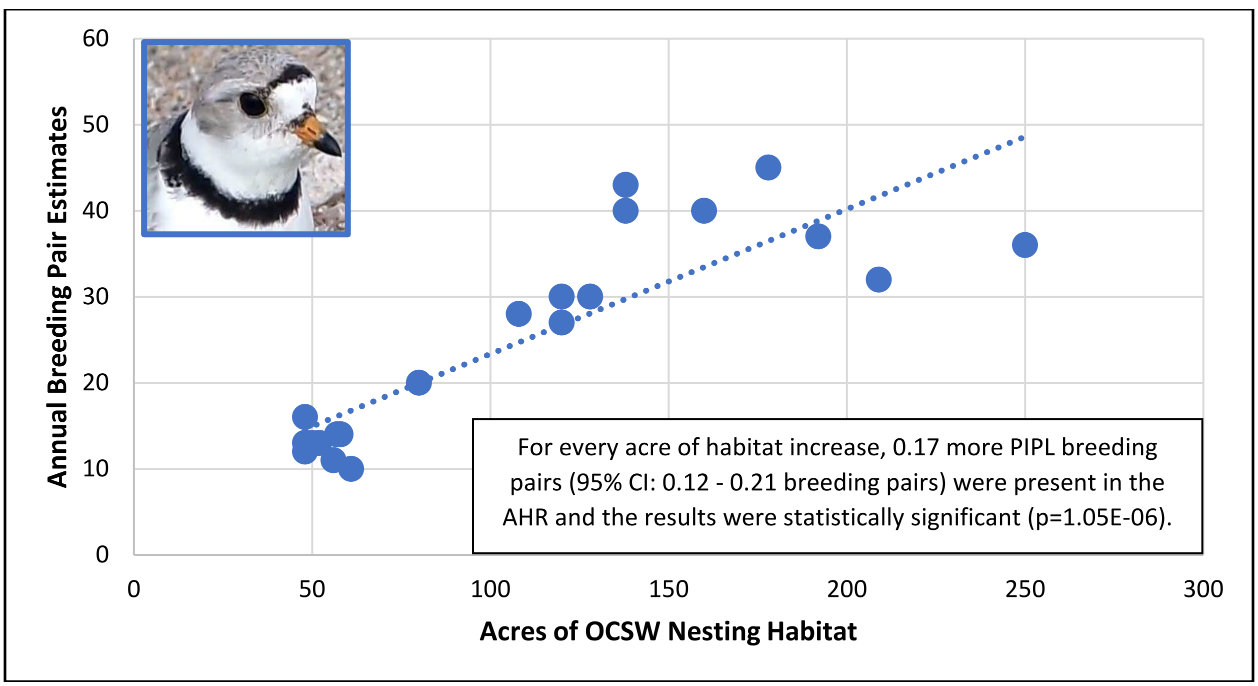

Figure 13. Relationship between numbers of piping plover breeding pairs and availability of monitored off-channel habitat within the Program Associated Habitat Reach, 2001-2021. Due to access restrictions that limited monitoring at some sites, available habitat from 2001-2009 only includes sites that were used in the reproductive and survival calculations each year.

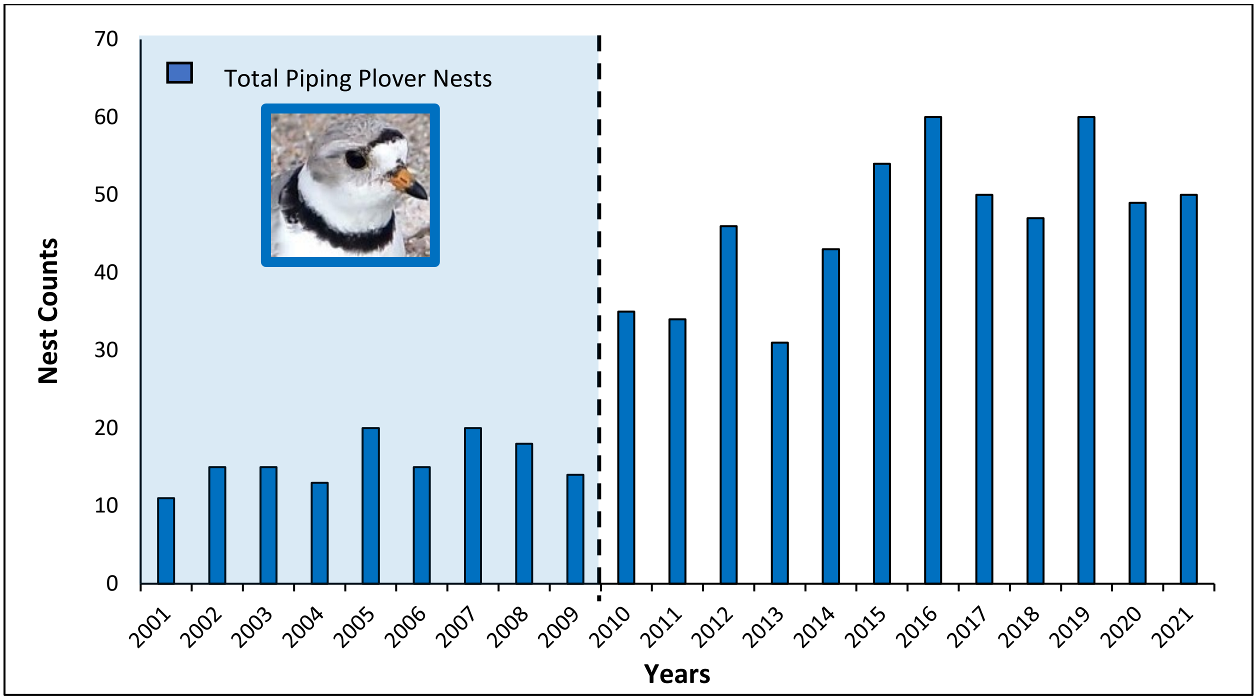

Figure 14. Total piping plover nests on- and off-channel within the Program Associated Habitat Reach, 2001-2021. The black dotted line represents changes in protocol, including an increase in monitoring effort, and the shaded area represent years that are not as easily comparable to current protocols.

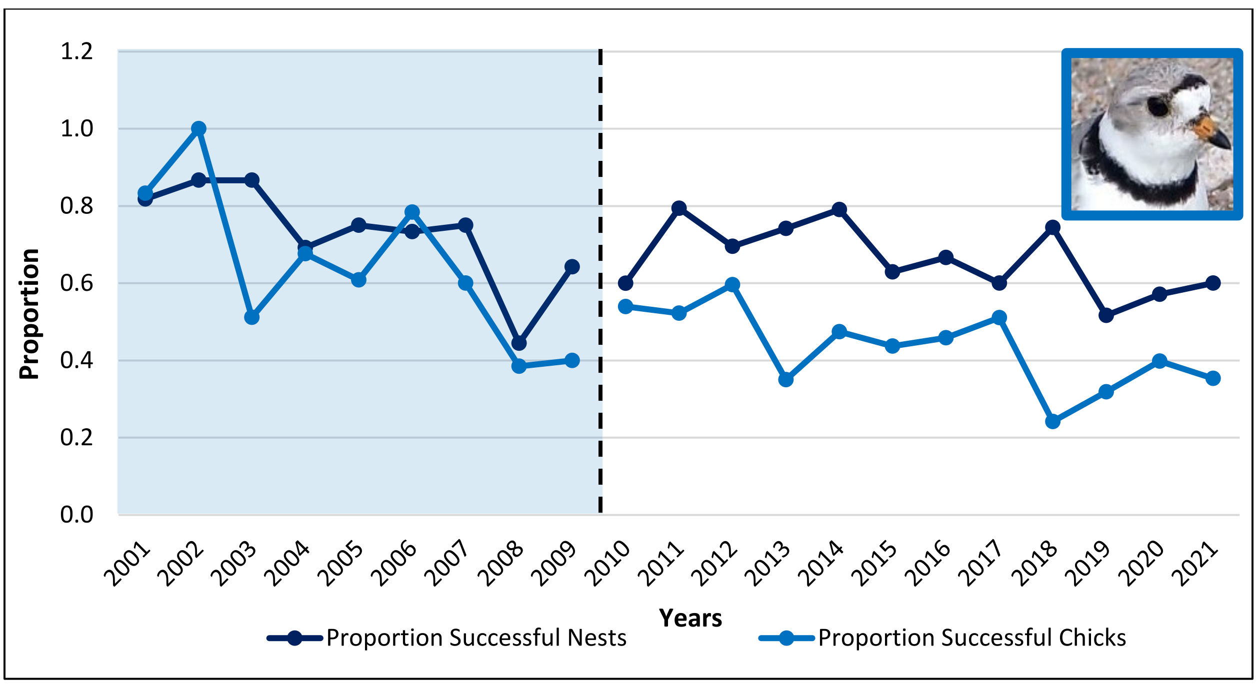

Figure 15. Proportion of successful nests (apparent nest success) and proportion of successful chicks (proportion of chicks fledged) for piping plovers from 2001-2021. The black dotted line represents changes in protocol, and the shaded area represents data that is not comparable. Among other changes, fledge age was changed from a 15-day success benchmark to 28 days for plovers

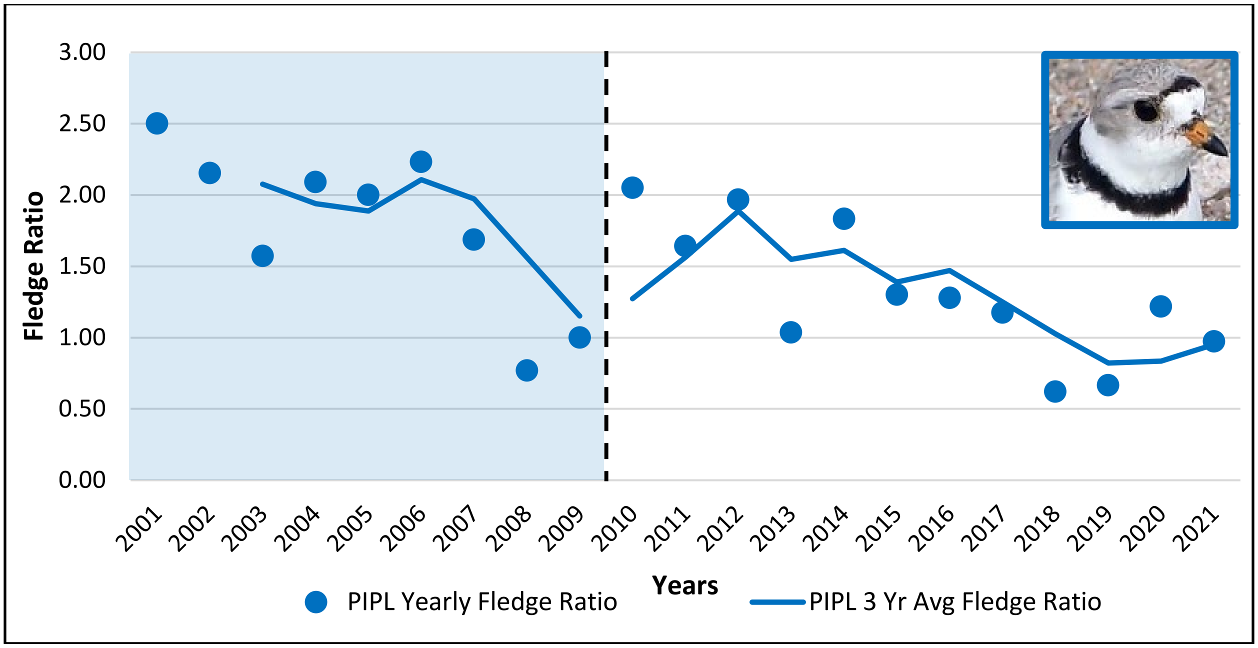

Figure 16. Annual fledge ratios (points) and 3-year running average fledge ratios (lines) for piping plovers from 2001-2021. The black dotted line represents changes in protocol, and the shaded area represents data that is not comparable. Among other changes, fledge age was changed from a 15-day success benchmark to 28 days for plovers. 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.

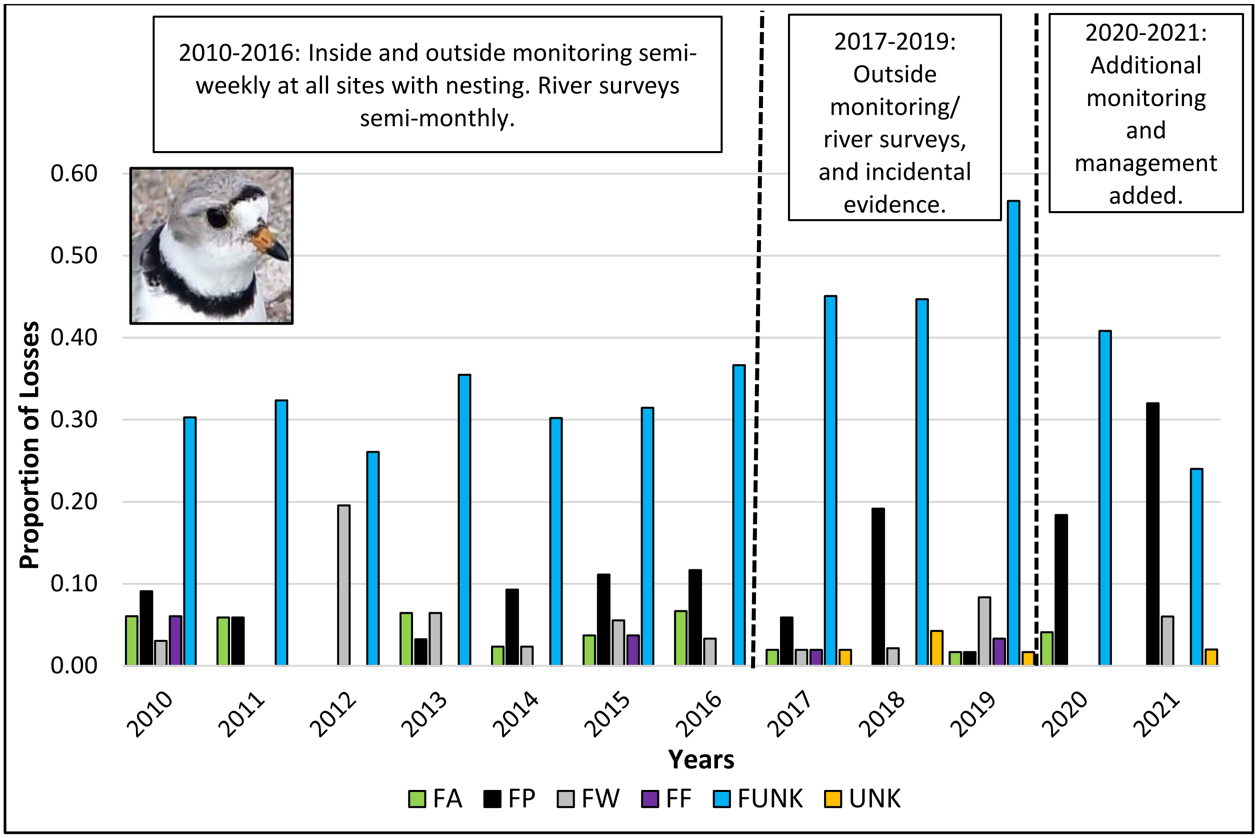

Figure 17. Proportion of combined nest and brood losses in each category for piping plovers from 2010-2021 across the AHR. Each loss represents a unique reproductive attempt. The assigned causes of loss include failed-abandoned (FA)(green), failed-predated (FP)(black), failed-weather (FW)(grey), failed-flooded (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.

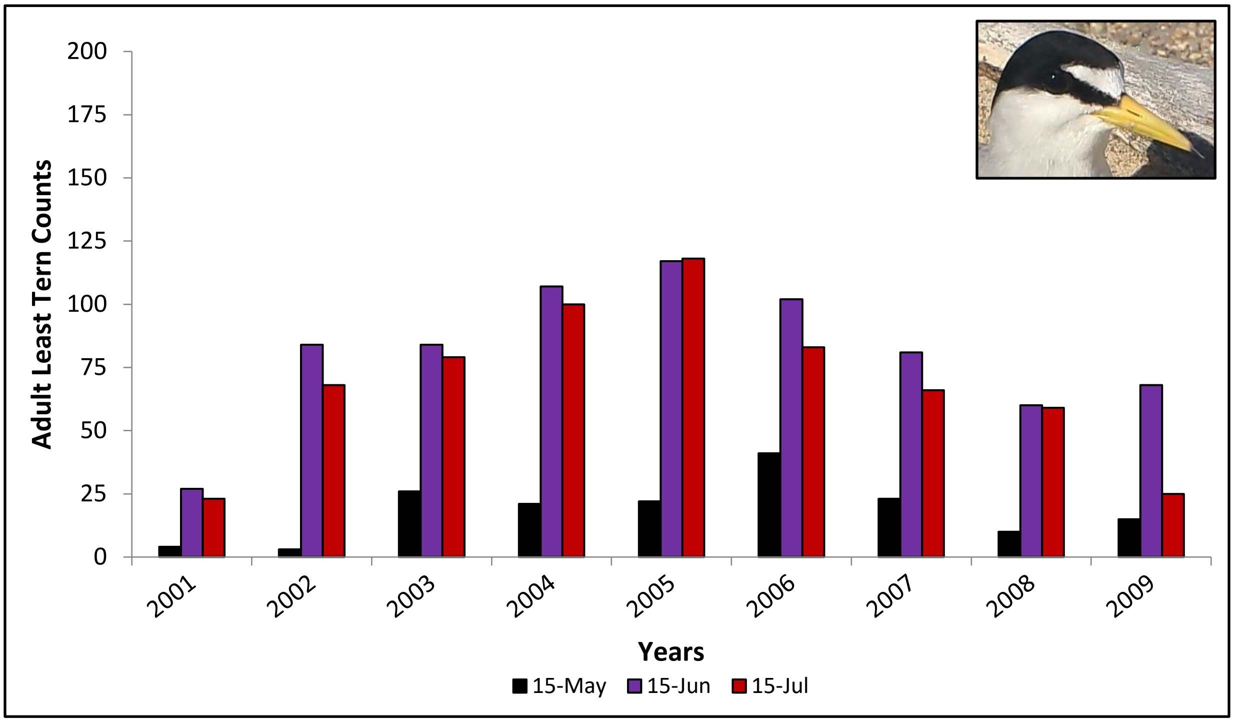

Figure 18. Numbers of least tern adults observed during 3 semi-monthly surveys of OCSW sites along the Platte River between Lexington and Chapman, Nebraska, 2001–2009.

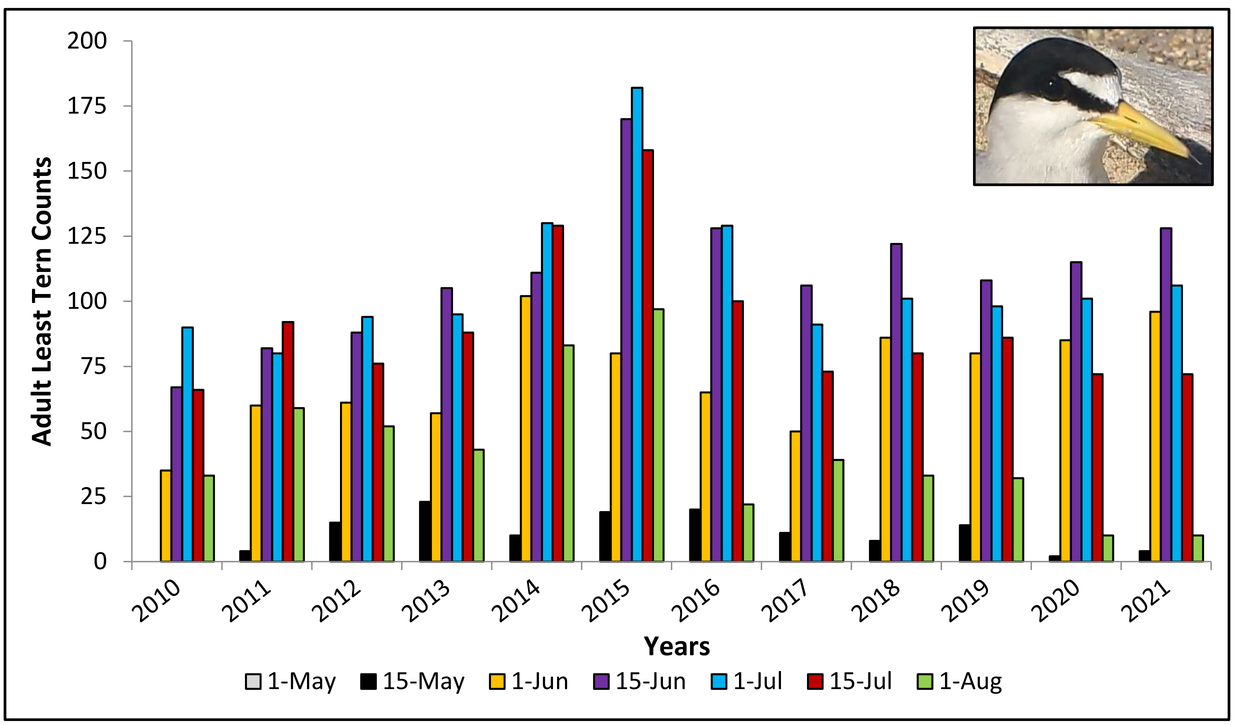

Figure 19. Numbers of least tern adults observed during 7 semi-monthly surveys of OCSW sites along the Platte River between Lexington and Chapman, Nebraska, 2010–2021.

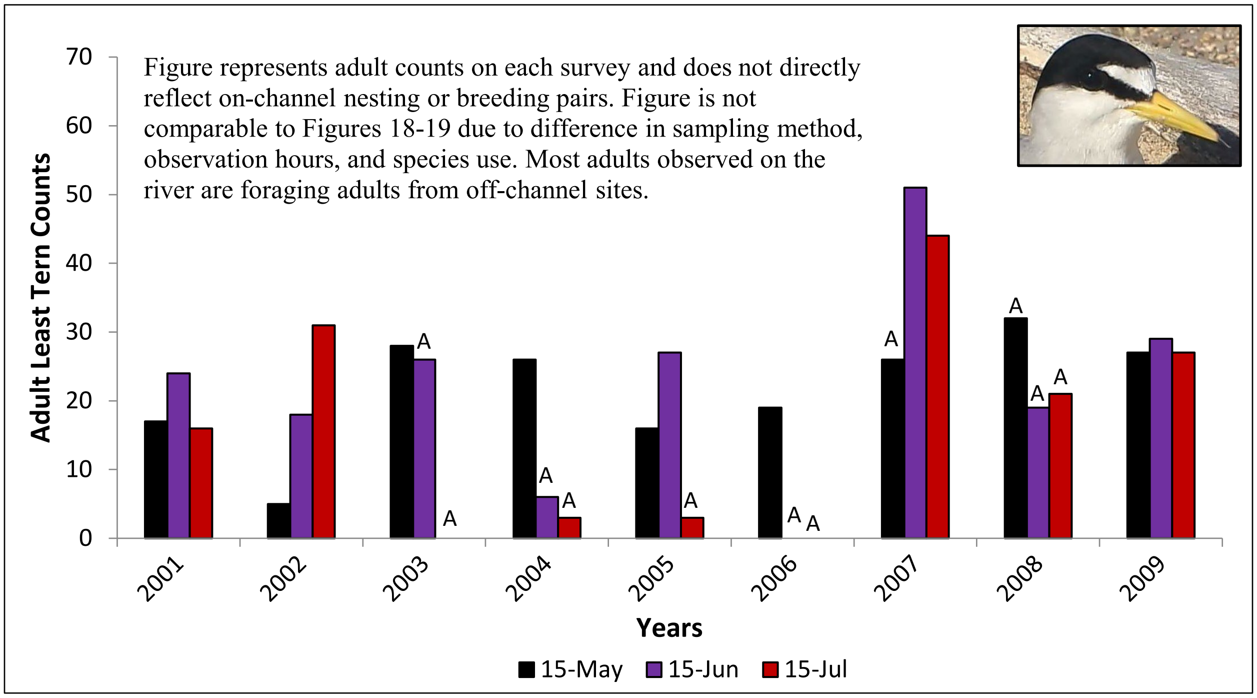

Figure 20. Numbers of least tern adults observed during 3 semi- monthly surveys of the Platte River between Lexington and Chapman, Nebraska, 2001-2009.

[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.

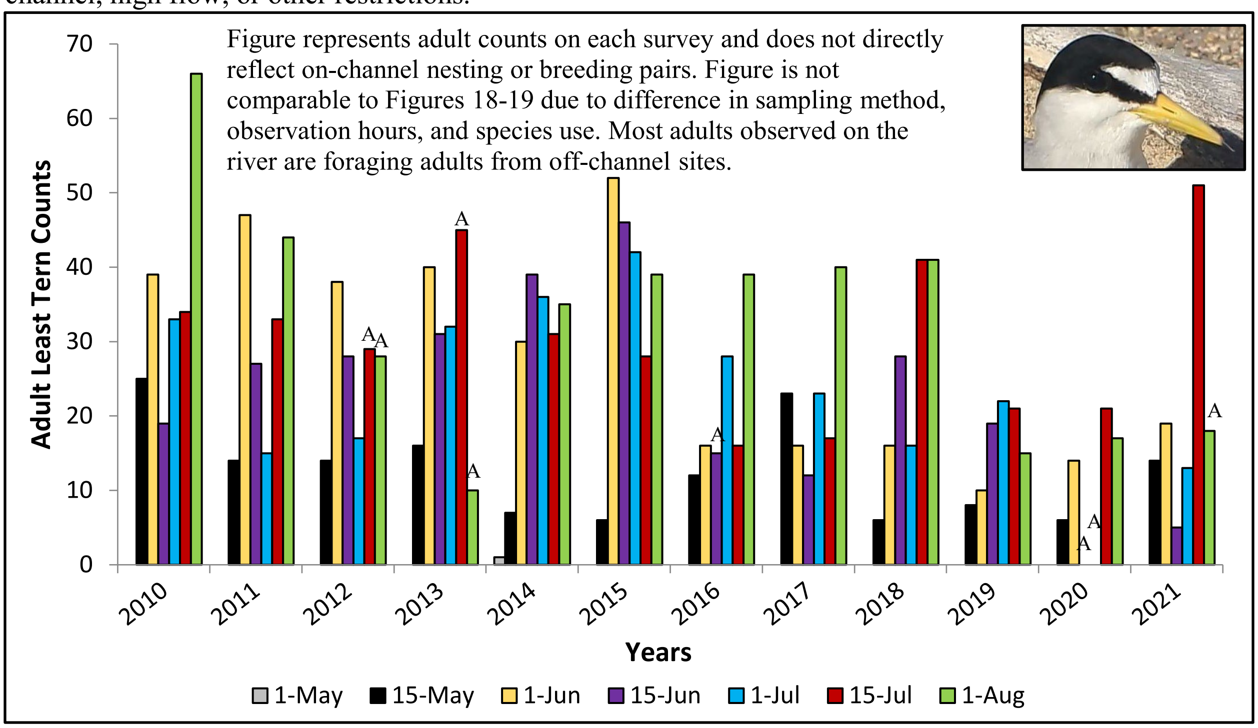

Figure 21. Numbers of least tern adults observed during 7 semi- monthly surveys of the Platte River between Lexington and Chapman, Nebraska, 2010-2021.

[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.

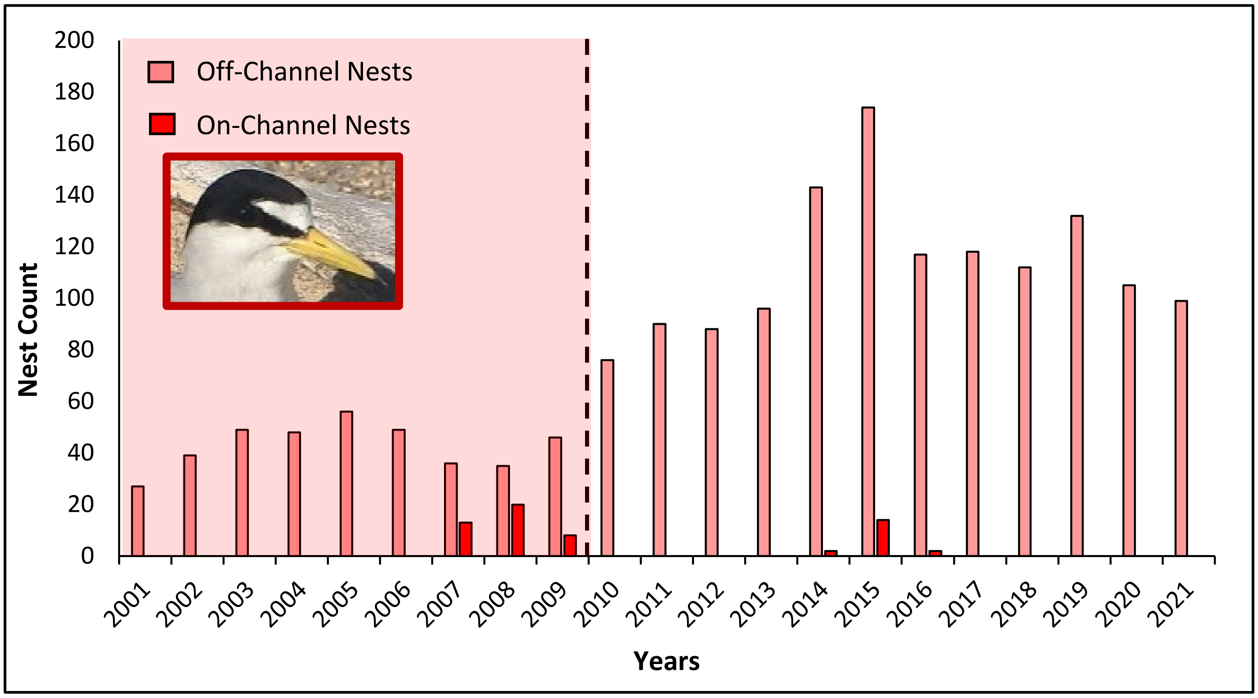

Figure 22. Comparison of least tern off-channel (light red bars) and on-channel (dark red bars) nests within the Program Associated Habitat Reach, 2001-2021. The black dotted line represents changes in protocol, including an increase in monitoring effort, and the shaded area represent years that are not as easily comparable to current protocols.

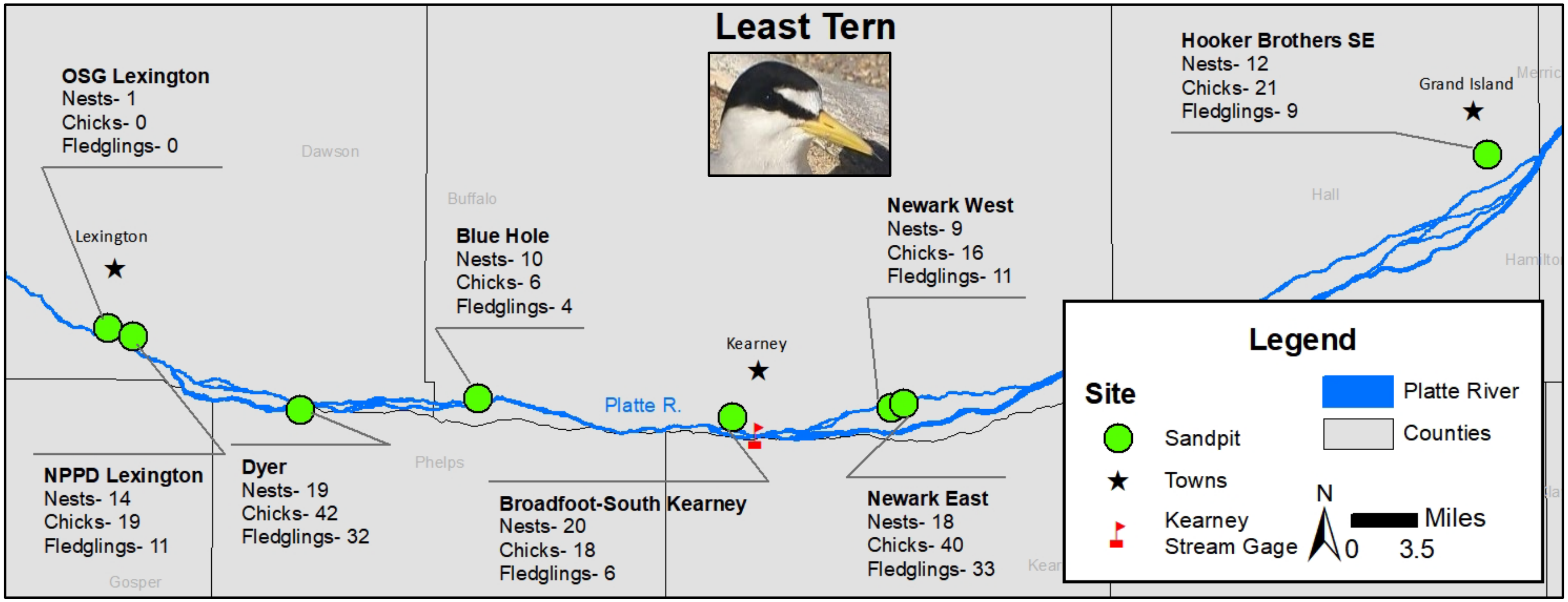

Figure 23. Distribution and numbers of least tern nests, chicks, and fledglings observed within Program associated habitats during 2021 surveys of sites. Least tern nests and/or chicks were observed and monitored at 8 of the 17 off-channel sites. Kearney stream gage (USGS gage 06770200) marked in red (USGS 2021).

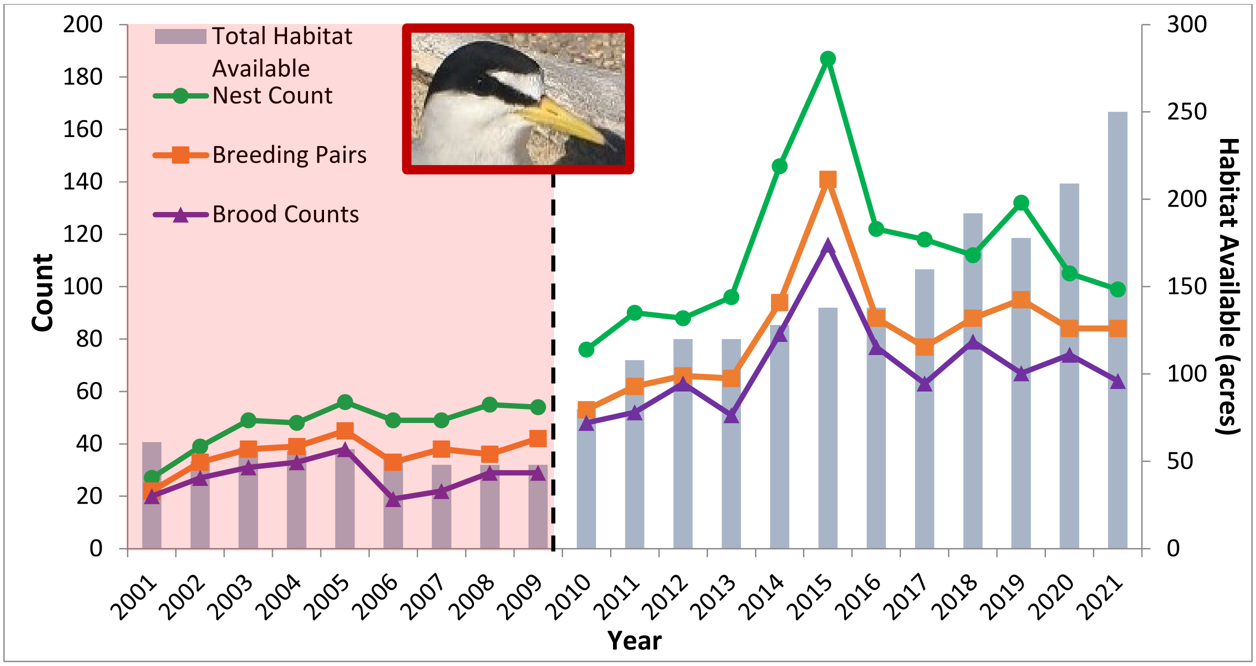

Figure 24. Annual total numbers of least tern nests (green line), peak breeding pairs (orange line), brood counts (purple line), and total on- and off-channel habitat available (blue bars) observed within the Program Associated Habitat Reach, 2001-2021. The black dotted line represents changes in protocol, 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.

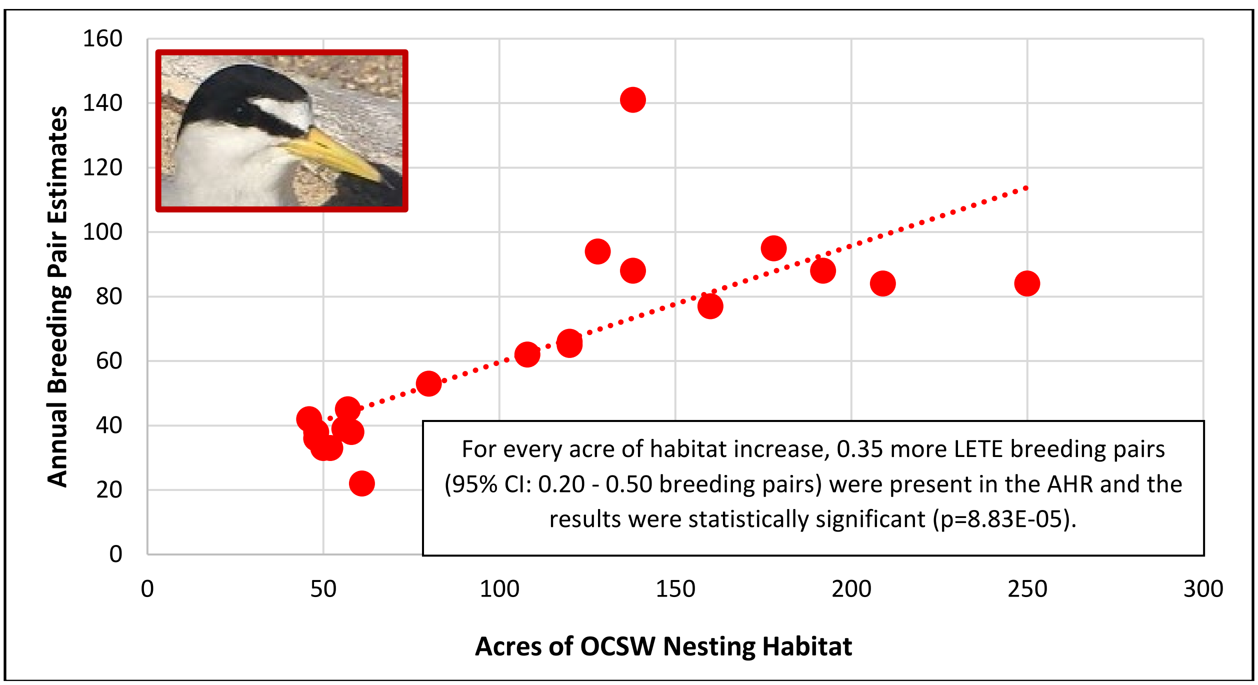

Figure 25. Relationship between numbers of least tern breeding pairs and availability of monitored off-channel habitat within the Program Associated Habitat Reach, 2001-2021. Due to access restrictions that limited monitoring at some sites, available habitat from 2001-2009 only includes sites that were used in the reproductive and survival calculations each year.

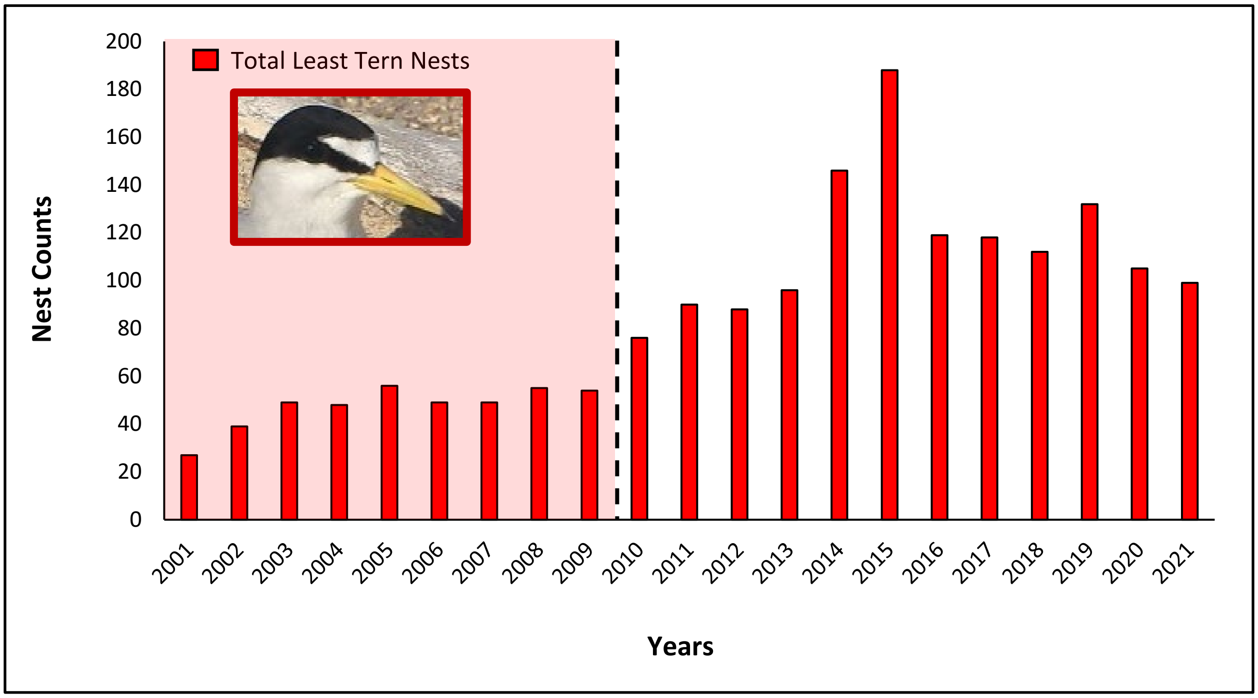

Figure 26. Total on- and off- channel least tern nests across the Associated Habitat Reach, 2001-2021. The black dotted line represents changes in protocol, including an increase in monitoring effort, and the shaded area represent years that are not as easily comparable to current protocols.

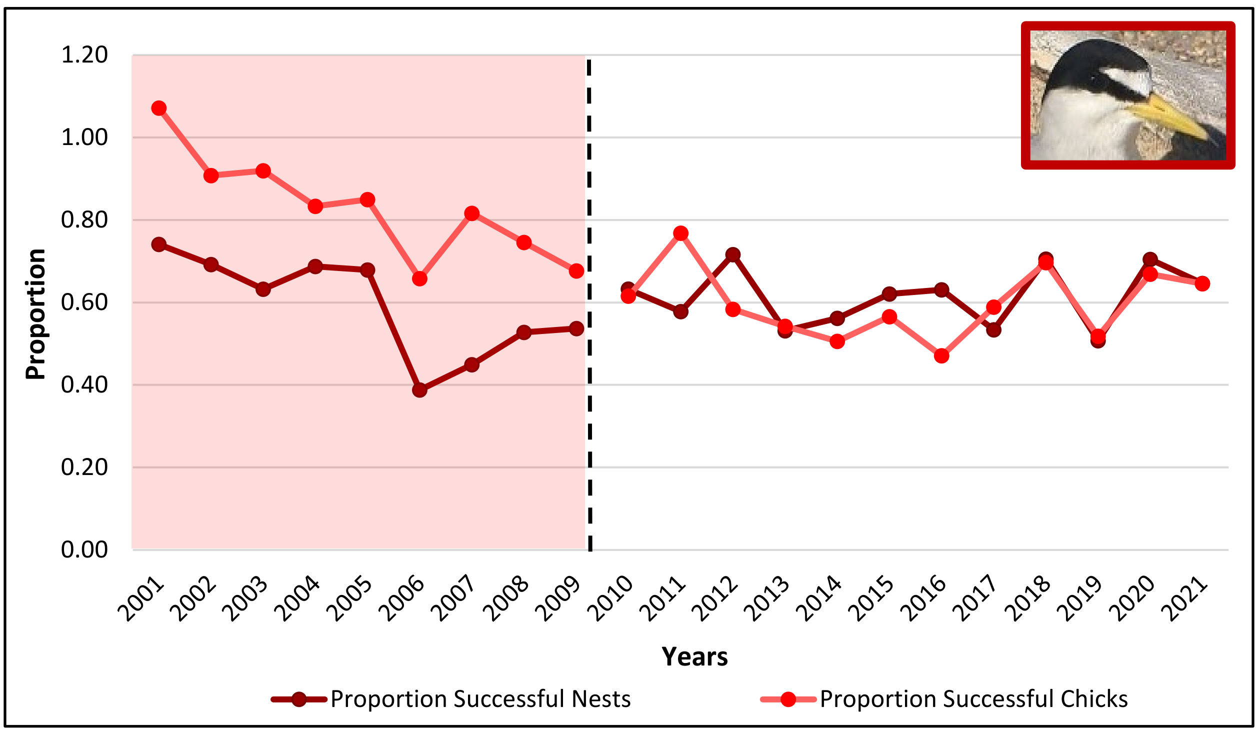

Figure 27. Proportion of successful nests (apparent nest success) and proportion of successful chicks (proportion of chicks fledged) for least terns from 2001-2021. The black dotted line represents changes in protocol, and the shaded area represents data that is not comparable. Among other changes, fledge age was changed from a 15-day success benchmark to 21 days for terns.

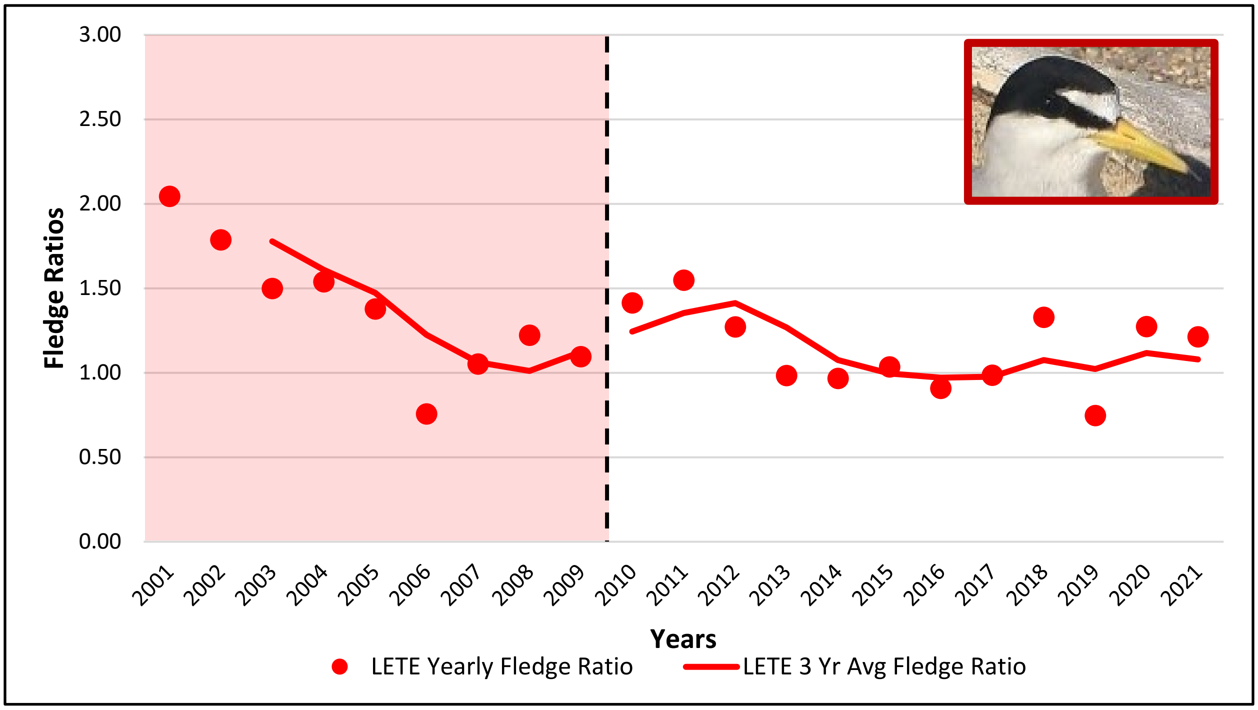

Figure 28. Annual fledge ratios (points) and 3-year running average fledge ratios (lines) for least terns from 2001-2021. The black dotted line represents changes in protocol, and the shaded area represents data that is not comparable. Among other changes, fledge age was changed from a 15-day success benchmark to 21 days for terns.

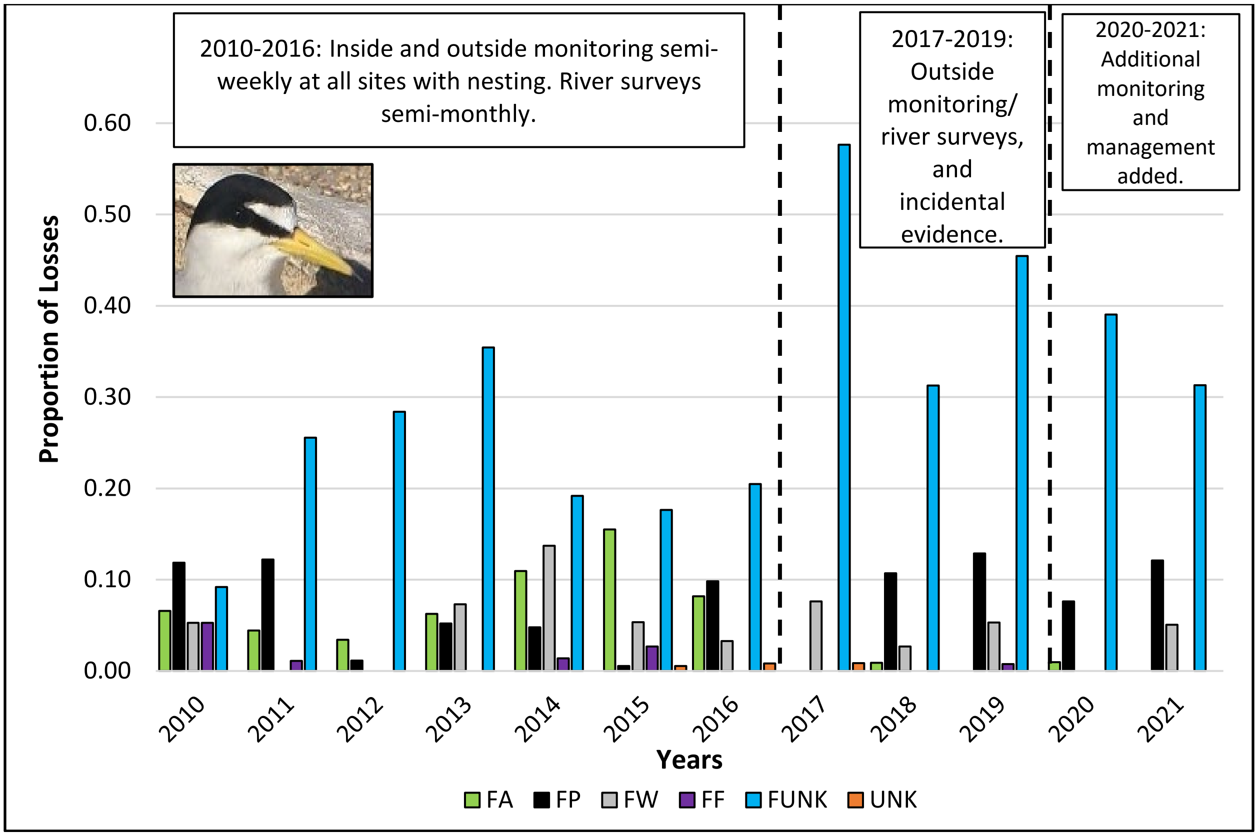

Figure 29. Proportion of combined nest and brood losses in each category for least terns from 2010-2021 across the AHR. Each loss represents a unique reproductive attempt. The assigned causes of loss include failed-abandoned (FA)(green), failed-predated (FP)(black), failed-weather (FW)(grey), failed-flooded (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.

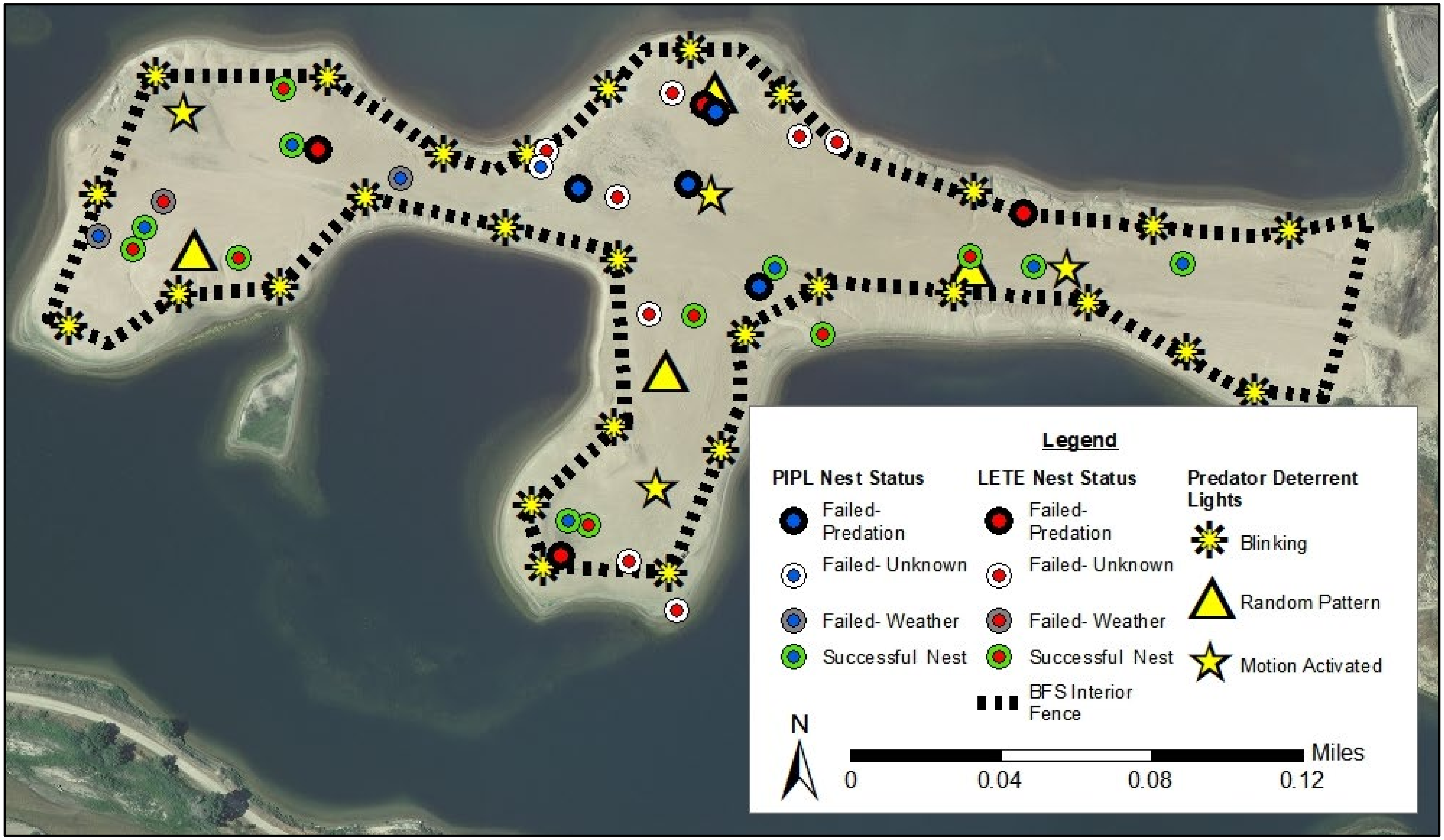

Figure 30. Piping plover (PIPL, blue inner dot) and least tern (LETE, red inner dot) nest locations and additional management setup on Broadfoot-South Kearney. The interior predator exclusion fence (black dashed line) was deployed along the shoreline, random pattern lights (yellow triangle) and motion 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 denoted by colored outer rings. Failed-predation is black, failed-unknown is white, failed weather is gray, and successful is green.

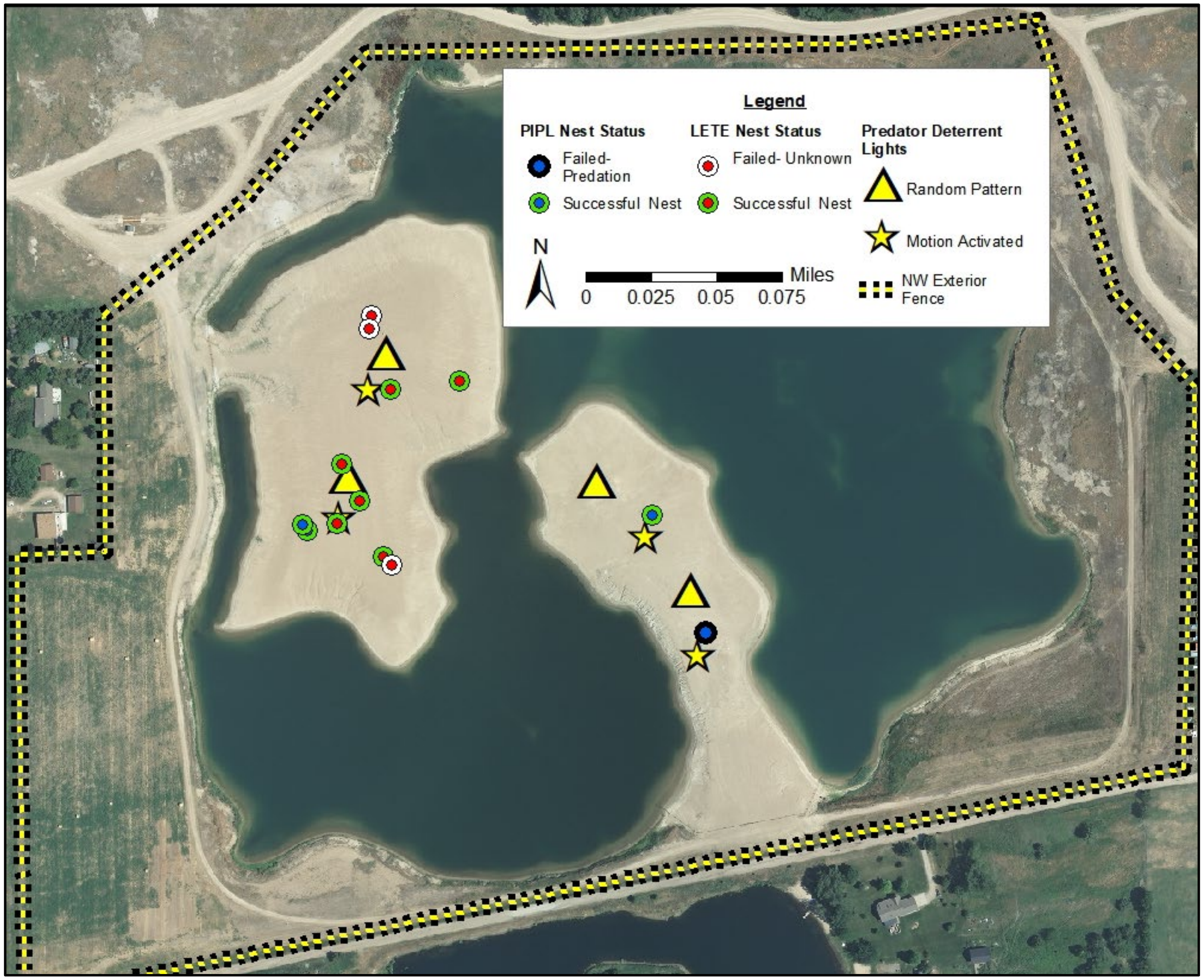

Figure 31. Piping plover (PIPL, blue inner dot) and least tern (LETE, red inner dot) nest locations and additional management setup at Newark West. The exterior predator exclusion fence (black and yellow dashed line) was deployed outside the moat, random pattern lights (yellow triangle) and motion activated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

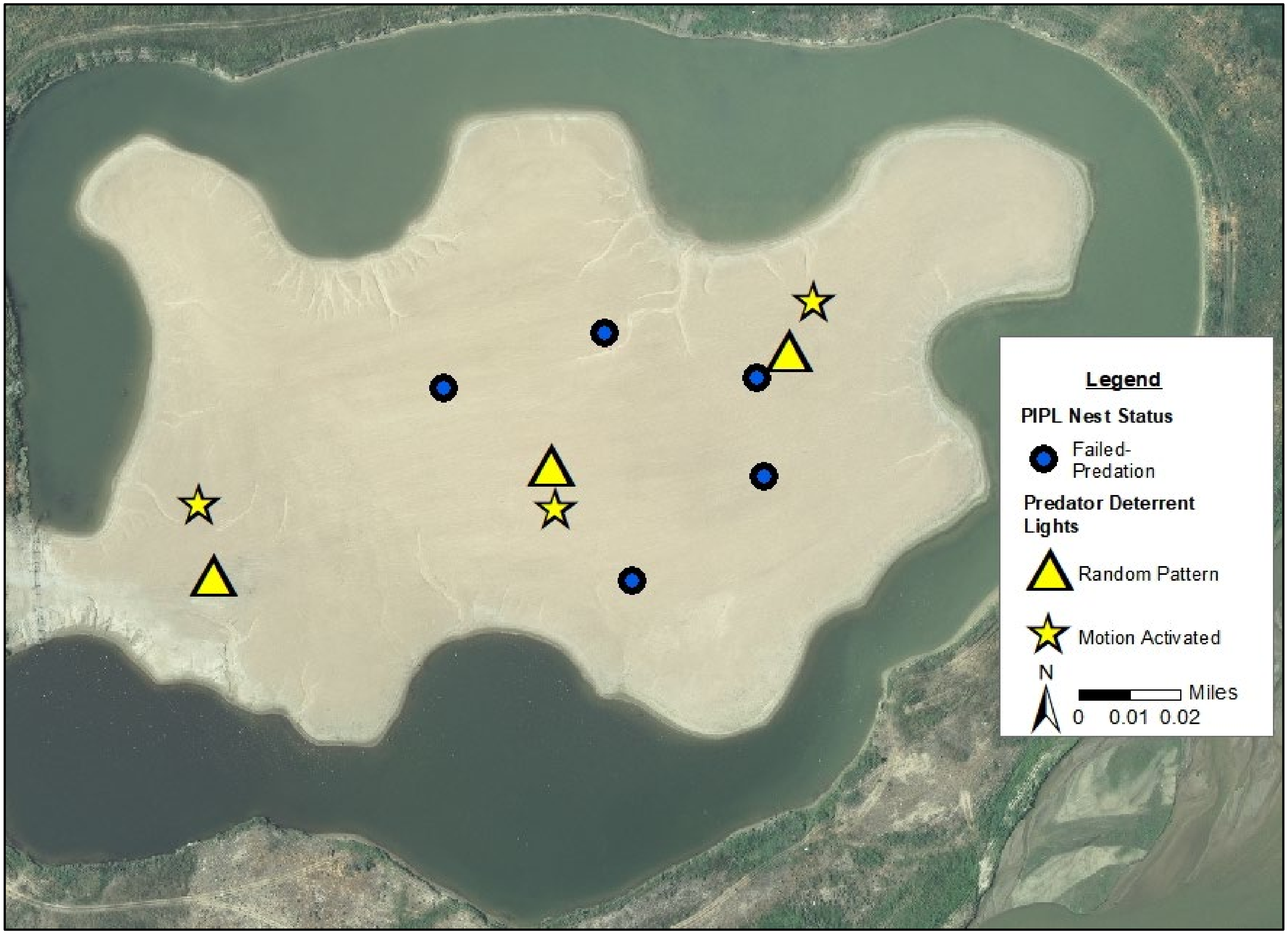

Figure 32. Piping plover (PIPL, blue inner dot) nest locations and additional management setup at Leaman East. The random pattern lights (yellow triangle) and motion activated lights (yellow stars) were deployed in sets and evenly distributed. Final nest status denoted by colored outer rings, with failed-predation represented by black.

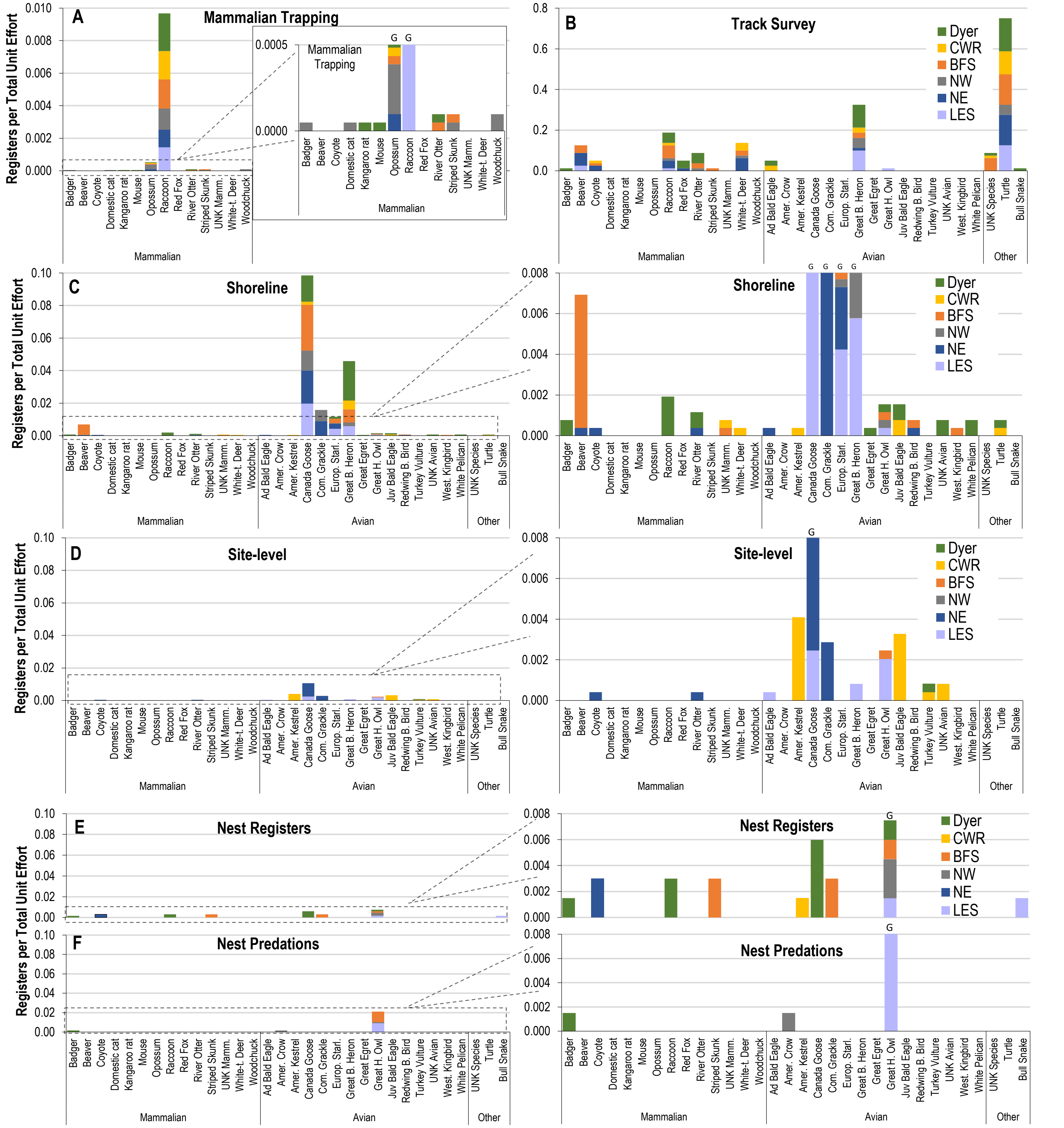

Figure 33 (A-F). Potential predators registered per total unit effort at off-channel nesting sites as registered by (**A**) mammalian trapping, (**B**) weekly track surveys, (**C**) shoreline cameras, (**D**) site-level cameras, and (**E**) registers and (**F**) predation events at nest-level cameras. For Figures A and C-F, panels on the right are enlarged to show detail at a smaller scale. Nesting sites include Dyer, Cottonwood Ranch (CWR), Broadfoot-South Kearney (BFS), Newark West (NW), Newark East (NE), and Leaman East (LES). 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, trap days, or track surveys) across all sites.
[G] Registers surpass y-axis scale. Refer to figure on the left for full scale.

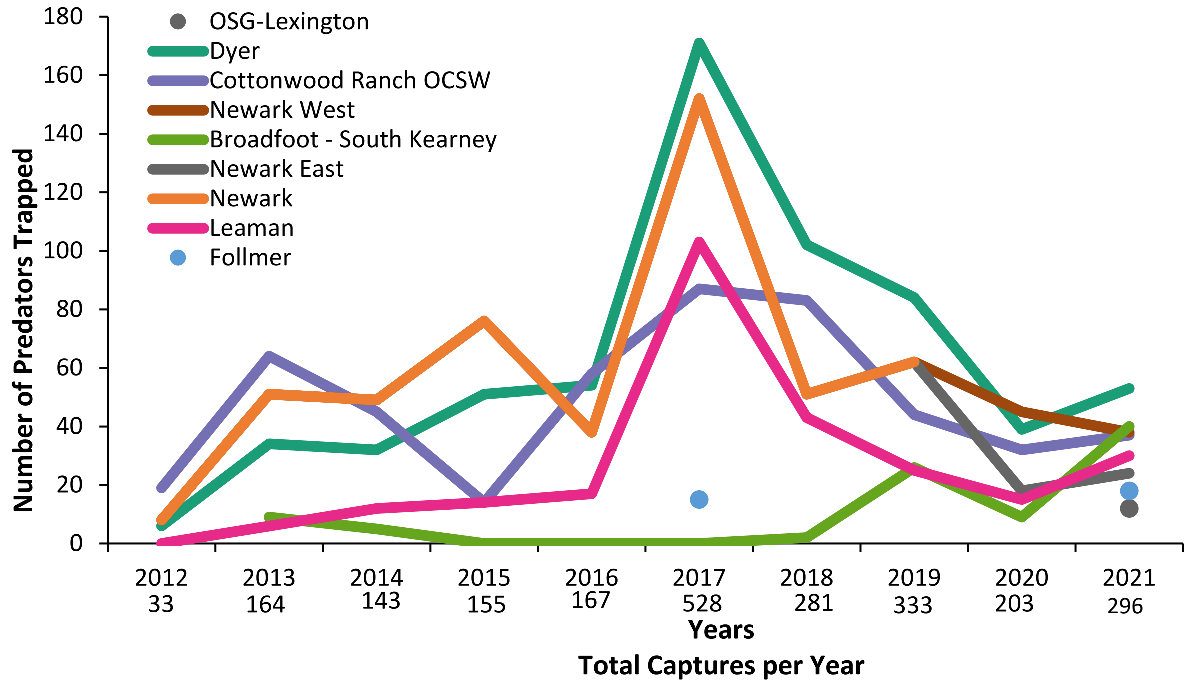

Figure 34. Numbers of predators trapped at Program-managed off-channel nesting sites 2012–2021. Predator trapping efforts at off-channel sites increased substantially in 2017. Trapping did not occur at Broadfoot-South Kearney during 2012. Captures only occurred at Follmer-Alda in 2017 and 2021 despite trapping effort in 2015-2017 and 2021. Predators trapped at Newark West and Newark East were previously reported as a total for both sites and are labeled here as Newark until 2020 when Newark East was reported separately from Newark West.

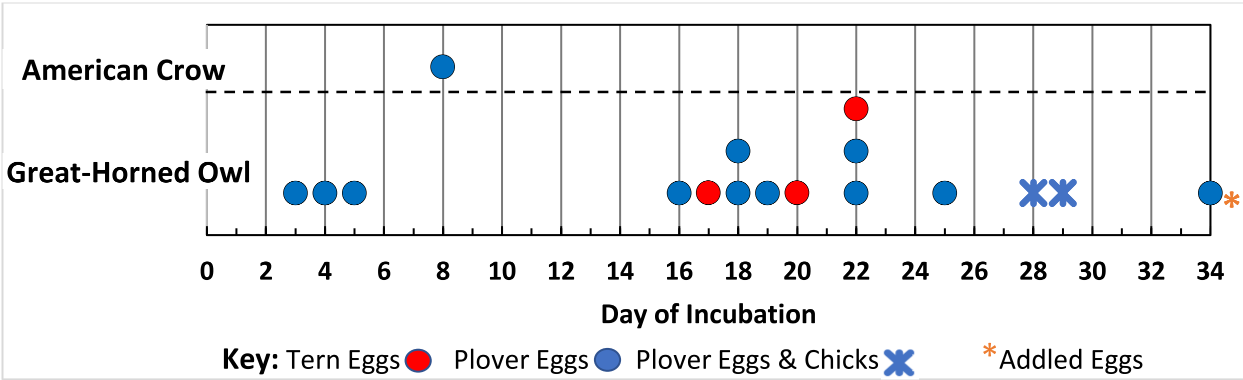

Figure 35. Incubation timeline for nests indicating the day predation occurred on plover nests (blue) and tern nests (red) by great-horned owls and an American crow as captured on nest cameras. All nests contained eggs and two plover nests also had newly hatched chicks present (blue X's) when predation occurred. Based on the nest initiation date, one plover nest likely contained addled eggs (orange asterisk) when predation occurred.

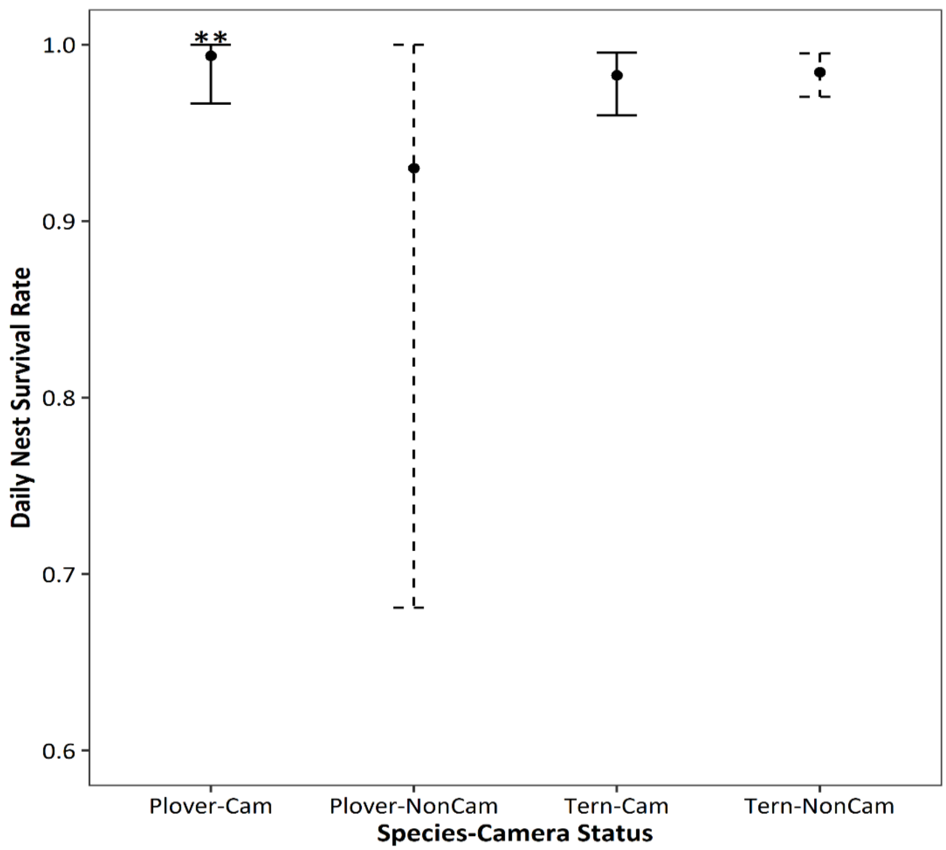

Figure 36. Species-specific average daily survival rates of plover and tern nests with a nest camera present (Cam, solid line = 95% CI) or absent (NonCam, dashed line = 95% CI) at 4 off-channel nesting sites in 2021. Plover average daily nest survival rates were significantly higher for nests with cameras than nests without cameras [z(1, N = 26) = 3.12; p = 0.002**]. However, only 6 plover nests without cameras were observed and their survival variability created a 95% confidence interval wider than other species and camera status categories with more nests.

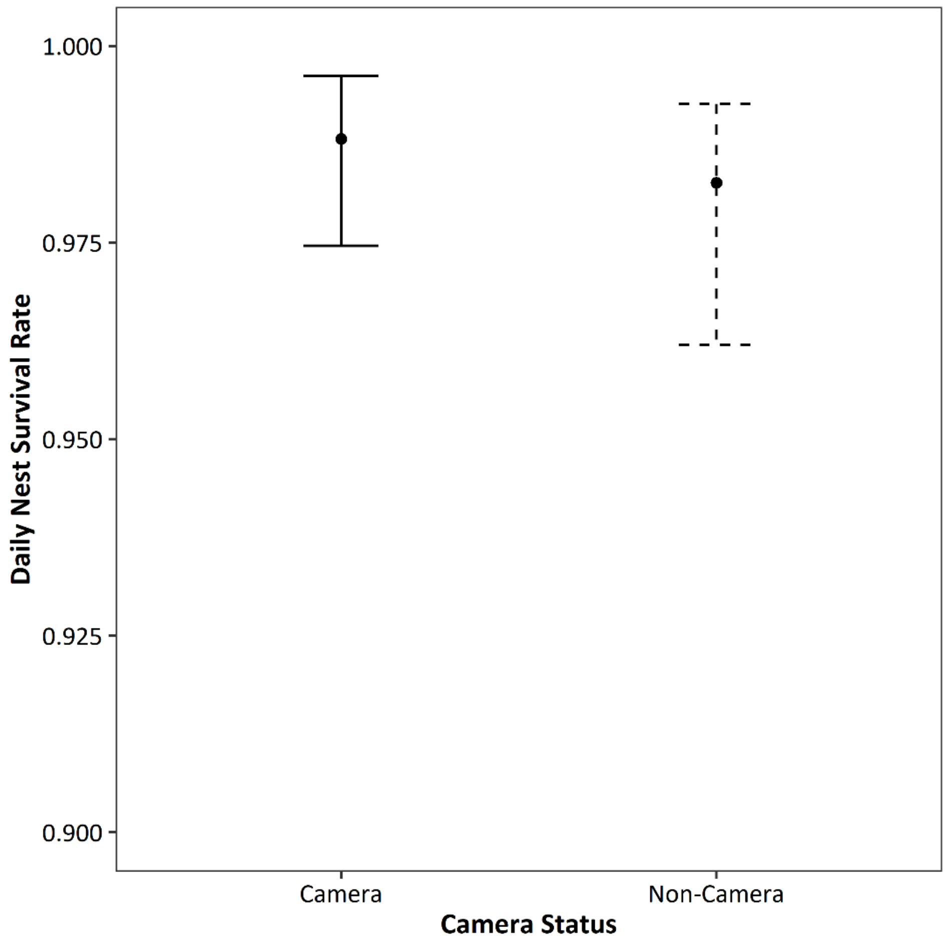

Figure 37. Estimated average daily survival rates of plover and tern nests with a nest camera present (Camera, solid line = 95% CI) or absent (Non-Camera, dashed line = 95% CI) at 4 off-channel nesting sites in 2021.

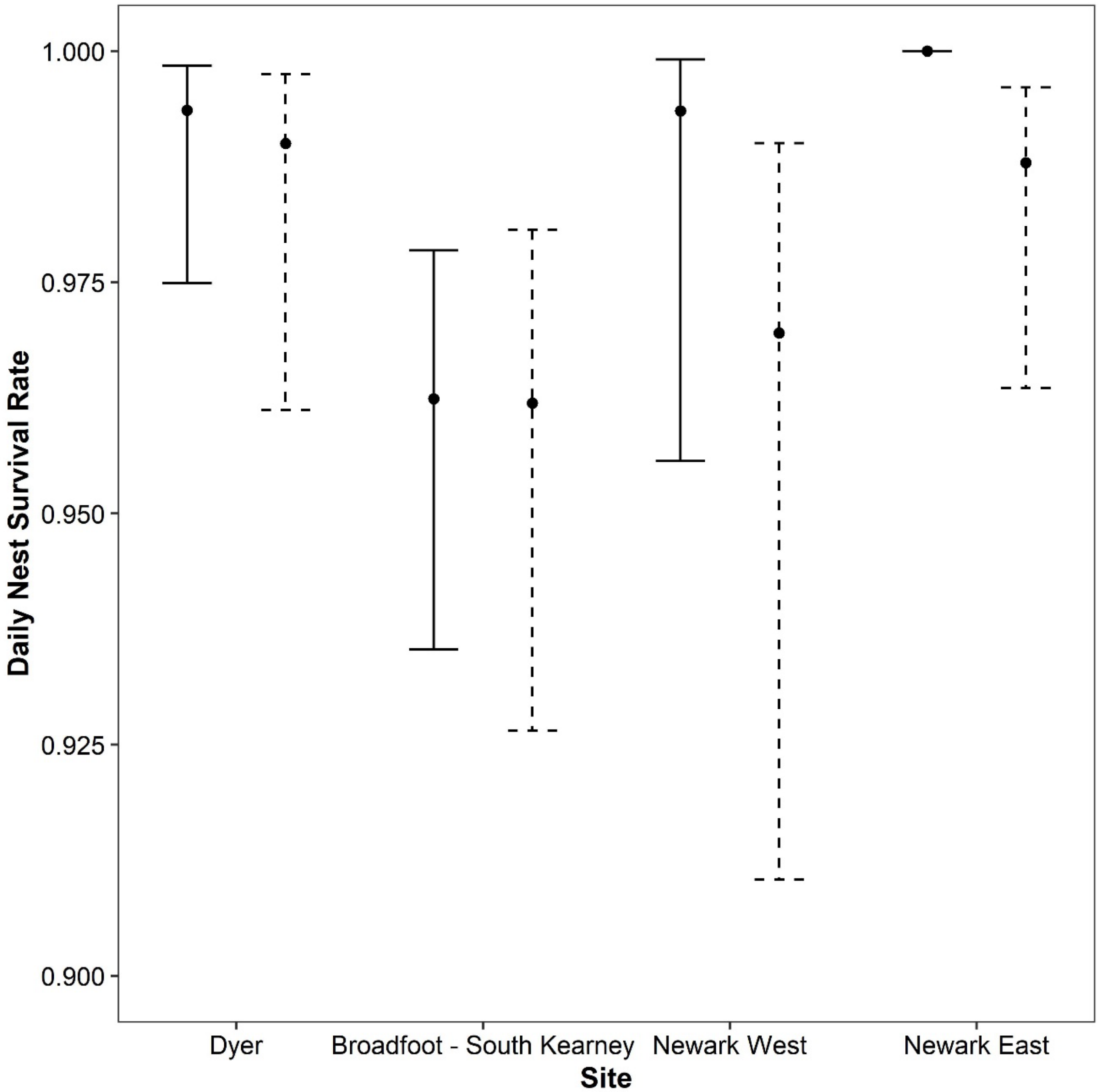

Figure 38. Estimated site-level average daily survival rates of plover and tern nests with nest cameras present (solid line = 95% CI) or not present (dashed line = 95% CI) at 4 off-channel nesting sites in 2021. All camera nests hatched chicks at Newark East, leading to a 95% confidence interval of 1 to 1 for the site.

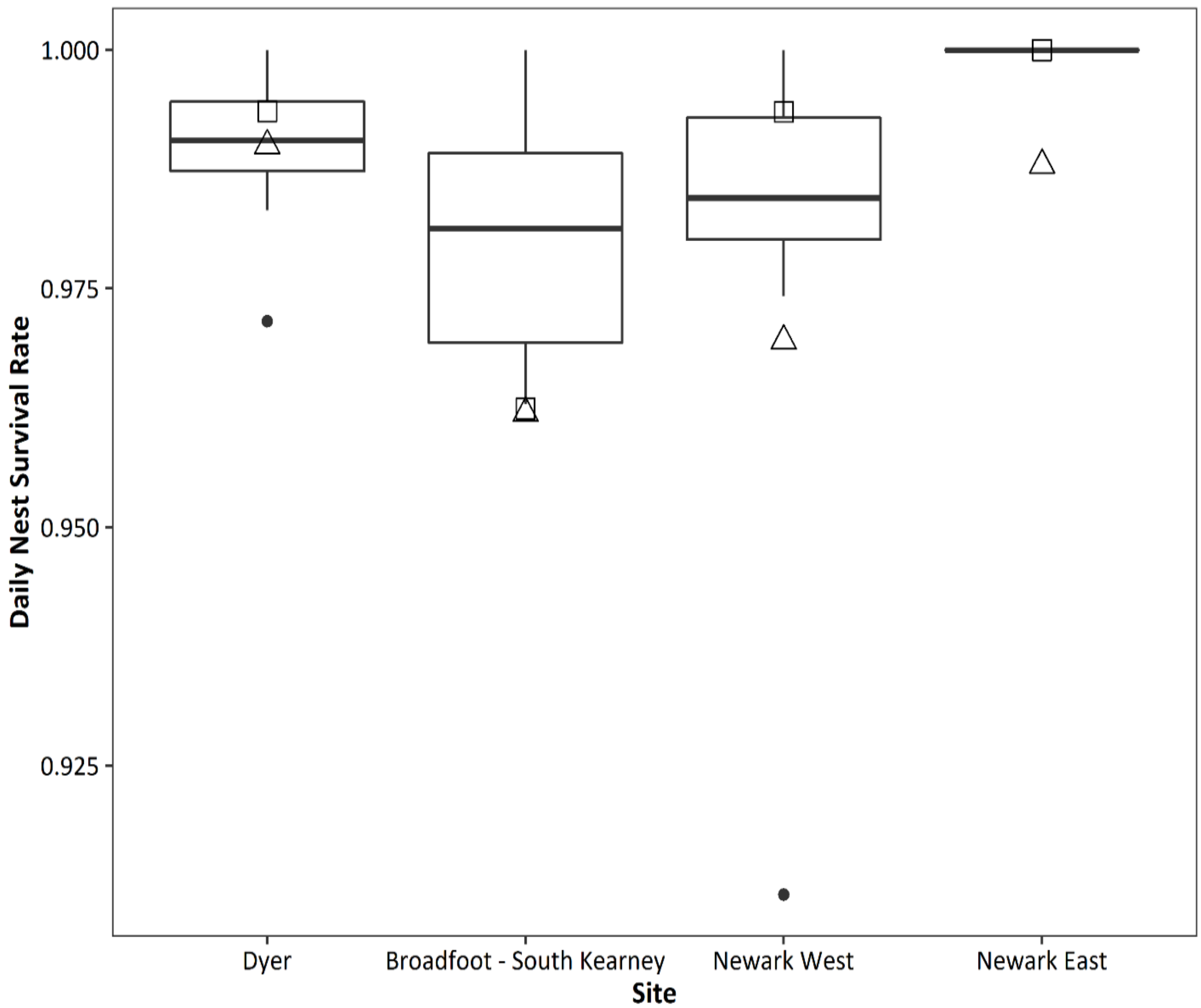

Figure 39. Combined 2021 plover and tern average daily nest survival rates of nests with a camera present (hollow square) and absent (hollow triangle) at 4 off-channel nesting sites compared to the distribution (boxplots) of plover and tern average daily nest survival rates prior to nesting site camera usage with outliers represented as filled circles (2010-2016). Site specific 2021 average daily nest survival rates with nest cameras were within the range of values observed at each site from 2010-2016, except at Broadfoot-South Kearney.