

Platte River Recovery Implementation Program

2019 Interior Least Tern and Piping Plover Monitoring and Research Report, Central Platte River, Nebraska



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Prepared by: Executive Director's Office

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**PLATTE RIVER
RECOVERY IMPLEMENTATION PROGRAM**

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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 interior least terns (least tern) and piping plovers during 2019. 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 #1014) and federal (TE183430-0) monitoring permits. *Data analyses are not final and should be treated as such when citing information, data, or analyses found in this document.*

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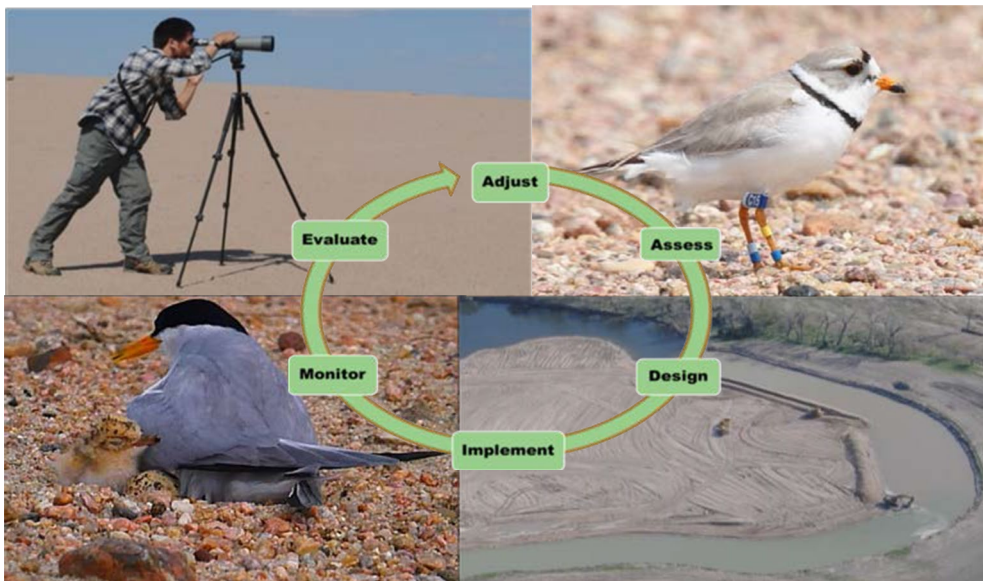
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INTRODUCTION

The Platte River Recovery Implementation Program (Program or PRRIP) was initiated on 1 January, 2007 as a result of a cooperative agreement negotiating process that started in 1997 between the states of Colorado, Wyoming, and Nebraska; the U.S. Department of the Interior (DOI); water users; and conservation groups. The Program is intended to address issues related to the Endangered Species Act and loss of habitat in the central Platte River between Lexington and Chapman, Nebraska by managing certain land and water resources following principles of adaptive management to provide benefits for four “target species” including the endangered interior least tern (*Sternula antillarum*) and the threatened piping plover (*Charadrius melodus*). 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, a recently completed five-year review recommends delisting least terns due to recovery. The U.S. Fish and Wildlife Service (USFWS) is now in the process of putting in place the necessary monitoring plans, conservation agreements, and population models in hopes of moving forward with a proposed delisting in the near future. The Program is led by a Governance Committee (GC) that is assisted by several standing advisory committees as well as an Executive Director (ED) and staff.

The Program has three main elements:

- Increasing stream flows in the central Platte River during relevant time periods through re-timing and water conservation or supply projects. The first increment objective is to re-time and improve flows in the central Platte River to reduce shortages to target flows by an average of 130,000 – 150,000 acre-feet per year at Grand Island.
- Enhancing, restoring, and protecting habitat lands for the target species. The first increment objective is to protect, restore, and maintain 10,000 acres of habitat.
- Accommodating certain new water-related activities.

The data summarized in this report were collected in accordance with the Program’s 2017 interior least tern and piping plover monitoring protocol. The primary objectives of protocol implementation include: 1) monitoring interior least tern (least tern) and piping plover (plover) use and productivity on midstream-river sandbars and sand and gravel mines; and 2) document habitat characteristics that are believed to influence nest site selection and nest and brood success along the central Platte River between Lexington and Chapman, Nebraska. The Program has also banded least tern and piping plover adults and chicks on the central Platte with three objectives:

1) quantify dispersal of adults between units of nesting habitat on the Central Platte River among years; 2) quantify colonization rate of newly constructed or managed nesting habitat by local versus immigrant adults; and 3) quantify frequency and location of re-nesting attempts by adults with failed nests. As such, banding least tern and piping plover adults and chicks was conducted for seven consecutive years on the central Platte River (2009–2016). The 2019 season marked the third year banding didn’t occur; we plan to continue band resighting over the coming years. We anticipate a final report documenting results of those efforts will be available on the Program’s online Public Library in 2020. Monitoring and research during 2019 were a collaborative effort between personnel of Headwaters Corporation (EDO or Program staff), Central Platte Natural Resources District (CPNRD), and Nebraska Public Power District (NPPD). Past data and analyses are reported in annual reports produced by West Incorporated (2001–2007) and Program staff (2008–2018) and are available in the Program’s online Public Library. Least tern and piping plover activity and reproductive success during 2019 are summarized in this report.

STUDY AREA

Our study area encompassed the “PRRIP Associated Habitats” region of the central Platte River between Lexington and Chapman, Nebraska (~90 river miles, Figure 1) as well as off-channel and sandpit sites within three miles of the river in this reach. In the central Platte River system, least tern and piping plover habitat was located at both on- and off-channel sites. River or on-channel habitat included midstream sandbars used for nesting and open river channel used for foraging. Off-channel habitat included spoil piles of sparsely- or non-vegetated sand and associated sandpit lakes at sand and gravel mines. Least terns nested on managed sandpit spoil piles or river islands and foraged in sandpit lakes and open river channel. Piping plovers nested on managed sandpit spoil piles or river islands and foraged on low elevation river islands or along the waterline of sandpit ponds.

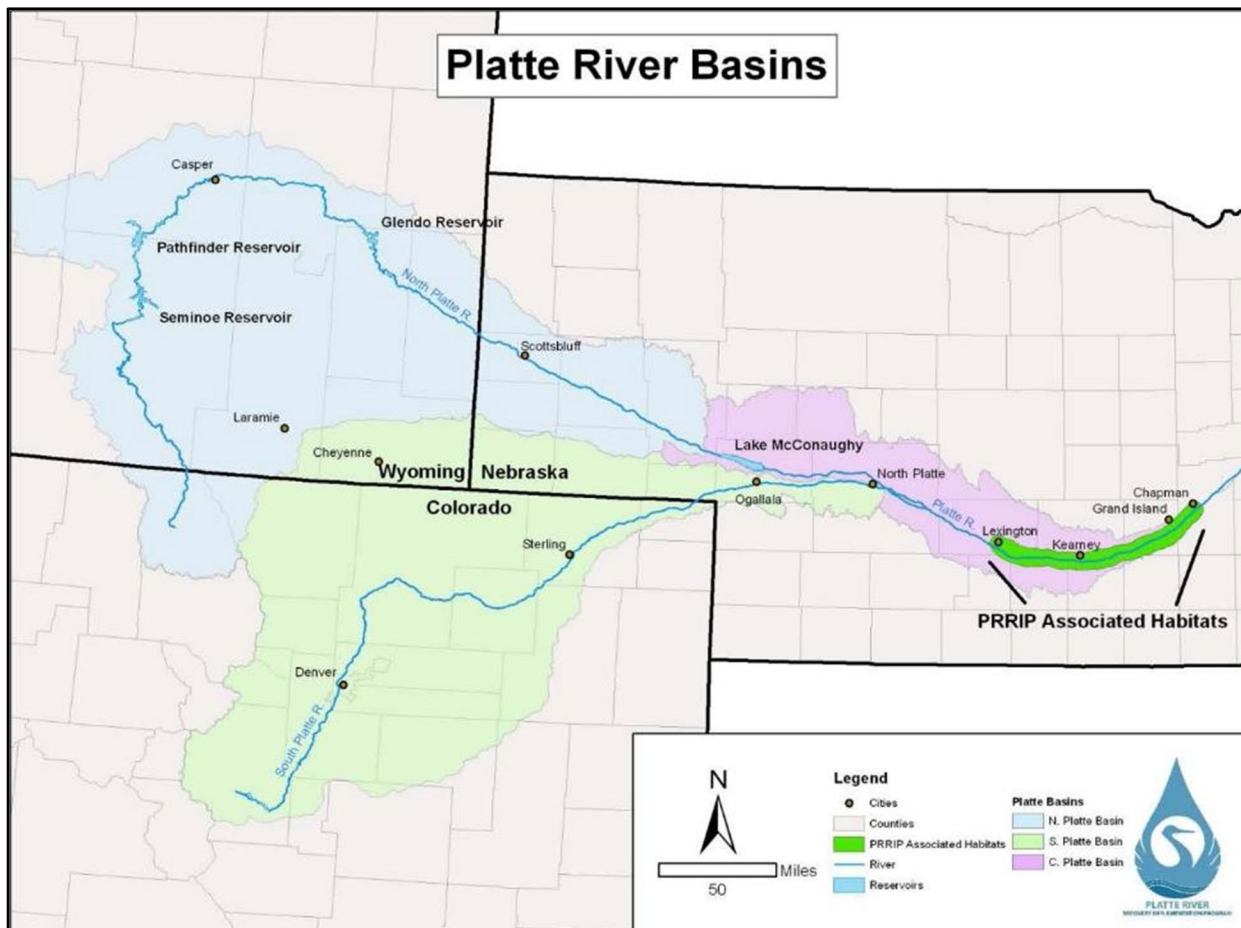


Figure 1. Platte River Basins extending from Colorado and Wyoming through Nebraska. The study area for our least tern and piping plover monitoring and research efforts was the PRRIP Associated Habitats region of the Platte River located between Lexington and Chapman, Nebraska.

2019 RIVER CONDITIONS

The number of low-elevation sandbars present within the PRRIP associated habitats region 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 least tern and piping plover nesting sites within the region has been dependent upon construction and vegetation management efforts.



Flooding at Broadfoot South nesting area

In 2019 daily flows were normal during May, with a spike in June, and one very large spike in July when the flooding came through.

The flows then dropped back down in August. The peak magnitude of flow for the 2019 season at the Kearney gage was 22,500 cubic feet per second (cfs), which is close to the highest recorded peak of 23,700 cfs in June of 1983.

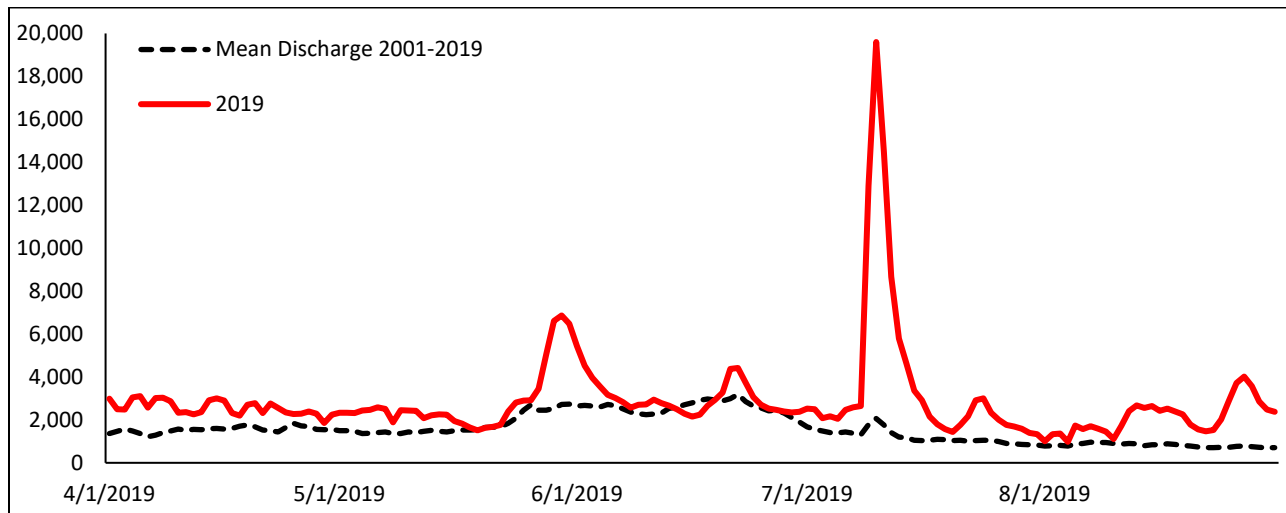


Figure 2. Mean daily discharge (ft³/second; cfs) at Kearney, Nebraska (USGS gage 06770200). Average across 2001–2019 from Kearney (USGS gage 06770200). See Figure 3 for the location of gage stations within our study area. Data available at:

waterdata.usgs.gov/ne/nwis/current/?type=flowandgroup_key=NONEandsearch_site_no_station_nm=platte%20river.

MANAGEMENT

Management actions designed to increase nesting habitat (bare sand) and productivity of least terns and piping plovers within Program associated habitats were taken at on- and off-channel sites during fall 2018 and spring 2019. 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, mowing, and nest furniture distribution); chemical application to kill or prevent emergence of vegetation (spring or fall herbicide application); and predator control (fencing and trapping).

SUMMARY OF HABITAT AVAILABILITY AND SPECIES RESPONSE, 2007–2019

On-Channel Mechanical Habitat Creation and Maintenance

Constructed on-channel habitat availability has been variable and somewhat limited during the First Increment of the Program (Table 1). Approximately 24 acres of constructed habitat were present in the Associated Habitat Reach (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. 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. 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. However, all of it was lost due to erosion during the 2015 and 2016 high flow events. On-channel habitat construction by other conservation organizations has been very limited since 2007.

Table 1. On- and off-channel nesting habitat in the Associated Habitat Reach by year, 2007–2019.

	On-Channel Habitat (ac)			Off-Channel Habitat (ac)		
	PRRIP	Others	Total	PRRIP	Others	Total
2007	0	24	24	0	48	48
2008	0	21	21	0	48	48
2009	0	15	15	0	48	48
2010	0	5	5	32	48	80
2011	0	5	5	60	48	108
2012	0	0	0	72	48	120
2013	55	0	55	72	48	120
2014	19	0	19	80	48	128
2015	47	0	47	90	48	138
2016	4	0	4	87	51	138
2017	0	0	0	99	61	160
2018	0	0	0	109	83	192
2019	0	0	0	94	84	178
Average	11.4	6.4	17.7	61.2	54.7	115.8

On- and Off-Channel Mechanical Habitat Creation and Maintenance

Approximately 48 acres of managed off-channel nesting habitat were present in the AHR at the beginning of the First Increment (Table 1). The Program began acquiring and restoring off-channel sites in 2009. Total managed off-channel habitat in the AHR increased to 178 acres during the period of 2009–2019 as the Program constructed and/or restored 130 acres of habitat. Habitat availability decreased compared to 2018 due to the flood events. The Program plans to acquire or construct an additional 60 acres of off-channel habitat prior to the end of the First Increment Extension in 2032. Mining at Follmer Alda and Newark East sites are still under way and more habitat should become available during the 2020 nesting season.

SANDPIT SITES:

Eleven of the fifteen off-channel sites monitored during 2019 were actively managed to increase least tern and piping plover reproduction. Program owned and/or managed sites are denoted with a superscript “P” (^P) and managed sites are identified by a superscript “M” (^M).

^M **Lexington Pit** – A pre-emergent herbicide was applied during spring 2018, the woven-wire predator fence with offset electric wires along the west side of the nesting areas was maintained, and predator trapping occurred during 2019. No sand and gravel mining occurred during 2019.

^{PM} **Dyer Pit** – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2018. A pre-emergent herbicide was applied during spring 2019, a permanent 4-foot tall woven wire predator fences with offset electric wires across the south ends of each peninsula were electrified, and sand around the fence was moved to combat accumulation. Predator trapping also occurred during 2019. No sand and gravel mining occurred during 2019.

^{PM} **Cottonwood Ranch OCSW** – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2018, a pre-emergent herbicide was applied, and predator trapping occurred during 2019. A permanent 4-foot tall woven wire predator fence with offset electric wires was maintained in 2019. No sand and gravel mining occurred.

^M **Blue Hole** – A pre-emergent herbicide was applied during spring 2019, a permanent 4-foot tall fence was installed along the west edge of the peninsula, and predator trapping occurred during 2019.

^M **Johnson Pit** – A pre-emergent herbicide was applied during spring 2019, the woven-wire predator fence with offset electric wires along the west side of the nesting area was maintained and electrified, and predator trapping occurred during 2019. No sand and gravel mining occurred during 2019.

Ed Broadfoot and Sons – Non-program unmanaged site. Sand and gravel mining occurred during 2019.

^{PM} **Broadfoot South** – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2018 and a pre-emergent herbicide was applied to the nesting area during spring 2019. A temporary 4-foot tall electrified predator fence was installed across the east end of the main peninsula, and predator trapping occurred during 2019. Sand and gravel mining occurred northwest of the main peninsula during 2019.

^{PM} **Broadfoot South—Non-Access Islands** – A 4-foot tall 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 2019. Nine acres of unmanaged, suboptimal habitat were available for least tern or piping plover nesting in 2019.

^{PM} **Newark West** – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2018. A pre-emergent



Broadfoot South Non-access Islands

herbicide was applied during spring 2019, permanent 4-foot tall woven wire predator fences with offset electric wires across the ends of each peninsula were electrified, and predator trapping occurred during 2019. No sand and gravel mining occurred during 2019.



Newark East Nesting Site

^{PM} **Newark East** – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2018. A pre-emergent herbicide

was applied during spring 2019. The west peninsula contains a permanent 4-foot tall woven wire predator fence with offset electric wires across the ends of the peninsula, which were electrified. A temporary 4-foot tall electrified predator fence was installed across the east peninsula. Sand and gravel mining and predator trapping occurred during 2019. Fourteen acres were available for least tern or piping plover nesting in 2019.

^{PM} **Leaman East OCSW** – A contact herbicide was applied to kill existing vegetation along the waterline during fall 2018. A pre-emergent herbicide was applied to the nesting area during spring and predator trapping occurred during 2019. A permanent, 4-foot tall woven wire predator fence with offset electric wires was maintained in 2019. No sand and gravel mining occurred.

Trust Wild Rose East – Not managed during 2019 and no sand and gravel mining occurred.

^{PM} **Follmer-Alda Pit** – A contact herbicide was applied to kill existing vegetation along the waterline during fall 2018. A pre-emergent herbicide was applied to the nesting area during spring 2019. Sand and gravel mining occurred east of the main peninsula during 2019.

DeWeese-Alda – Not managed. Sand and gravel mining occurred during 2019.

Hooker Brothers - GI South East – Not managed. Sand and gravel mining occurred during 2019.

MONITORING

In 1997, the DOI 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 least terns and piping plovers 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. In 2007, the Program assumed responsibilities of the protocol; Program staff, contracted personnel, and cooperators have since implemented it. The protocol was revised prior to the 2010 nesting season and again prior to the 2017 nesting season (PRRIP 2017).

SEMI-MONTHLY RIVER AND SANDPIT SURVEYS:

METHODS

We conducted 7 semi-monthly surveys (1 and 15 May, June, and July and 1 August) of the central Platte River between Chapman and Lexington, Nebraska (river surveys). In addition, we surveyed all sandpits within Program Associated Habitats that met the Program’s minimum habitat criteria (sandpit surveys) to document adults, breeding pairs, nests, chicks, and fledglings during 2019. We derived least tern and piping plover breeding pair estimates (BPE; Baasch et al. 2015) by adding the number of active, or recently failed nests to the number of active, or recently failed or fledged broods observed on a given date. 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 2010–2019); 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 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; 3) piping plover chicks fledged at 28 days of age (fledging age 2010–2018); and 4) piping plover chicks that survived to 15 days of age (fledging age 2007–2009) also fledged. We included summaries of the total number of adults, breeding pairs, nests, chicks, and fledglings observed during river surveys, sandpit surveys, and a combination of river and sandpit surveys (semi-monthly survey totals) to provide 7 snap-shots of the numbers observed during the 2019 nesting seasons. All counts of adults, breeding pairs, nests, chicks, and fledglings reported during semi-monthly surveys represent minimums present.

Semi-monthly River Surveys – Program staff conducted semi-monthly river surveys between the J2 Return and the Chapman Bridge on 1-2 May; 14-15 May; 4-5 June; 19-20 June; 1-2 July; 16-18 July; and 30-31 July during 2019. We used an airboat to survey all channels wider than 75 yards between Lexington and Chapman, NE that could be safely navigated and documented all observations of least tern and piping plover adults, breeding pairs, nests, chicks, and fledglings located within this reach of river.

Semi-monthly Sandpit Surveys – We conducted semi-monthly surveys from outside the nesting colony at 15 sandpit sites to count individual birds and document least tern and piping plover adults, breeding pairs, nests, chicks, and fledglings. Semi-monthly sandpit surveys were conducted outside the nesting area on 29 April - 10 May; 13-17 May; 30 May – 4 June; 13-17 June; 1-4 July; 8-16 July; and 31 July – 2 August during 2019. Program staff and personnel from CPNRD and NPPD conducted semi-monthly sandpit surveys during 2019.

Semi-monthly Survey Totals – To obtain an estimate of numbers of least tern and piping plover adults, breeding pairs, nests, chicks, and fledglings within the Program Associated Habitat Area throughout the 2019 nesting season, we summed numbers detected during semi-monthly river and sandpit surveys nearest 1 and 15 May, June, and July and 1 August. We derived least tern and piping plover breeding pair estimates (BPE) by adding the number of active, or recently failed nests to the number of active, or recently failed or fledged broods observed on a given date (Baasch et al. 2015).

RESULTS

Semi-monthly River Surveys – Each of the 7 semi-monthly river surveys between Lexington and Chapman, Nebraska during 2019 required 2–3 days to conduct. We observed the most least tern adults (22) on the river during the 1-July river survey. The most piping plover adults (18) were observed on the river during the 1-July river survey in 2019 (Table 2). We observed no least tern or piping plover breeding pairs during 2019 river surveys. All least tern and piping plover adults and fledglings observed during semi-monthly river surveys in 2019 were either known (banded) or were presumed (near areas with sandpits that fledged chicks) to be associated with nearby sandpit nesting sites.

Table 2. Number of Least Tern and Piping Plover adults, breeding pairs (pair), nests, chicks, and fledglings observed during semi-monthly airboat surveys of the Platte River between Lexington and Chapman, Nebraska, in 2019.

Survey	Interior Least Tern					Piping Plover				
	Adults	Pair*	Nests	Chicks	Fledglings	Adults	Pair*	Nests	Chicks	Fledglings
1-May	0	0	0	0	0	1	0	0	0	0
15-May	8	0	0	0	0	8	0	0	0	0
1-Jun	10	0	0	0	0	2	0	0	0	0
15-Jun	19	0	0	0	0	5	0	0	0	0
1-Jul	22	0	0	0	0	18	0	0	0	0
15-Jul	21	0	0	0	8	1	0	0	0	1
1-Aug	15	0	0	0	9	1	0	0	0	1

* Pair represents the number of breeding pairs, as defined above, present on river islands on 1 and 15 May, June, and July, and 1 August. Breeding pair counts were obtained using the Program’s Breeding Pair Estimator (BPE). Quantities of Nests may be different from Breeding Pair because semi-monthly surveys occurred over several days and Breeding Pair counts were determined on the 1st or 15th of the month.

Semi-monthly Sandpit Surveys – Each of the 7 semi-monthly sandpit surveys from outside the nesting area required 1 day to conduct in 2019, though some sites were surveyed on different dates. Similar to past years, most least tern and piping plover breeding pairs, nests, and chicks were observed on sandpit sites where management activities occurred prior to the nesting seasons. However, we observed 1 piping plover breeding pair and 1 nest on the Broadfoot South non-access islands; this nest failed. There was also a 1 piping plover breeding pair observed on Ed Broadfoot and Sons sandpit and 1 nest; the nest was unknown since the nest disappeared around the hatch date and the chicks were never viewed. It was left as unknown as we did not have access to view the rest of the pit. We observed the most adult least terns (108) and the most active nests (77) during the 15-June sandpit survey (Table 3). The most least tern breeding pair (88) were observed during the 1-July survey. We observed the most piping plover adults (65) during the 15-June survey. The most piping plover breeding pairs and nests were observed during the 1-June sandpit survey, when there were 39 active nests and 36 chicks present across all sandpit sites. A total of 15 sites were monitored during each of the semi-monthly survey periods.

Table 3. Number of least tern and piping plover adults, breeding pairs (pair), nests, chicks, and fledglings documented from outside the nesting area during semi-monthly sandpit surveys in 2019.

Survey	Interior Least Tern					Piping Plover				
	Adults	Pair*	Nests	Chicks	Fledglings	Adults	Pair*	Nests	Chicks	Fledglings
1-May	0	0	0	0	0	34	3	2	0	0
15-May	14	0	0	0	0	62	31	31	0	0
1-Jun	80	56	51	0	0	54	39	36	6	0
15-Jun	108	79	77	0	0	65	37	19	43	0
1-Jul	98	88	31	67	0	43	30	7	25	9
15-Jul	86	76	25	23	37	19	19	2	8	4
1-Aug	32	58	2	8	10	0	1	0	0	0

* Pair represents the number of breeding pairs, as defined above, present on sandpits on 1 and 15 May, June, and July, and 1 August. Breeding pair counts were obtained using the Program’s Breeding Pair Estimator (BPE). 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.

Semi-monthly Survey Totals – Semi-monthly survey totals include both sandpit and river survey counts of adults, breeding pairs, nests, chicks, and fledglings observed during the 7 semi-monthly sandpit and river surveys and represent an estimate of the overall numbers present within Program Associated Habitats during 7 time periods in the 2019 nesting season. In 2019, we observed 77 active least tern nests during the 15-June survey when 127 adults were observed (Table 4). We observed 67 least tern chicks during the 1-July survey and 45 fledglings during the 15-July survey. In 2019, we observed 70 piping plover adults during the 15-May and 15-June survey. During the 1-June survey there were 39 breeding pairs and 36 active piping plover nests. For the 1-July survey there were only 9 piping plover fledglings observed. A total of 15 sandpit sites and the river were surveyed each semi-monthly survey period (Table 4).

Table 4. Number of least tern and piping plover adults, breeding pairs (pair), nests, chicks, and fledglings observed within Program Associated Habitats during semi-monthly surveys of sandpits and the river in 2019.

Survey	Interior Least Terns					Piping Plovers				
	Adults	Pair*	Nests	Chicks	Fledglings	Adults	Pair*	Nests	Chicks	Fledglings
1-May	0	0	0	0	0	35	3	2	0	0
15-May	22	0	0	0	0	70	31	31	0	0
1-Jun	90	56	51	0	0	56	39	36	6	0
15-Jun	127	79	77	0	0	70	37	19	43	0
1-Jul	120	88	31	67	0	61	30	7	25	9
15-Jul	107	76	25	23	45	20	19	2	8	5
1-Aug	47	58	2	8	19	1	1	0	0	1

* Pair represents the number of breeding pairs, as defined above, present on river islands on 1 and 15 May, June, and July, and 1 August. Breeding pair counts were obtained using the Program’s Breeding Pair Estimator (BPE). 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.

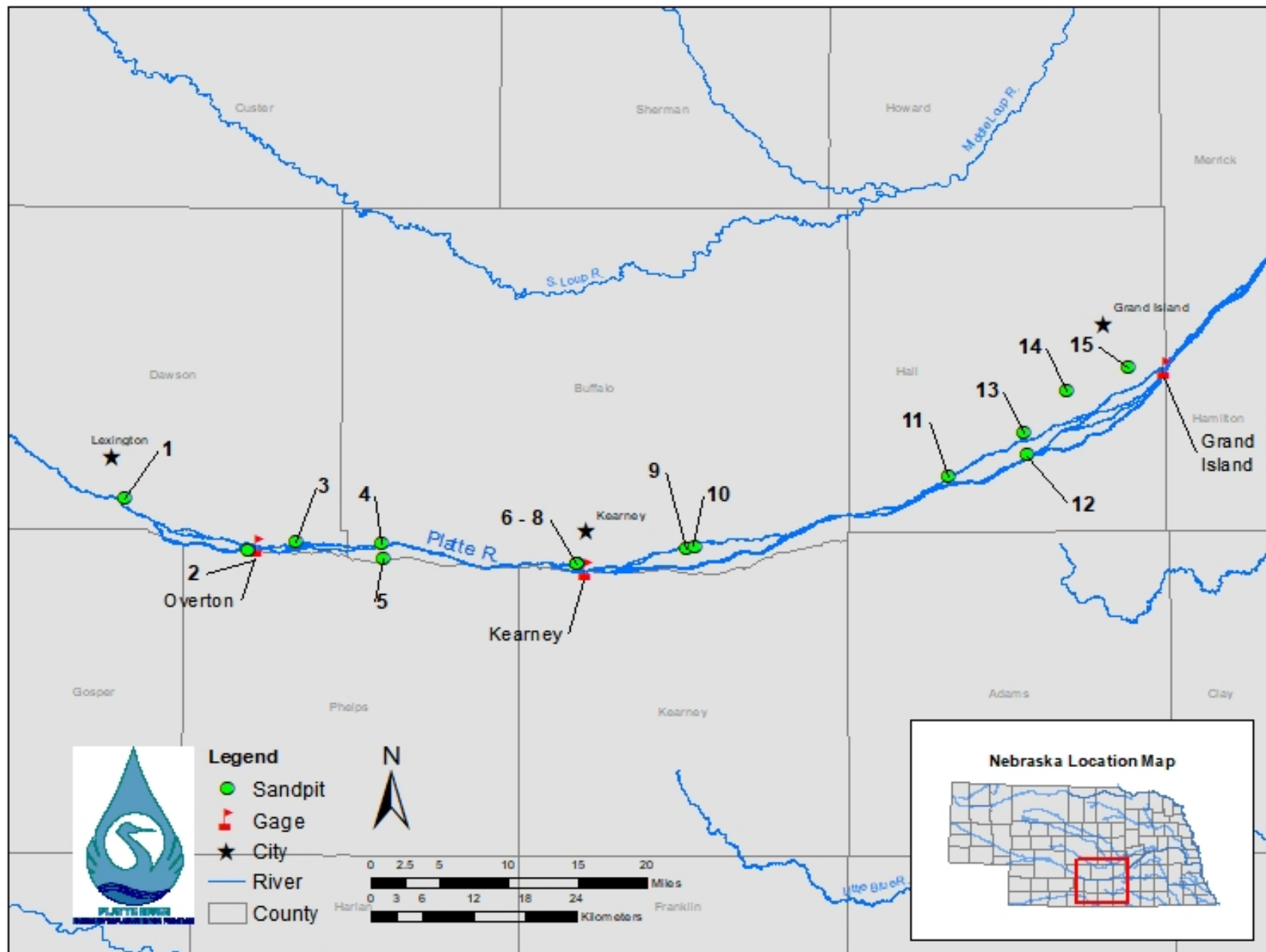


Figure 3. Study area including sandpits and river channels monitored for least tern and piping plover nesting and foraging activities during 2019. Names of sites are located in Table 7.

MID-MONTH AND SEMI-MONTHLY SURVEYS

River Surveys, 2001–2019: We observed slight use of the river by least terns and piping plovers throughout the nesting season. Counts of least tern and piping plover adults observed during river surveys in 2019 were generally similar to numbers observed prior to Program implementation (2001–2006; Figure 4). The trend in numbers of adult least terns observed during the 2019 river surveys of the central Platte River were generally lower than the last couple of years. The numbers of piping plovers on the river were a little higher than 2018, but similar.

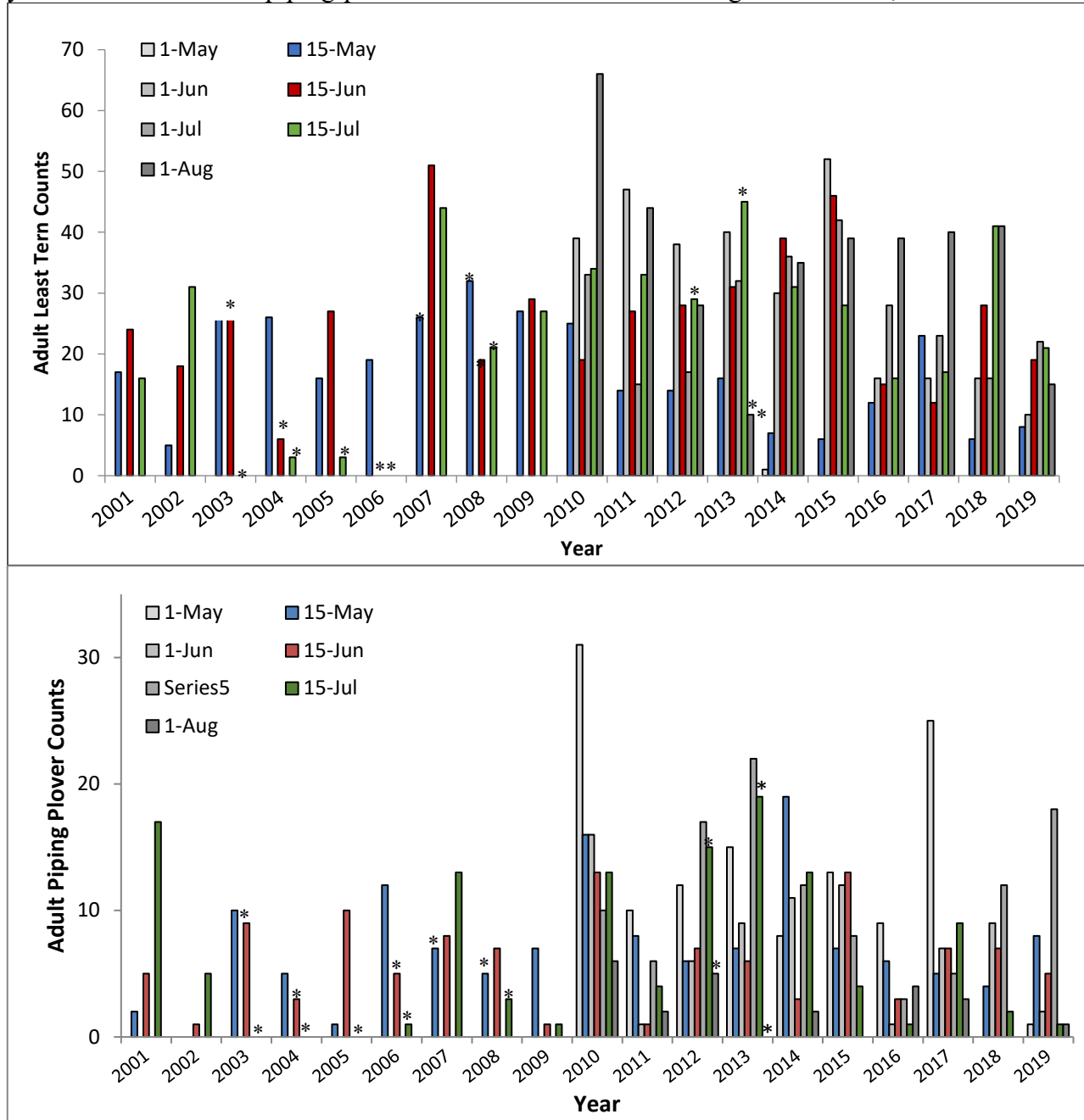


Figure 4. Numbers of least tern (top) and piping plover (bottom) adults observed during mid-month and semi-monthly surveys of the Platte River between Lexington and Chapman, Nebraska, 2001-2019. * indicates minimum numbers present as several river surveys were not completed due to a lack of flow in the channel.

Sandpit Surveys, 2001–2019: We observed slightly less least tern adults on sandpits within the Program Associated Habitat Area in 2019 than we did in 2018, but the numbers were similar (Figure 5). Piping plover counts on sandpit sites during 2019 were slightly higher than counts observed in 2017 and 2018, but similar to 2015 and 2016. We observed the most adult least terns (108) during semi-monthly sandpit surveys that occurred during the 15-June. We observed the most adult piping plovers (65) during the 15-June semi-monthly sandpit survey.

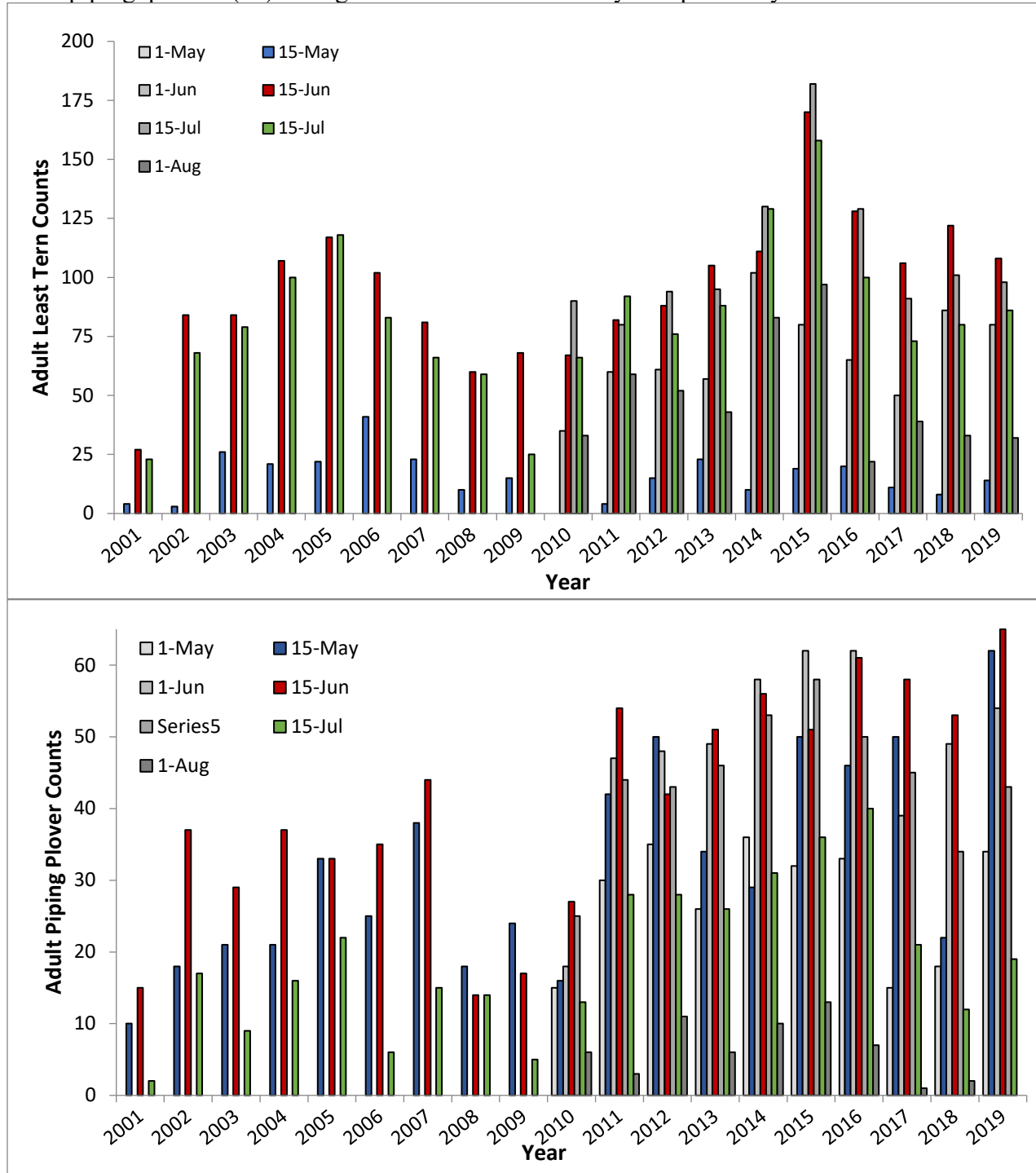


Figure 5. Numbers of least tern (top) and piping plover (bottom) adults observed during mid-month and semi-monthly surveys of sandpits along the Platte River between Lexington and Chapman, Nebraska, 2001–2019.

Sandpit-River Surveys, 2001–2019: We observed slightly lower numbers of least tern adults within the Program Associated Habitat Area in 2019, but the numbers were still similar to the past 3 years (Figure 6). We observed higher numbers of piping plover adults during 2019 semi-monthly surveys as compared to last year. However, the numbers were comparable to the numbers seen from 2011–2017. The most adult least terns (127) were observed during the mid-June semi-monthly sandpit and river surveys. Piping plovers had their highest observed numbers (70) during the 15-May and 15-June surveys. The river was used exclusively for foraging by both species as all least tern and piping plover nests were located on off-channel sandpits.

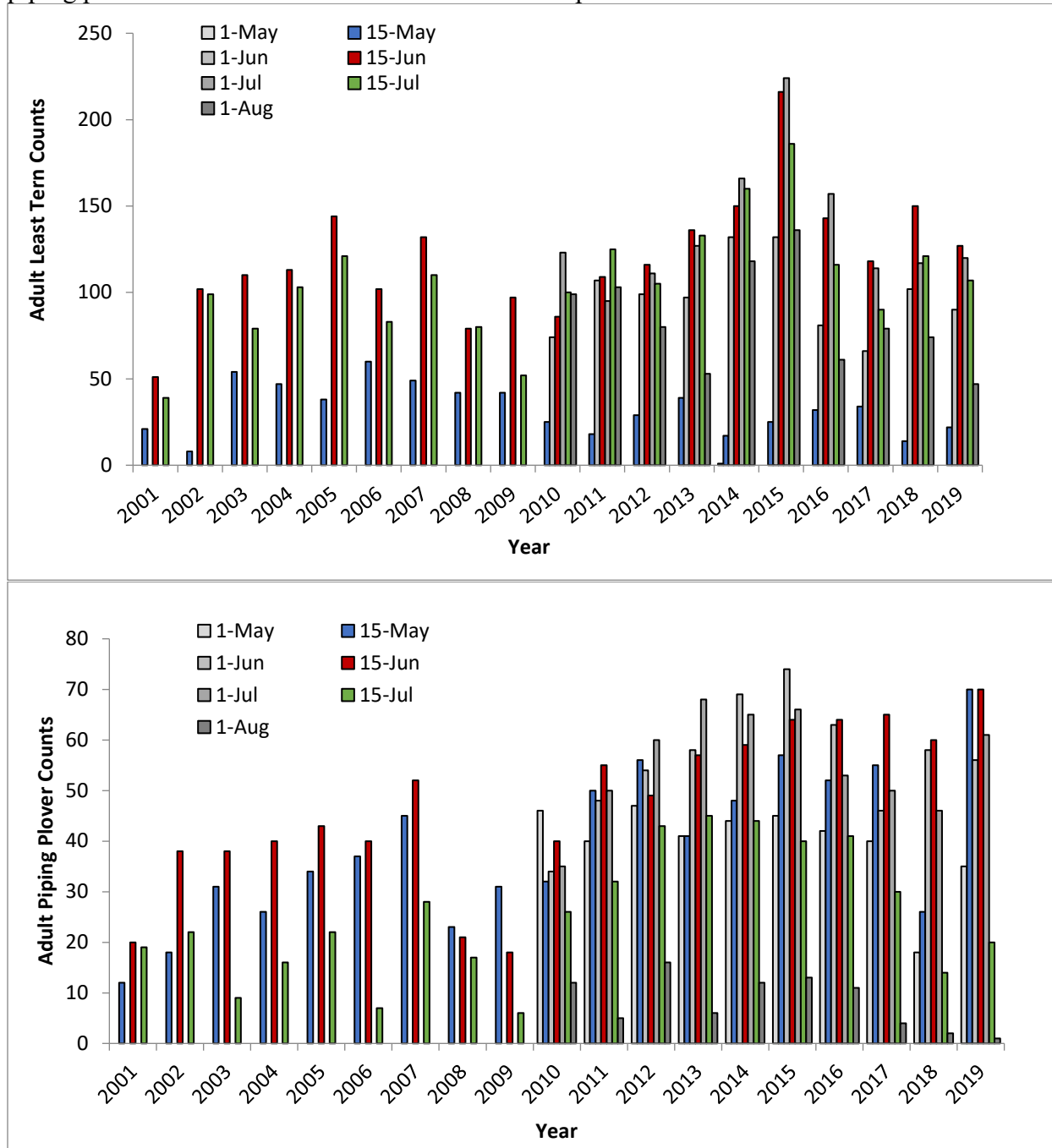


Figure 6. Numbers of adult least tern (top) and piping plover (bottom) adults observed during mid-month and semi-monthly surveys of sandpits and central Platte River channels between Chapman and Lexington, Nebraska, 2001–2019. Counts during past years represent minimum numbers present as several river surveys were not completed due to a lack of flow in the channel (see Figure 4).

Numbers of adult least terns and piping plovers observed during mid-month surveys of the Program Associated Habitat Area declined sharply after 2007, but have since rebounded to where counts observed during 2019 were similar or higher than numbers observed prior to Program implementation (Figure 7). Program analyses indicate least tern and piping plover adult and breeding pair counts are positively correlated with habitat availability; however, analyses of future data will be used to confirm the relationship between breeding pair counts and available habitat.



Least tern adult at nest

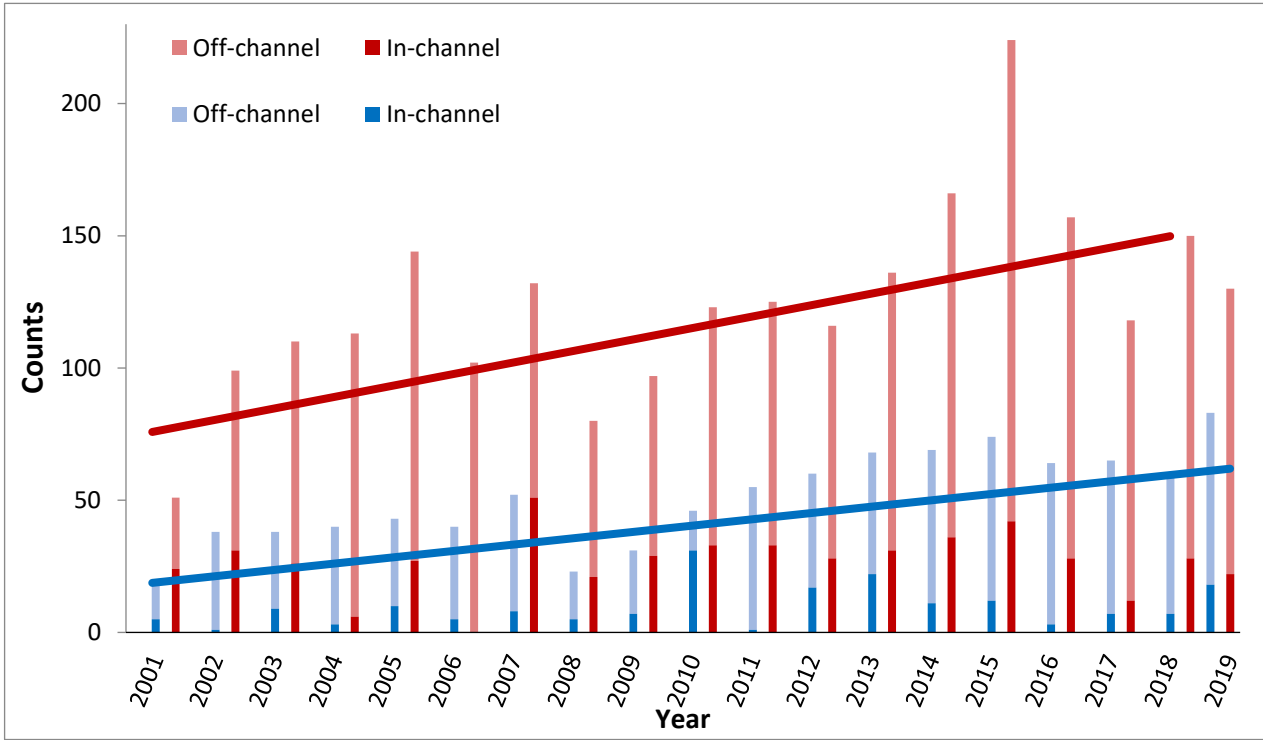


Figure 7. Trends (lines) in peak counts of least tern (red bars) and piping plover (blue bars) adults observed during mid-month and semi-monthly surveys of sandpits (light blue and light red bars) and the Platte River (dark blue and dark red bars) between Lexington and Chapman, Nebraska, 2001-2019.

NEST AND CHICK MONITORING

METHODS:

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 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 and technicians and Program partners monitored nesting sites during 2019.

We recorded date, observation start and stop times, and the number of least tern and piping plover adults, nests, broods, chicks, and fledglings present during each semi-weekly site visit. We used a GIS to determine distances to predator perch, nearest waterline and elevation of each nest above the waterline. When chicks or fledglings were observed, we estimated the date of

hatching or fledging based on current and previous chick observations. We determined the amount of nesting habitat available at each site using a GIS. Summaries of the habitat metrics for Off-channel least tern and piping plover nests from 2007–2019 can be found in Tables 12-13 under the Research portion of this report.

Outside Monitoring – Outside surveys were performed using binoculars and/or spotting scopes, at a distance great enough to not cause disturbance to nesting birds (usually >165 ft., but closer or farther as terrain dictated), and for at least 1/2 hour. Observations were conducted from multiple locations to provide as complete of coverage of the site as possible. Nests and chicks were often located by observing adult birds.

Survival – We calculated daily and incubation-period nest survival rates using package RMARK in Program RStudio (R Core Team 2017). We included nests located at sandpit and riverine sites that were monitored during 2019 by Program staff and technicians and personnel from CPNRD and NPPD to determine survival rates. 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, observed to be active and intact 12 days after it was initiated was found to be empty (no eggs) 16 days after it was initiated with no sign of chicks of appropriate age in the area, we censored 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 29 days after it was initiated we observed an empty nest bowl and no sign of chicks of appropriate age in the area, we assigned the fate of the nest to be 27 days (midpoint of the 2 observation periods) and assigned a “successful” status to the nest. Our assumption was that, on average, we discarded survived and failed intervals in the same proportion they existed in the data.

We also used package RMARK in Program 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 broods to be the midpoint of when a brood was last observed active and first documented as an “unknown” status and 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:

Mortality: We observed no research-related mortality during 2019. Weather was attributed as the cause of 3 piping plover nest (0.5%) and 2 least tern nests (0.02%) failures during 2019. We experienced flooding at several sites and along the river. This caused nest loss due to flooding and loss of nesting area. There was at least 1 (0.01%) tern nest and 2 (0.03%) piping plover nests that were failed due to flooding. Predation was documented as the cause of loss 11 least tern nests



Part of a predated least tern adult

(0.08%) and was suspected in the loss of several other additional least tern and piping plover nests and chicks during 2019. This number is slightly misleading, since many of the unknown nests and chicks were likely predated. Of the nests documented as being lost to predation, 5 of them occurred at Blue Hole sandpit and 4 occurred at Broadfoot-South during 2019. One piping plover nest (0.02%) was determined abandoned. Twenty-four least tern (0.18%) and fifteen piping plover (0.25%) nest failures were attributed to unknown causes and these were fated as failed unknown. Twenty-four least tern nests (0.18%) and eight piping plover nests (0.13%) were declared to have unknown outcomes. Because inside monitoring was not performed this year, determining nest fates was not as precise as previous years. One reason for the large number of unknown outcomes this year was from lack of access to off channel nesting sites due to the flooding.

So even though chicks were never associated to a nest, we were unable to determine if they failed as a nest or chicks. Along with the flooding there were also evidence of large predation events at two of the sandpits. Several nests and chicks disappeared during these predation events, but not all of them could be attributed to predation due to their hatch date coinciding with the event. This meant that even though they were likely lost to predation, it was undetermined whether they were lost before or after they hatched.

Least Terns: Least tern nests were observed and monitored at 9 of the 15 sandpits monitored during 2019 (Table 7, Figure 8). All counts of adults, nests, chicks, and fledglings reported in Table 5 represent maximum numbers observed from outside the nesting colony during all surveys. The first observation of a least tern nest occurred on 24 May, 2019 and the last nest was first observed on 12 July, 2019. The first observation of a least tern chick occurred on 14 June, 2019 and the last nest known to hatch did so on 6 August, 2019. At least 1 egg from 51% (67/132) of least tern nests hatched which resulted in which resulted in 137 chicks and an overall nest-success rate of 1.04 chicks/nest and chicks/breeding pair (137 chicks/95 breeding pairs) during 2019 (Table 5). Average daily survival rate of least tern nests during 2019 was 0.9769 (range =0-1.0000; Appendix 1) with at least one significant difference observed between sites [$\chi^2(6, N=132) = 38.485$; $p < 0.001$]; average survival rate over the 21-day incubation period was 0.612 (range = 0–1.0000). We observed the first least tern fledgling on 8 July, 2018 and the last known least tern chick to fledge did so on 28 August, 2018. Apparent fledge success at all sites monitored was 0.54 fledglings/nest (71 fledglings/132 nests) or 0.75 fledglings/breeding pair (71 fledglings/95 breeding pairs) with all nests occurring on sandpit sites during 2019. Average daily survival rates for least tern broods across all sites during 2019 was 0.9735 (range = 0.9436–1.0000; Appendix 2) with at least one significant difference observed between sites [$\chi^2(6, N=67) = 35.797$; $p < 0.001$]; average brooding-period survival rate across all sites was 0.5685 (range = 0.2956–1.0000).

We tested for an effect of ownership (i.e., Program or other) on nest and brood survival rates during 2019. Least tern incubation period survival was higher at Program owned and/or managed nesting areas than non-Program sites. The rates were 0.6540 and 0.4739 respectively, with a significant difference observed between them [$\chi^2(1, N=132) = 13.474$; $p < 0.001$] (Appendix 5). Brooding period survival rates were higher at Program owned and/or managed nesting areas than non-Program sites. The rates were 0.5769 and 0.5240 respectively, but this difference was not significant [$\chi^2(1, N=67) = 0.083$; $p = 0.773$] (Appendix 6).

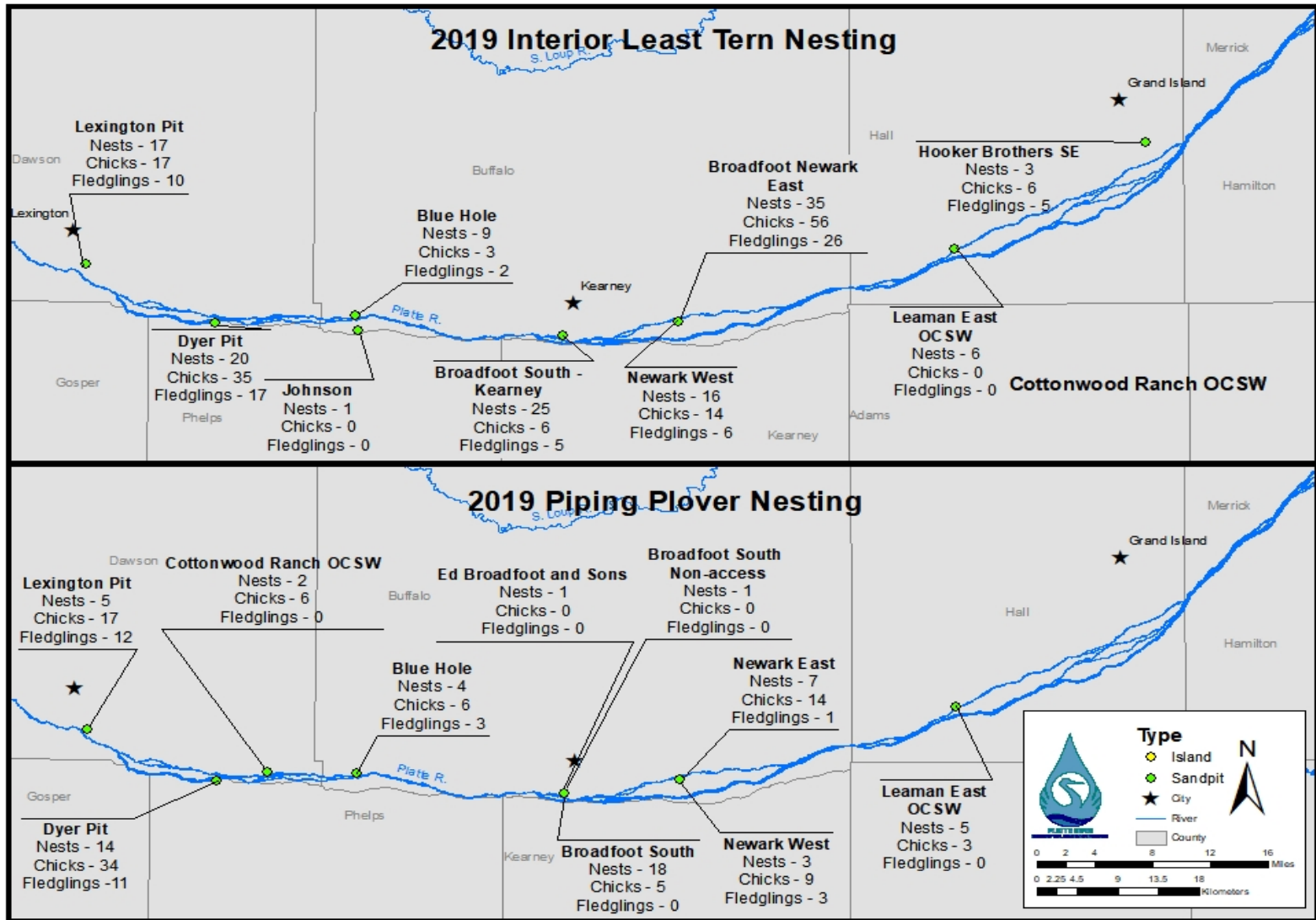


Figure 8. Distribution and numbers of least tern and piping plover nests, chicks, and fledglings observed within Program associated habitats during 2019 surveys of sandpits and naturally occurring river islands. Least tern nests and/or chicks were observed and monitored at 9 of the 15 sandpits and piping plover nests and chicks were observed and monitored at 10 of the 15 sandpits monitored during 2019.

Table 5. Summary of least tern reproductive success at sandpit and river-island sites on the central Platte River in Nebraska, 2007–2019. Site-specific details on numbers of adults, nest, chicks, and fledglings observed during 2019 are provided in Table 7. Site-specific details of daily, incubation- and brooding-period survival rates for 2019 are provided in Appendices 1-2 (RMark estimates).

Least Tern													
Reproductive Parameter	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Maximum Adults Observed	132	80	97	123	125	116	136	166	224	157	118	174	169
Breeding Pairs	39	37	42	53	60	64	58	98	141	88	77	88	95
Total Nests Observed	53	64	60	76	90	88	95	145	188	119	118	113	132
Successful Nests (≥ 1 egg hatched)	22	27	37	43	52	63	51	80	116	74	63	79	67
Apparent Nest Success	0.42	0.42	0.62	0.57	0.58	0.72	0.54	0.55	0.62	0.62	0.53	0.67	0.51
Daily Nest Survival Rate (All sites)	0.97	0.98	0.99	0.98	0.97	0.99	0.97	0.97	0.98	0.98	0.98	0.98	0.98
Incubation-period Survival Rate (All sites)	0.55	0.61	0.73	0.64	0.58	0.76	0.56	0.52	0.63	0.71	0.61	0.65	0.61
Chicks Observed (<15D)	50	54	71	105	124	144	118	180	258	170	129	168	137
Hatch Ratio (<15D Chicks/Total Nests)	0.94	0.84	1.18	1.38	1.38	1.64	1.24	1.24	1.37	1.43	1.09	1.49	2.04
Hatch Ratio (<15D Chicks/Breeding Pair)	1.28	1.46	1.69	1.98	2.07	2.25	2.03	1.84	1.83	1.93	1.68	1.91	1.44
Chicks ($\geq 15D$)	40	44	48	67	98	95	70	104	158	91	78	117	74
Fledglings (21D)	---- ^A	-----	----	64	89	84	64	91	146	80	76	117	71
Historic Fledge Ratio ($\geq 15D$ Chicks/Total Nests)	0.75	0.69	0.80	0.88	1.09	1.08	0.74	0.72	0.84	0.76	0.66	1.04	0.56
Fledge ratio (21D Chicks/Nest)	-----	-----	----	0.84	0.99	0.95	0.67	0.63	0.78	0.67	0.64	1.04	0.54
Historic Fledge Ratio ($\geq 15D$ Chicks/Breeding Pair)	1.03	1.19	1.14	1.26	1.63	1.48	1.21	1.06	1.12	1.03	1.01	1.33	0.78
Fledge Ratio (21D Chicks/Breeding Pair)	-----	-----	----	1.21	1.48	1.31	1.10	0.93	1.04	0.91	0.99	1.33	0.75
Daily Brood Survival Rate (All sites)	-----	0.98	0.98	0.98	0.99	0.99	0.97	0.98	0.98	0.98	0.97	0.98	0.97
Brooding-period Survival Rate (All sites) ^B	-----	0.75	0.79	0.72	0.89	0.81	0.59	0.69	0.68	0.61	0.56	0.69	0.57

^A “-----” indicates these data were not reported.

^B Brood survival rates reported in the table are not comparable because estimates are reported as survival for a 15-day interval for least tern chicks during 2007–2009 and in 2010 the Program began to use 21 days as the fledge age for least tern chicks.

Piping Plovers: Piping plover nests were observed at 10 of 15 sandpits monitored during 2019 (Table 7; Figure 8). The first observation of a piping plover nest was made on 3 May, 2019 and the last nest was first observed on 8 July, 2019. The first observation of a piping plover chick occurred on 30 May, 2019 and the last successful nest observed hatched on 15 July, 2019. At least one egg from 52% (31/60) of piping plover nests hatched, which resulted in 94 chicks and an overall hatch ratio of 1.57 chicks/nest or 2.09 chicks/breeding pair (94 chicks/45 breeding pairs) during 2019 (Table 6). Piping plover daily nest survival rate across all sites during 2019 was 0.9760 (range = 0.9498–1.0000; Appendix 3) with at least one significant difference observed between sites [$\chi^2(6, N=60) = 24.671$; $p < 0.001$]; average incubation-period survival rate was 0.5062 (range = 0.2362–1.0000). We first observed a piping plover fledgling on 24 June, 2019 and the last known piping plover chick to fledge did so on 22 July, 2019. We observed an apparent nest-based fledging rate of 0.50 (30 fledglings/60 nests) and a pair-based fledging rate of 0.67 (30 fledglings/45 breeding pairs) at all sites monitored during 2019 (Table 6). Average daily survival rates for piping plover broods across all sites during 2019 was 0.9713 (range = 0.5774–1.000; Appendix 4), with no significant differences observed between sites [$\chi^2(5, N=31) = 10.753$; $p = 0.0565$]; average brooding-period survival rate across all sites was 0.4427 (range = 0.0000–0.5204).



Piping Plover Chicks

We tested for an effect of ownership (i.e., Program or other) on nest and brood survival rates during 2019. Piping plover incubation period survival rates were higher at non-Program owned and/or managed nesting areas than at Program sites. The rates were 0.7573 and 0.4629, with no significant difference observed between them [$\chi^2(1, N=60) = 1.963$; $p = 0.1612$]; Piping plover brooding period survival rates were lower at Program sites compared to non-Program owned and/or managed nesting areas; 0.3303 and 1.0 respectively, this difference was not significant at $\alpha = 0.05$ level [$\chi^2(1, N=31) = 9.193$; $p = \sim 1.0$; Appendix 8].

Table 6. Summary of piping plover reproductive success at sandpit sites along the central Platte River in Nebraska, 2007–2019. Site-specific details on numbers of adults, nest, chicks, and fledglings observed during 2019 are provided in Table 7. Site-specific details of daily, incubation- and brooding-period survival rates for 2019 are provided in Appendices 3-4 (RMark estimates).

Reproductive Parameter	Piping Plover												
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Maximum Adults Observed	52	23	31	46	55	60	68	69	74	64	65	74	88
Breeding Pairs	19	13	12	20	27	30	27	30	39	43	40	37	45
Total Nests Observed	27	21	15	33	34	46	31	43	54	60	51	47	60
Successful Nests (≥ 1 egg hatched)	15	8	9	21	27	32	23	34	34	40	30	35	31
Apparent Nest Success	0.56	0.38	0.60	0.64	0.79	0.70	0.74	0.79	0.63	0.68	0.59	0.74	0.52
Daily Nest Survival Rate (All sites)	0.99	0.98	0.99	0.98	0.99	0.99	0.99	0.99	0.98	0.99	0.98	0.99	0.98
Incubation-period Survival Rate (All sites)	0.71	0.58	0.67	0.54	0.77	0.69	0.73	0.77	0.64	0.69	0.61	0.68	0.51
Chicks Observed ($<15D$)	44	26	27	76	87	99	80	116	119	120	92	95	94
Hatch Ratio ($<15D$ Chicks/Nest)	1.63	1.24	1.80	2.30	2.56	2.15	2.58	2.70	2.2	2.00	1.80	2.02	1.57
Hatch Ratio ($<15D$ Chicks/Breeding Pair)	2.32	1.24	2.25	3.80	3.22	3.30	2.96	3.87	3.05	2.79	2.30	2.57	2.09
Chicks ($\geq 15D$)	27	10	18	53	61	68	43	67	73	70	53	36	42
Fledglings (28D)	----- ^A	-----	-----	42	45	59	28	55	52	55	47	23	30
Historic Fledge Ratio ($\geq 15D$ Chicks/Nest)	1.00	0.48	1.20	1.61	1.79	1.48	1.39	1.56	1.35	1.17	1.04	0.77	0.70
Fledge ratio (28D Chicks/Nest)	-----	-----	-----	1.27	1.32	1.28	0.90	1.28	0.96	0.92	0.92	0.49	0.50
Historic Fledge Ratio ($\geq 15D$ Chicks/Breeding Pair)	1.42	0.77	1.50	2.65	2.26	2.27	1.59	2.23	1.87	1.63	1.33	0.97	0.93
Fledge Ratio (28D Chicks/Breeding Pair)	-----	-----	-----	2.01	1.67	1.97	1.04	1.83	1.33	1.28	1.18	0.62	0.67
Daily Brood Survival Rate (All sites)	-----	0.94	0.98	0.99	0.99	0.99	0.98	0.99	0.99	0.98	0.98	0.96	0.97
Brooding-period Survival Rate (All sites) ^B	-----	0.42	0.79	0.70	0.73	0.78	0.62	0.69	0.68	0.55	0.63	0.29	0.44

^A “-----” indicates these data were not reported.

^B Brood survival rates reported in the table are not comparable because estimates are reported as survival for a 15-day interval for piping plover chicks during 2007–2009 and in 2010 the Program began to use 28 days as the fledge age for piping plover chicks.

Table 7. Site-specific numbers of adults, nests, chicks, and fledglings observed while monitoring sandpits for least tern and piping plover reproduction during 2019. 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 3.

Site #/Name	Habitat Type ^A	Management ^A	Surveys		Least tern								Piping plover							
					Survey Time (hr.)	Breeding Pairs ^B	Bre. Pair (Max) ^B	Adults (Max) ^B	Nests	Nests Hatched	Chicks 0-14 Days	Chicks 15-21 D.	Fledglings	Breeding Pairs ^B	Bre. Pair (Max) ^B	Adults (Max) ^B	Nests	Nests Hatched	Chicks 0-14 Days	Chicks 15-28 D.
1 Lexington Pit	SP	PFT	35	55	10	13	20	17	9	17	10	10	5	5	9	5	5	17	12	12
2 Dyer Pit	SP	PFTS	27	29	20	20	27	20	16	35	21	17	12	12	19	14	12	34	12	11
3 Cottonwood Ranch OCSW	OC	PFTH	21	10	0	0	0	0	0	0	0	0	2	2	6	2	2	6	3	0
4 Blue Hole	SP	PFT	23	35	7	7	18	9	1	3	2	2	4	4	8	4	2	6	5	3
5 Johnson Pit	SP	PFT	8	4	0	1	5	1	0	0	0	0	0	0	0	0	0	0	0	0
6 Ed Broadfoot and Sons ^C	SP	N	21	2	0	0	2	0	0	0	0	0	0	1	2	1	0	0	0	0
7 Broadfoot South	SP	PFTHS	28	38	15	16	25	25	3	6	5	5	13	13	17	18	2	5	0	0
8 Broadfoot South - Non-Access Islands ^C	SP	FT	23	7	0	0	2	0	0	0	0	0	1	1	2	1	0	0	0	0
9 Newark West	SP	PFTHS	32	25	11	14	19	16	8	14	5	6	3	3	8	3	3	9	5	3
10 Newark East	SP	PFTH	29	28	28	28	37	35	27	56	26	26	7	3	10	7	4	14	5	1
11 Leaman East OCSW	OC	PFTHS	26	11	2	5	7	6	0	0	0	0	2	3	5	5	1	3	0	0
12 Trust Wild Rose East	SP	N	8	14	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
13 Follmer-Alda Pit	SP	PH	7	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14 Deweese – Alda Pit	SP	N	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15 Hooker Brothers – GI South East Pit	SP	N	20	11	0	3	7	3	3	6	5	5	0	0	0	0	0	0	0	0

^A Habitat types include sandpits (SP), off-channel sand and water (OC), or river islands (RI). Management actions applied to each site following the 2018 nesting season and prior to the 2019 nesting season could include: mowed (M), burned (B), disked (D), graded (G), tree/vegetation removal (R), or contact herbicide (H) during fall 2018; pre-emergent herbicide (P), predator fencing (F), predator trapping (T), or Nest Furniture Distribution (S) during spring 2019; active sand/gravel mining within primary nesting peninsula (A), no management (N); unknown (U); or construction (C) which include monitored sites that were considered non-habitat prior to June 15 due to construction activities.

^B Breeding pair counts were determined on 21 June for least terns and 25 May for piping plovers when numbers observed within the Program Associated Habitat area first peaked. Breeding pair counts, however, do not necessarily represent maximum numbers of least tern or 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. Bre. Pairs (Max) represents the maximum number of pairs at a site during the nesting season, regardless of Breeding Pair peak dates. Adults (Max) represent the maximum number adults observed during any single survey at the site.

^C Includes 1 piping nest that was outside the managed nesting areas and thus not surrounded by electrified fence and water. The nest was determined to have failed.



Least Tern Chick

Breeding Pair Counts: We estimated numbers of least tern and piping plover breeding pairs by adding the number of active and recently (within five days) failed nests to the number of active and recently failed least tern and piping plover broods and recently fledged least terns and fledged piping plovers observed on each Least tern breeding pair counts peaked at 95 pairs on 21 June, 2019. Piping plover breeding pair counts peaked at 45 pairs 25 May, 2019.

Similar to nest and adult counts, least tern breeding pair counts have increased steadily since 2001 (Figure 9). Piping plover breeding pair counts increased slightly from 2001–2007, declined during 2008 and 2009, and have since increased (Figure 10). We observed an increase in least tern and piping plover breeding pairs in 2019; counts are also much higher than counts observed during the years prior to the Program implementation. Though nesting has

occurred on riverine sandbars, off-channel sandpits have provided the most consistent nesting habitat for both species to date.

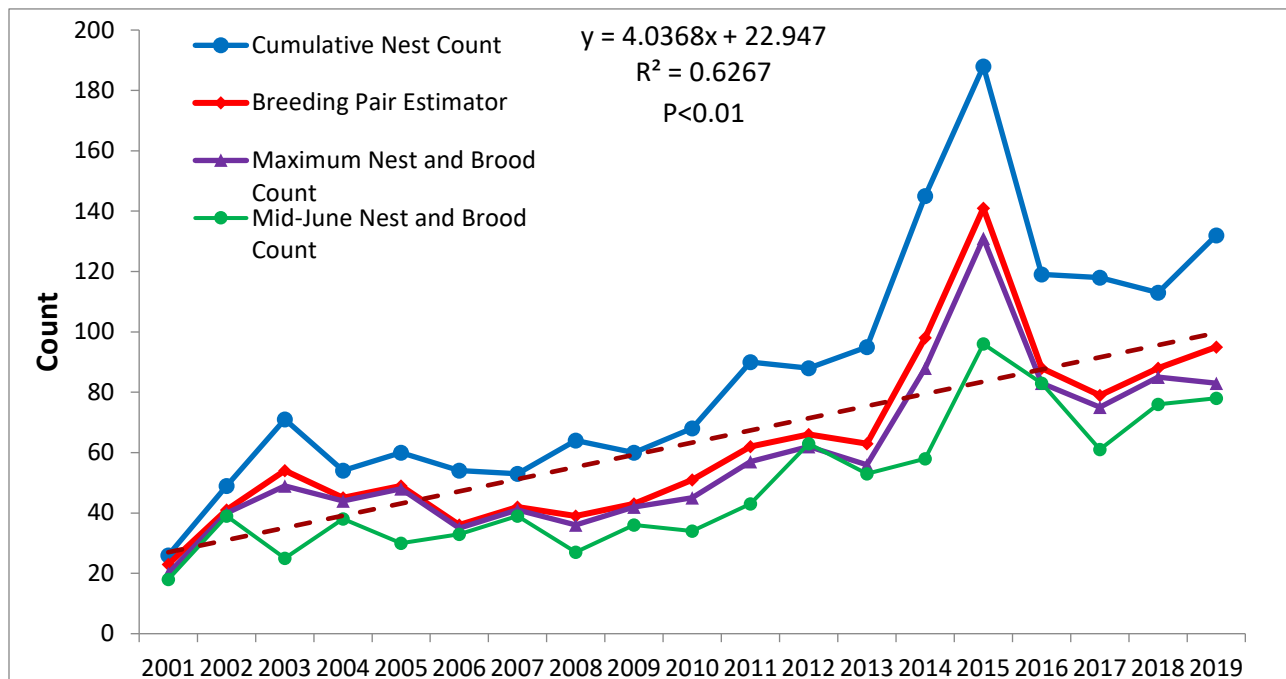


Figure 9. Comparison of cumulative numbers of least tern nests, Program-defined breeding pairs, maximum nest and brood quantities, and the mid-June nest and brood quantities observed within the Program Associated Habitat Area, 2001-2019.

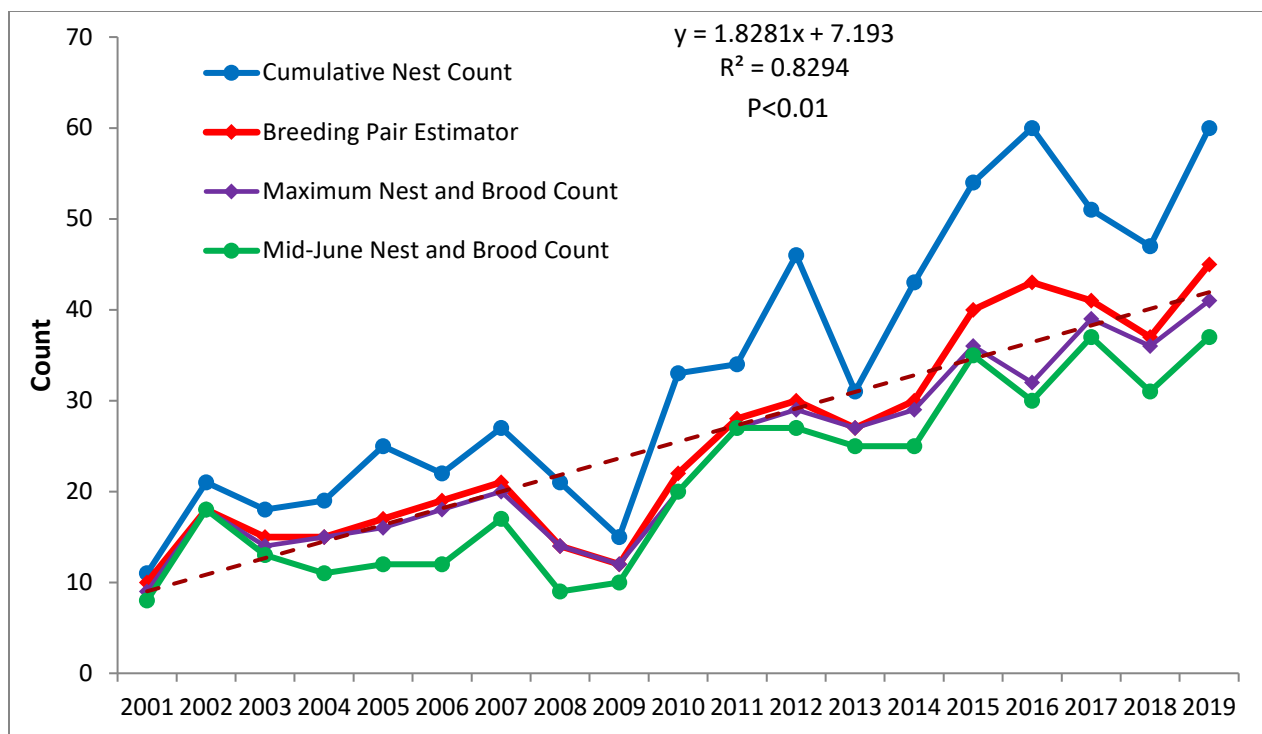
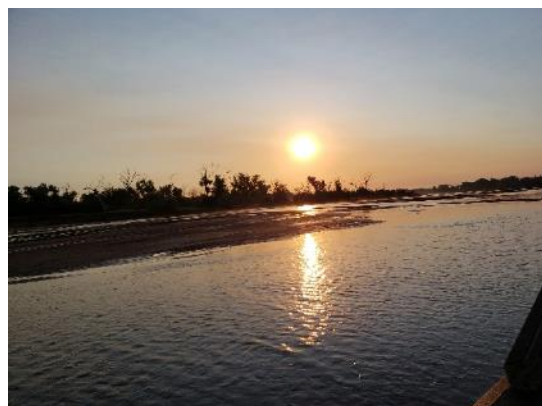


Figure 10. Comparison of numbers of piping plover cumulative nests, Program defined breeding pairs, maximum nest and brood quantities, and the mid-June nest and brood quantities observed within the Program Associated Habitat Area, 2001–2019.

Species Response to Habitat Creation and Maintenance

The total number of breeding pairs has increased for both species during the First Increment of the Program (Table 8). In 2019, a total of 95 least tern and 45 piping plover breeding pairs were observed in the AHR (Figure 11). Most of the nesting in the AHR during the First Increment of the Program has occurred on managed off-channel habitats (Figures 12 and 13). The limited amount of on-channel nesting observed at the beginning of the First Increment declined as on-channel habitat was lost during several high flow events (Table 1). Off-channel habitat accounts for most of the nesting in the AHR and the number of breeding pairs has generally increased over the course of the First Increment as the Program has constructed additional off-channel habitats (Tables 1 and 10). Overall, the Program has observed a species response to off-channel habitat construction (Figure 14), while the species response to and productivity on on-channel habitat construction has been low. Even though there has been an upward trend in cumulative counts for breeding pairs (Figures 9 and 10), cumulative nest count (Figures 9 and 10), and cumulative fledge counts; this is likely in part due to the increasing habitat availability. There has still however been a downward trend in the proportion of successful chicks (Figures 15 and 16) and the fledge to breeding pair ratio (Figures 17 and 18) for both species. One of the possible factors being looked at is predation and ways the Program can reduce it.



Sandbars near Dyer sandpit

Table 8. Least tern and piping plover on- and off-channel nesting incidence by year, 2007–2019.

Year	Least Tern					Piping Plover				
	Br.* Pairs	Nests	Succ. Nests	Fledglings	Fledglings Per Pair	Br. Pairs	Nests	Succ. Nests	Fledglings	Fledglings Per Pair
2007	42	53	22	40	0.95	21	27	15	25	1.19
2008	39	64	27	44	1.13	14	21	8	10	0.71
2009	43	60	36	46	1.07	12	15	9	12	1.00
2010	51	80	44	64	1.25	22	33	22	46	2.09
2011	62	90	53	89	1.44	28	34	27	45	1.61
2012	66	88	63	84	1.27	30	46	32	59	1.97
2013	63	95	51	64	1.02	27	31	23	28	1.04
2014	98	145	54	91	0.93	30	43	25	59	1.97
2015	141	188	116	146	1.04	39	54	34	52	1.33
2016	88	119	74	80	0.91	43	60	40	55	1.28
2017	77	118	63	76	0.99	40	51	30	47	1.18
2018	88	113	79	117	1.33	37	47	35	23	0.62
2019	95	132	67	71	0.75	45	60	31	30	0.67
Mean	73.31	103.46	57.62	77.85	1.08	29.85	40.15	25.46	37.77	1.28

*Breeding pairs within table 8 represent numbers of breeding pairs present on off-channel sites the day breeding pairs within the system were maximized; therefore, nests and fledglings per breeding pair are occasionally disproportionately large.

Table 9. Least tern and piping plover on-channel nesting incidence and productivity by year, 2007–2019.

Year	Least Tern					Piping Plover				
	*Br. Pairs	Nests	Succ. Nests	Fledglings	Fledglings Per Pair	*Br. Pairs	Nests	Succ. Nests	Fledglings	Fledglings Per Pair
2007	11	13	2	2	0.18	1	4	2	7	7.00
2008	10	20	7	9	0.90	3	5	1	3	1.00
2009	3	8	5	4	1.33	2	2	1	1	0.5.0
2010	0	0	0	0	0.00	4	11	4	10	2.50
2011	0	0	0	0	0.00	0	0	0	0	0.00
2012	0	0	0	0	0.00	1	1	1	4	4.00
2013	0	0	0	0	0.00	0	0	0	0	0.00
2014	0	2	0	0	0.00	1	2	1	4	4.00
2015	8	14	3	0	0.00	5	7	1	1	0.20
2016	2	2	0	0	0.00	2	2	1	1	0.50
2017	0	0	0	0	0.00	0	0	0	0	0.00
2018	0	0	0	0	0.00	0	0	0	0	0.00
2019	0	0	0	0	0.00	0	0	0	0	0.00
Mean	2.62	4.54	1.31	1.15	0.19	1.46	2.62	0.92	2.38	1.60

*Breeding pairs within table 9 represent numbers of breeding pairs present on in-channel islands the day breeding pairs within the system were maximized; therefore, nests and fledglings per breeding pair are occasionally disproportionately large.

Table 10. Least tern and piping plover off-channel nesting incidence and productivity by year, 2007–2019.

Year	Least Tern					Piping Plover				
	*Br. Pairs	Nests	Succ. Nests	Fledglings	Fledglings Per Pair	*Br. Pairs	Nests	Succ. Nests	Fledglings	Fledglings Per Pair
2007	31	40	20	38	1.23	20	23	13	18	0.90
2008	29	44	20	35	1.21	11	16	7	7	0.64
2009	40	52	31	42	1.05	10	13	8	11	1.10
2010	51	80	44	64	1.25	18	22	18	36	2.00
2011	62	90	53	89	1.44	28	34	27	45	1.61
2012	66	88	63	84	1.27	29	45	31	55	1.90
2013	63	95	51	64	1.02	27	31	23	28	1.04
2014	98	143	54	91	0.93	29	41	24	55	1.90
2015	133	174	113	146	1.09	34	47	33	51	1.50
2016	86	117	74	80	0.93	42	58	39	54	1.29
2017	77	118	63	76	0.99	40	51	30	47	1.18
2018	88	113	79	117	1.33	37	47	35	23	0.62
2019	95	132	67	71	0.75	45	60	31	30	0.67
Mean	68.67	96.17	55.42	77.17	1.15	27.08	35.67	24	35.83	1.31

*Breeding pairs within table 10 represent numbers of breeding pairs present on off-channel nesting sites the day breeding pairs within the system were maximized. See Table 8 for maximum off-channel breeding pairs by site.

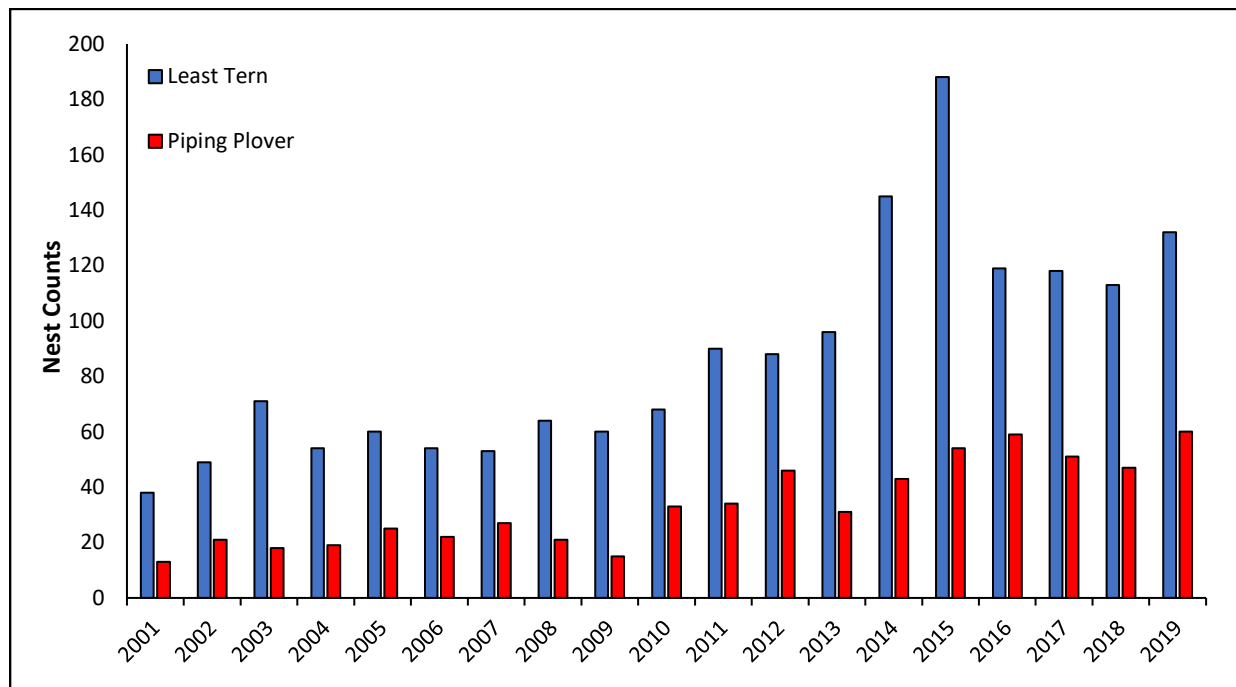


Figure 11. Comparison of total least tern (blue bars) and piping plover (red bars) nests within the Program Associated Habitat Area, 2001-2019.

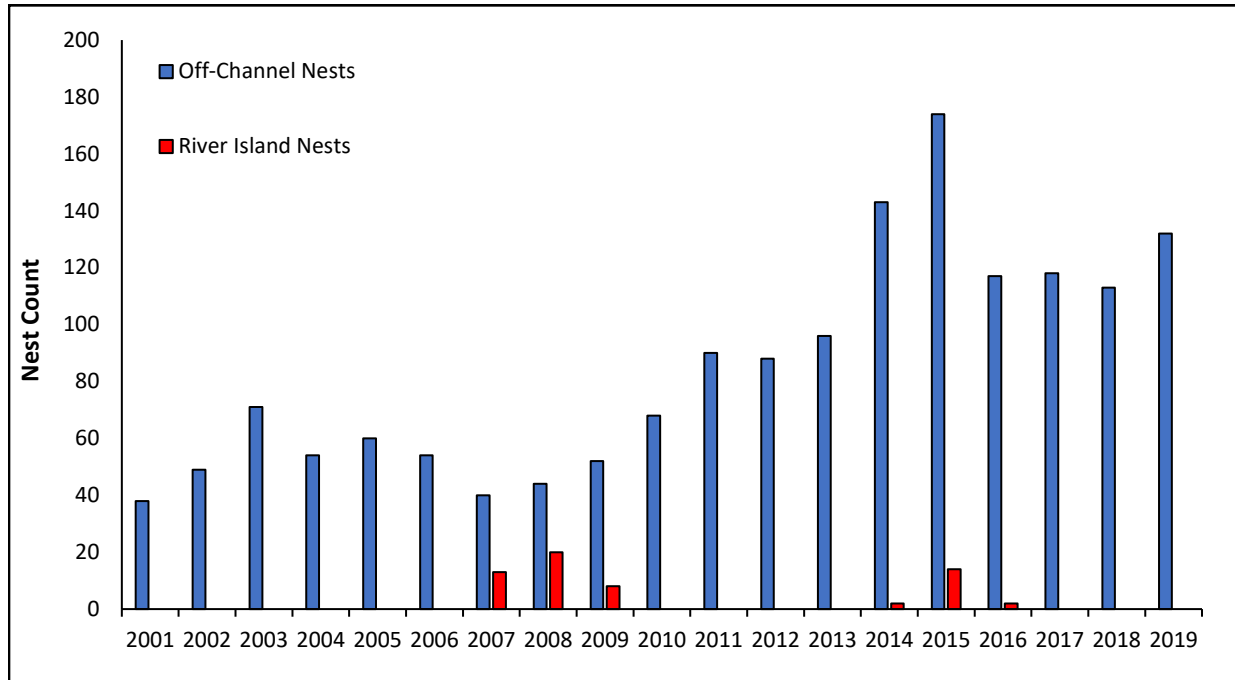


Figure 12. Comparison of least tern off-channel (blue bars) and on-channel (red bars) nests within the Program Associated Habitat Area, 2001-2019.

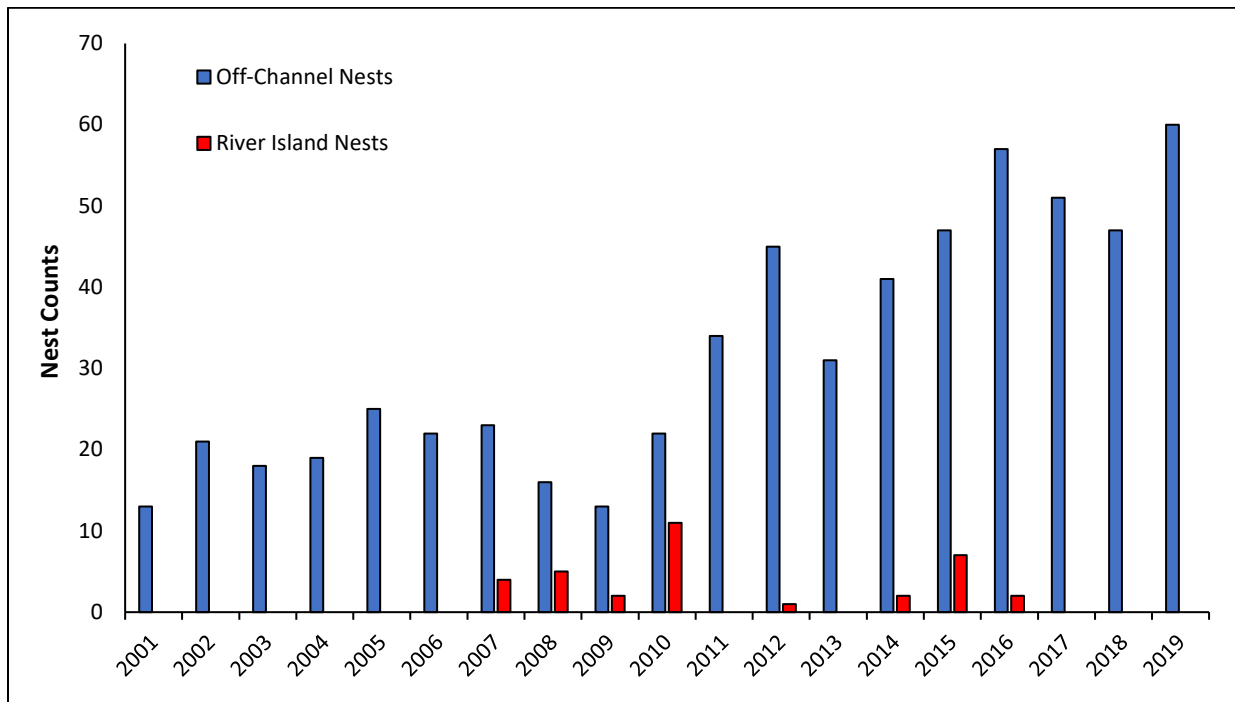


Figure 13. Comparison of piping plover off-channel (blue bars) and on-channel (red bars) nests within the Program Associated Habitat Area, 2001-2019.

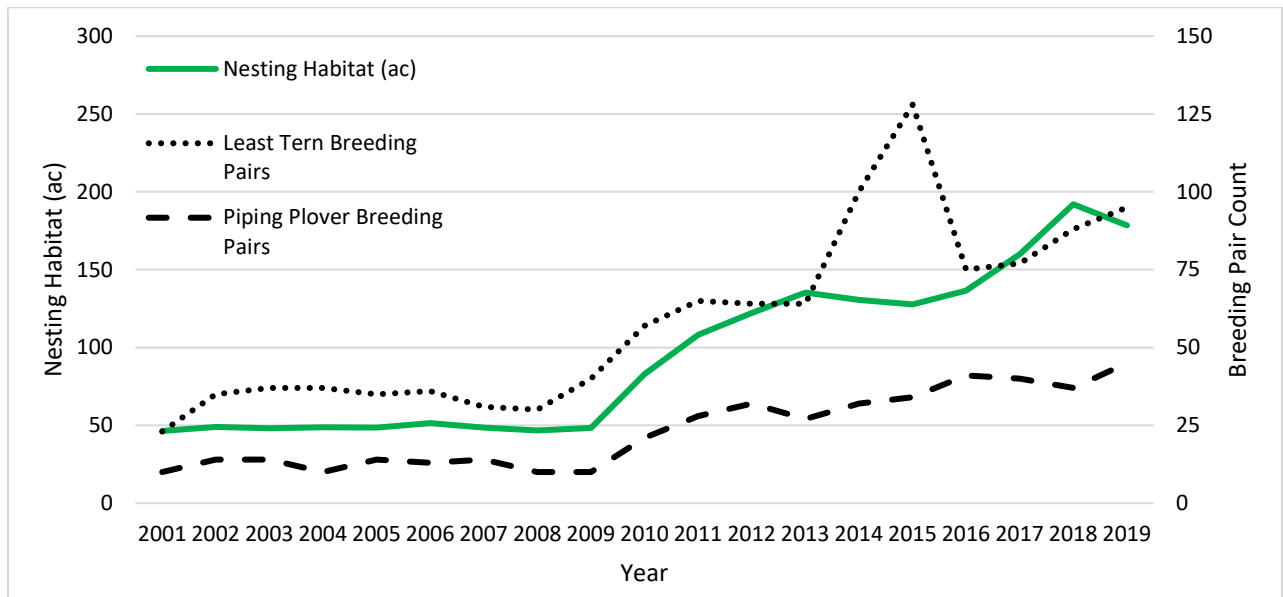


Figure 14. Comparison of numbers of least tern (dotted line) and piping plover (dashed line) breeding pairs and availability of off-channel habitat (solid line) within the Program Associated Habitat Area, 2001-2019.

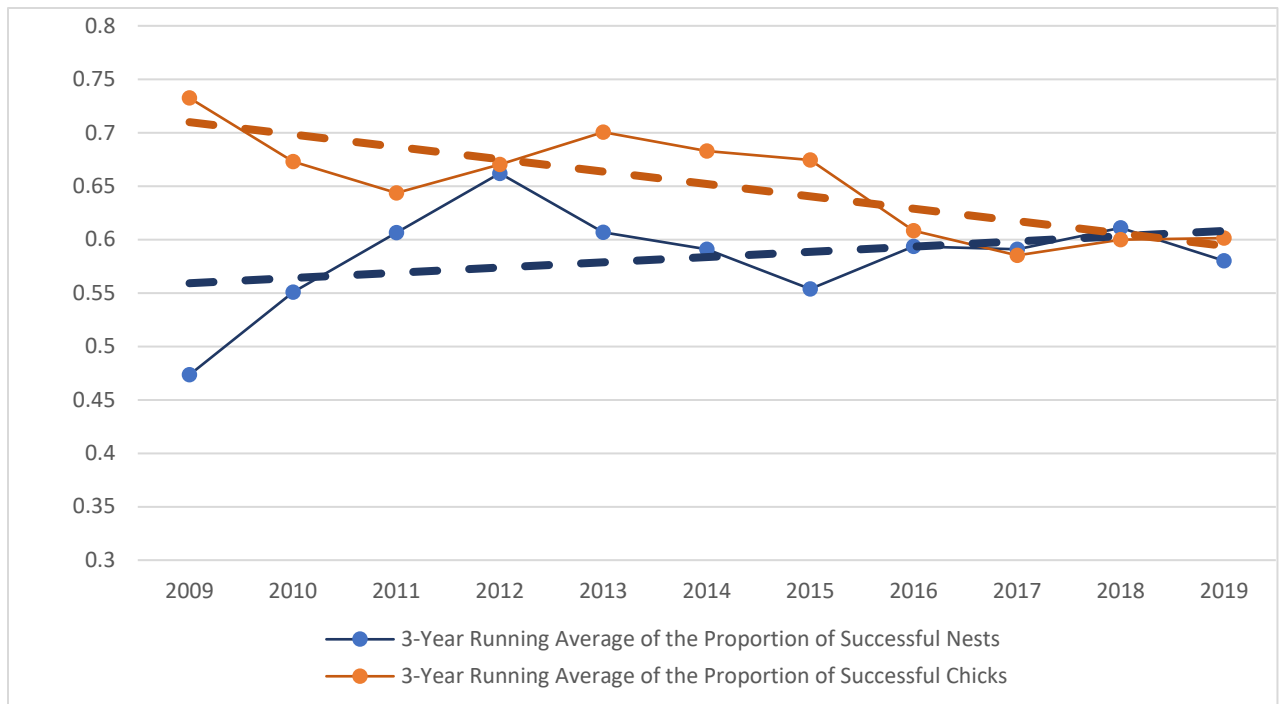


Figure 15. Three year running average of the proportion of successful nests and chicks for least terns from 2007-2019.

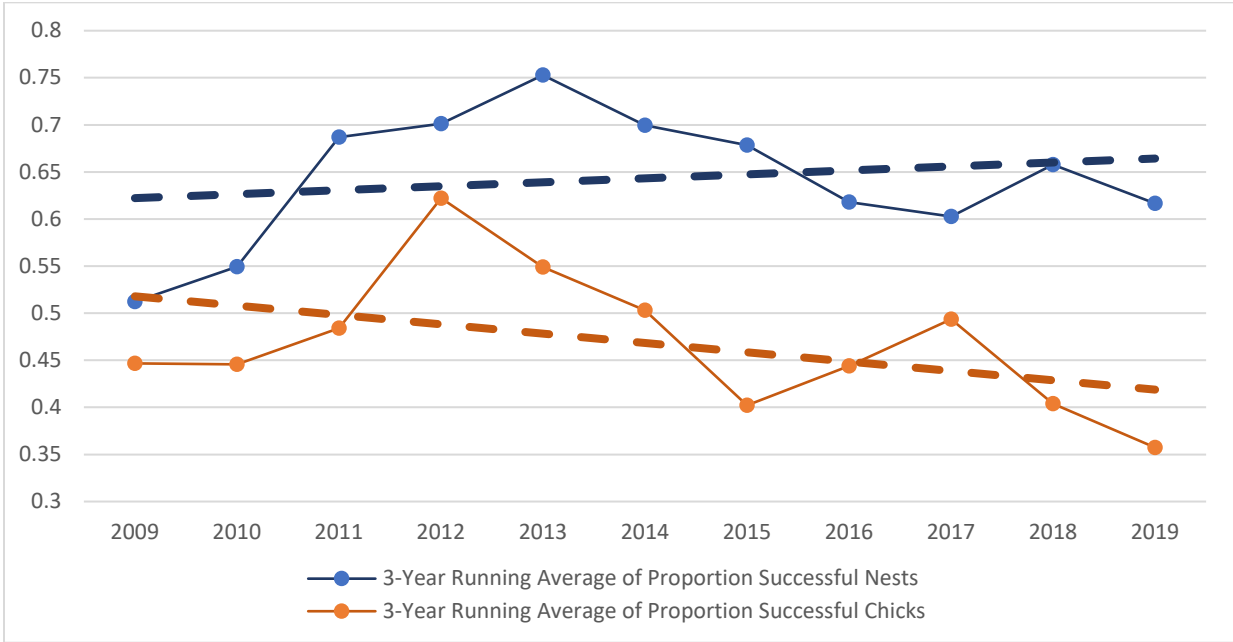


Figure 16. Three year running average of the proportion of successful nests and chicks for piping plovers from 2007-2019.

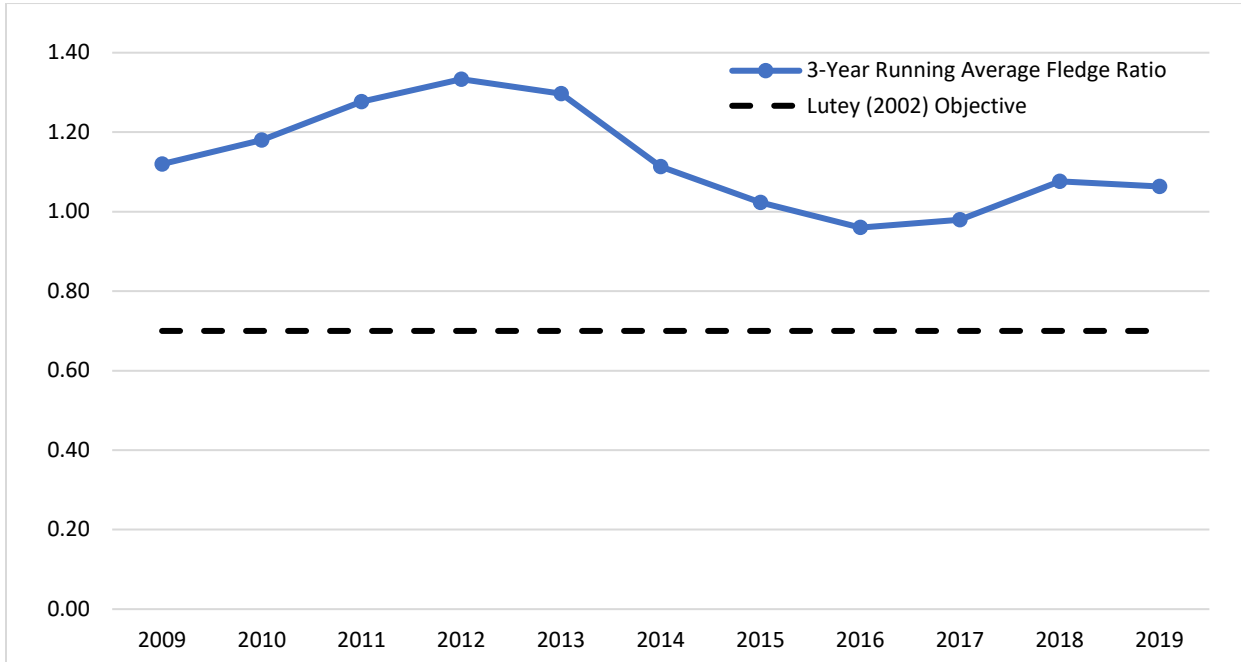


Figure 17. Three year running average of fledglings per breeding pair for least terns, 2007-2019, as compared to the Lutey (2002) objective reported to be necessary for a sustained population along the central Platte River.

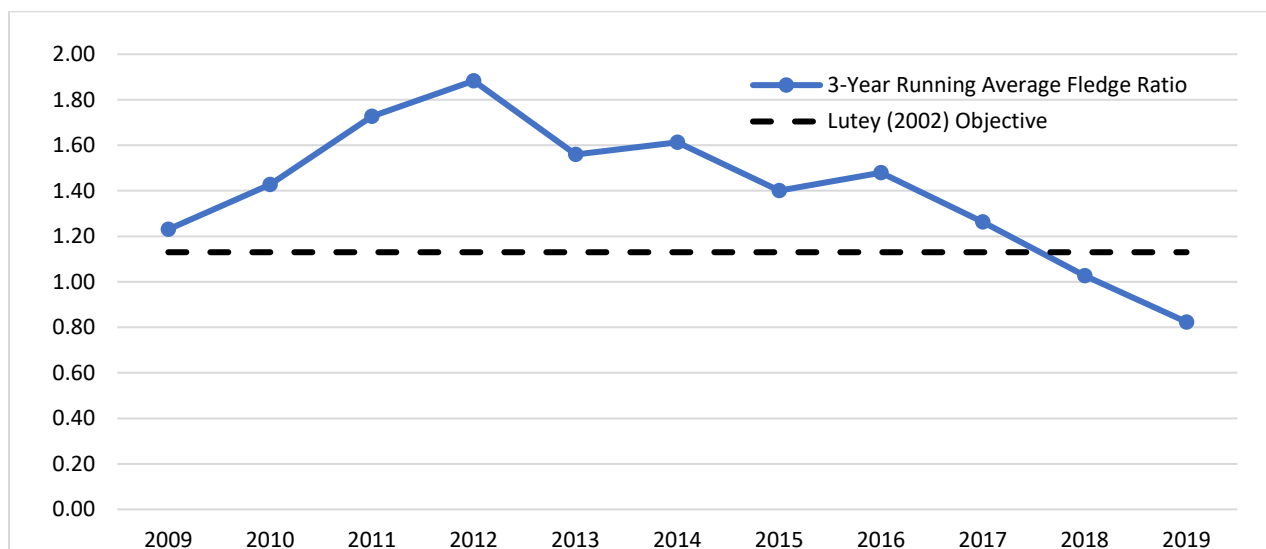


Figure 18. Three year running average of fledglings per breeding pair for piping plovers, 2007-2019, as compared to the Lutey (2002) objective reported to be necessary for a sustained population along the central Platte River.

RESEARCH

In addition to implementation of the Program’s surveillance monitoring protocol, conservation monitoring and directed research will be conducted during the course of the Program’s First Increment to provide data to evaluate the Program’s management objectives and priority hypotheses. Design and implementation of research activities will be guided by the ED Office and the TAC, will be reviewed by the Program’s Independent Scientific Advisory Committee (ISAC) and ultimately approved by the Program’s Governance Committee (GC).

FORAGING HABITS STUDY

The first directed research project related to least terns and piping plovers on the central Platte River began in 2009 with the implementation of the Foraging Habits Study. A contract to conduct this study over two field seasons (2009–2010) was awarded to the USGS-NPWRC. The research was jointly funded by the Program and the USGS-NPWRC. Final results of the Foraging Habits Study can be found in the Program Library at the following link:

<https://www.platteriverprogram.org/PubsAndData/ProgramLibrary/Forms/DispForm.aspx?ID=158>

HABITAT COLONIZATION STUDY

In 2011, the Program and the USGS entered into an agreement for the USGS to conduct a study to evaluate Habitat Colonization and Productivity of Least Terns and Piping Plovers Nesting on Central Platte River sandpits and sandbars. This study was designed to address three specific objectives contributed to the understanding of habitat use by least terns and piping plovers:

- 1. Dispersal**
Quantify dispersal of adults between units of nesting habitat on the Central Platte River among years.
- 2. Colonization**
Quantify colonization rate of newly constructed or managed nesting habitat by local vs. immigrant adults.
- 3. Renesting**
Quantify frequency and location of renesting attempts by adults with failed nests.

The research was jointly funded by the Program and the USGS-NPWRC. Details about findings of this research can be found in the Final Research Project Report that will be produced after the 2018 nesting season and will include banding and resighting data from continued efforts performed during 2009–2018.

Adult and Chick Band Observations – As part of Program-funded research implemented by USGS field crews, 152 adult and 685 juvenile least terns and 85 adult and 591 juvenile piping plovers were banded along the central Platte River between 2009 and 2016 (Table 11).



Setting up nest cameras for band re-sighting efforts

Table 11. Numbers of least tern and piping plover adults and chicks banded along the central Platte River, 2009–2016.

Year	Least Tern Adults	Least Tern Chicks	Piping Plover Adults	Piping Plover Chicks
2009	16	35	11	25
2010	7	74	13	64
2011	4	98	2	68
2012	9	103	15	86
2013	32	99	12	64
2014	28	114	11	106
2015	56	162	21	88
2016	39	107	28	90
Total	152	685	85	591

After nine years of band resighting efforts on the central Platte River, we have compiled valuable information regarding site and habitat (sandpit or riverine) fidelity and philopatry, wintering ground locations for central Platte River piping plovers, survival and recruitment, re-nesting events, and disturbance. We have observed several adult least terns and piping plovers return to nest at the site where they were banded (and at other sites). We observed least tern and piping plover fledglings at non-natal sites late in the nesting season on multiple occasions, which may be an indication that fledglings begin selecting nesting habitat for the subsequent year prior to departing for the winter grounds. This 2019 band resighting season was a success as a total of 29 least terns and 14 piping plover bands were recorded (Table 12 and 13). Of the banded birds observed, 29 (100%) least terns and 13 (92%) piping plovers were banded within the AHR.



Banded piping plover adult

Table 12. Totals for 2019 least tern band resighting efforts with individual totals for each off-channel nesting site.

Interior Least Terns

Sites Monitored	Nests Monitored	Banded Adults	Unbanded Adults	Banded Pairs	Unbanded Pairs	Adult 1 Banded, Adult 2 Unbanded	Adult 1 Banded, Adult 2 Not Observed	Adult 1 Unbanded, Adult 2 Not Observed	Neither Adult Observed
Lexington	4	4	0	0	0	0	4	0	0
Dyer	4	4	0	1	0	0	2	0	0
Cottonwood Ranch OCSW	0	0	0	0	0	0	0	0	0
Blue Hole	4	1	2	0	0	0	1	2	1
Johnson	0	0	0	0	0	0	0	0	0
Broadfoot South	10	6	6	1	1	3	3	3	1
Newark West	2	1	0	0	0	0	1	0	1
Newark East	19	13	8	3	1	0	7	6	2
Leaman OCSW	0	0	0	0	0	0	0	0	0
Trust Wild Rose - East	0	0	0	0	0	0	0	0	0
Total	43	29	16	5	2	3	18	11	5

Table 13. Totals for 2019 piping plover band resighting efforts with individual totals for each off-channel nesting site.

Piping Plover

Sites Monitored	Nests Monitored	Banded Adults	Unbanded Adults	Banded Pairs	Unbanded Pairs	Adult 1 Banded, Adult 2 Unbanded	Adult 1 Banded, Adult 2 Not Observed	Adult 1 Unbanded, Adult 2 Not Observed	Neither Adult Observed
Lexington	0	0	0	0	0	0	0	0	0
Dyer	5	1	3	0	0	0	1	3	1
Cottonwood Ranch OCSW	0	0	0	0	0	0	0	0	0
Blue Hole	4	3	0	0	0	0	3	0	1
Johnson	0	0	0	0	0	0	0	0	0
Broadfoot South	12	6	7	0	0	3	3	4	2
Newark West	1	2	0	1	0	0	0	0	0
Newark East	5	2	4	0	1	1	1	1	1
Leaman OCSW	0	0	0	0	0	0	0	0	0
Trust Wild Rose - East	0	0	0	0	0	0	0	0	0
Total	27	14	14	1	1	4	8	8	5

NEST DATA

Over the past eleven years we have collected habitat measures believed to influence nest placement and productivity. We used a GIS and LiDAR to determine elevation of each nest above the waterline and to determine distances to predator perch and nearest waterline for all nests. Based off predator camera data, we also included permanent fence lines as predator perches. It was not included as such in previous years. Electric wires are being added to the top of the fence to prevent this in the coming years. Summaries of the habitat metrics found to influence nest-site selection by least terns and piping plovers are presented in Tables 14 & 15.

Table 14. Average off-channel least tern nest elevations above water, distances to edge of water, and distances to predator perch by site during 2019. These covariates were found to influence nest site selection by least terns on off-channel sites along the central Platte River (Baasch et al. 2017).

Interior Least Terns			
Site Name	Average Elevation Above Water (in)	Average Distance to Edge of Water (yds)	Average Distance to Predator Perch (yds)
Lexington Sandpit	123	40	136
Dyer Sandpit	83	37	191
Blue Hole	79	40	194
Johnson	15	18	77
Broadfoot - Kearney South	74	17	92
Newark West	94	28	138
Newark East	60	26	152
Leaman East OCSW	74	40	134
Hooker Brothers South-East	NA	21	142

Table 15. Average off-channel piping plover nest elevations above water, distances to edge of water, and distances to predator perch by site during 2019. These covariates were found to influence nest site selection by piping plovers on off-channel sites along the central Platte River (Baasch et al. 2017).

Piping Plover			
Site Name	Average Elevation Above Water (in)	Average Distance to Edge of Water (yds)	Average Distance to Predator Perch (yds)
Lexington Sandpit	103	35	108
Dyer Sandpit	84	38	169
Cottonwood Ranch Sandpit	237	47	192
Blue Hole	66	34	159
Ed Broadfoot and Sons	63	16	150
Broadfoot - Kearney South	79	28	62
Broadfoot South - Non-Access Islands	58	7	191
Newark West	98	31	110
Newark East	45	21	161
Leaman East OCSW	70	36	125

HABITAT SELECTION STUDY

The EDO used resource selection functions and 15 years of data to assess the influence physical site attributes and inter- and intra-specific interactions have on nest site selection by least terns and piping plovers on off-channel nesting sites (Baasch et al. 2017). We found nest site selection by least terns and piping plovers was influenced by factors the Program can manage such as distance to predator perch and elevation above waterline as well as factors that cannot be managed. The relative probability of use for both species was maximized when distance to the nearest predator perch was ≥ 150 m and elevation above the waterline was ≥ 3 m. Probability of use for nesting by least terns increased as distance to water increased whereas the probability of use by piping plovers was maximized when distance to water was ~ 50 m. In addition, we found piping plovers avoided nesting near each other, whereas colonial least terns selected nest sites near those of conspecifics. Our results suggest that important features of constructed, off-channel nesting sites for both species should include no potential predator perches within 150 m of nesting habitat and nesting areas at least 3 m above the waterline. Efficient site designs for least terns would be circular, maximizing the area of nesting habitat away from the shoreline whereas an effective site design for piping plovers would be more linear, maximizing the area of nesting habitat near the waterline. 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.

OFF-CHANNEL NEST AND BROOD SURVIVAL

The Program and its partners have invested substantial resources in creating and managing off-channel nesting habitat for least terns and piping plovers along the central Platte River. Among other things, management activities implemented at nesting sites to increase nest and brood survival included tree removal, predator trapping, construction of a water barrier surrounding the nesting area and installation of predator fences. We used 15 years of data at off-channel sites along the central Platte River to assess the influence of several biotic and abiotic factors on the survival of least tern and piping plover nests and broods (Farrell et al. 2018). We found productivity of least terns and piping plovers was reduced during both the nesting and brood rearing stage by climactic factors rather than factors the Program can manage. As such, we conclude habitat management activities implemented at off-channel sites to date are sufficient for maintaining high levels of productivity for least terns and piping plovers along the central Platte River.

INSIDE VERSUS OUTSIDE MONITORING

The Program implemented four years of season-long monitoring from within (inside) and outside the nesting colonies at off-channel least tern and piping plover nesting sites along the central Platte River to compare these monitoring techniques and their influence on productivity estimates. We found inside monitoring efforts resulted in more nests and early-development chicks being detected so excluding these from nest and chick survival analyses would result in estimates of nest and chick survival rates that are higher for outside monitoring crews. However, more chicks ≥ 15 days old were observed by outside monitoring crews. While fledgling counts between methods were similar for piping plovers, more least tern fledglings were observed from outside the nesting colony which, when combined with lower breeding pair counts, would result in higher productivity measures such as fledge ratios. The most appropriate method of survey appears to depend on the objectives of the study and availability of resources. If resources are

limited, monitoring from outside the colony can result in reasonable estimates of abundance and productivity measures, provided a majority of the nesting area can be observed from outside the nesting colony and an appropriate estimate of the proportion of nests and breeding pairs that are not observed is available.

PREDATOR CAMERA STUDIES



Juvenile Bald Eagles

of the study is to investigate predator presence and possible predation events at off-channel nesting sites and the effectiveness of panel wings. Both tasks will be executed using remote cameras. Results from the study will help to identify possible actions that can be implemented to help prevent future predation. Based on the results, the most common predator present at off-channel nesting sites are juvenile bald eagles, followed by the other most common predators (Figure 19). No evidence was found of juvenile bald eagles depredate nests or chicks.

2019 was the third year that predator identification research was conducted at off-channel nesting sites. Prevention of predation by terrestrial predators is an important objective for increasing productivity of least terns and piping plovers. As such, permanent electrified fences are in place on the entrance of each off-channel nesting site. Non-electrified panel wings are positioned on the ends of the permanent fence and extend 2–3 meters into the water. However, predation is still a factor for reducing productivity at off-channel nesting sites. Predation events and predator species type are truly unknown factors because it is difficult to determine those specifics when the event was not seen firsthand. The purpose



Fox at nest on Broadfoot South

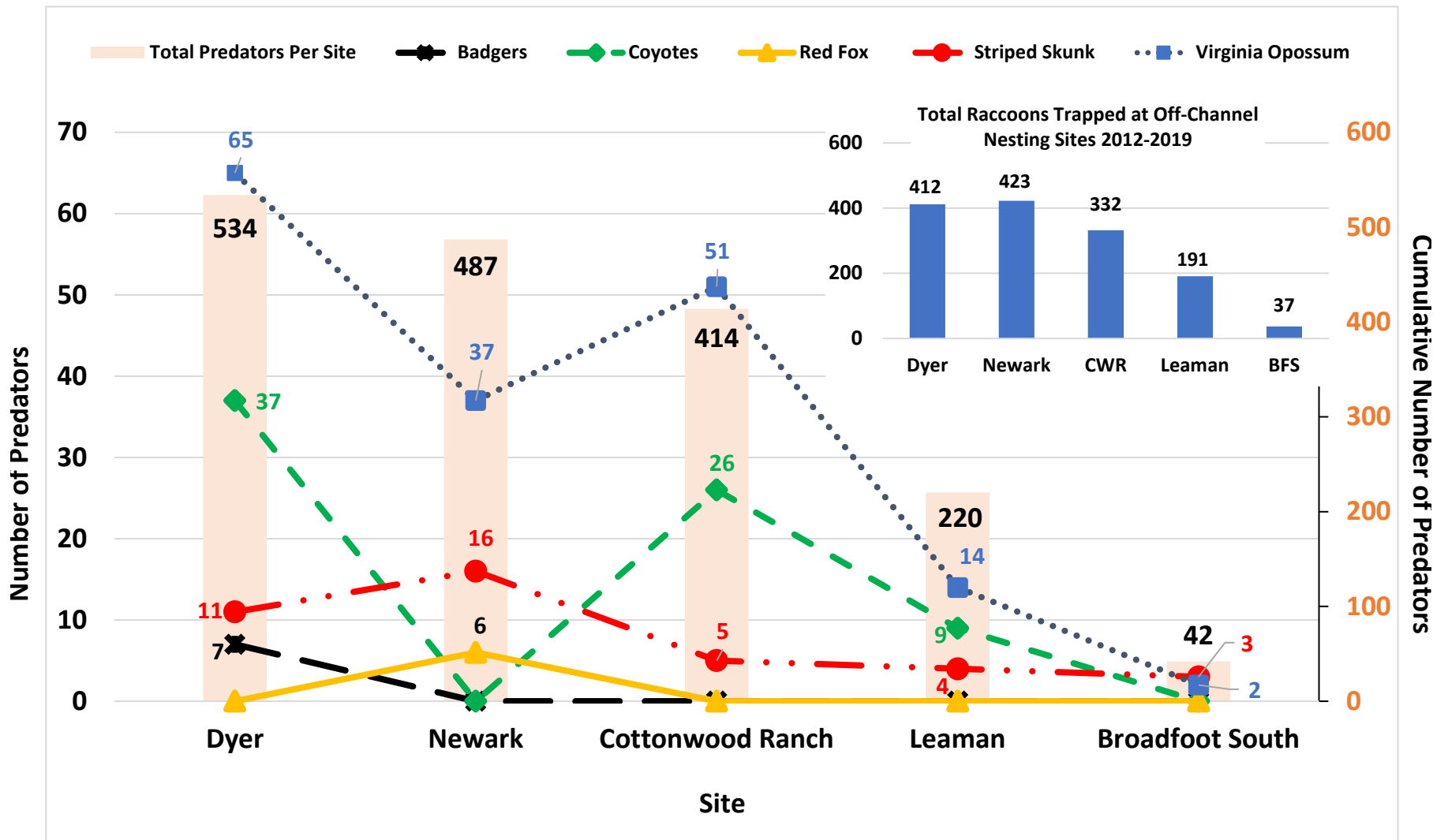


Figure 19. Total predators trapped at off-channel nesting sites from 2012-2019. The axis on the left represents totals for individual species and the axis on the right represents the cumulative number of all predators. Raccoons were present in much higher amounts, so a separate graph representing the total numbers of raccoons at each site was placed in the top right.

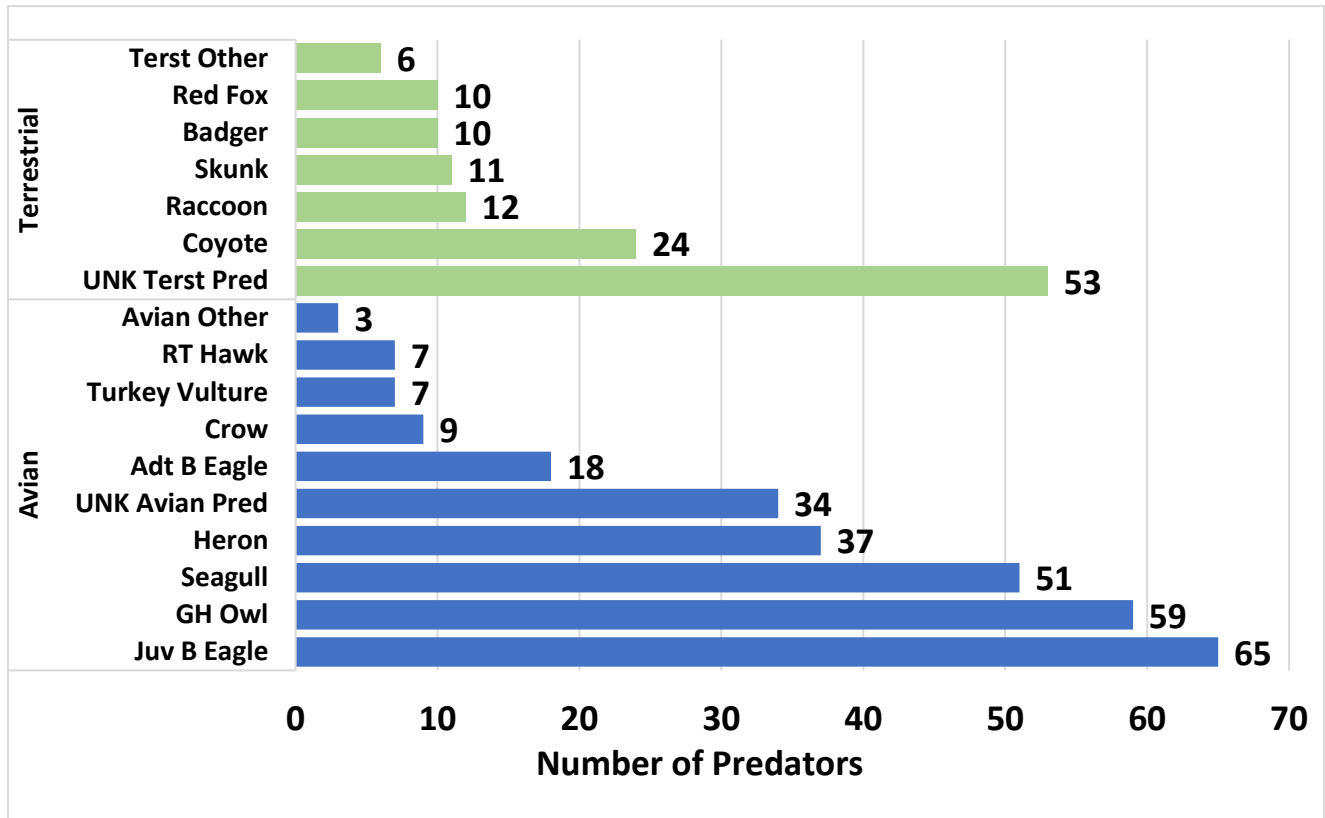


Figure 20. Avian vs. terrestrial total counts. ‘Terst Other’ are terrestrial species with a count of 3 or lower. Mink, Opossum, Otter, Snake, and Bobcat. ‘Avian Other’ are avian species with a count of 3 or lower. Barn Owl and Osprey.

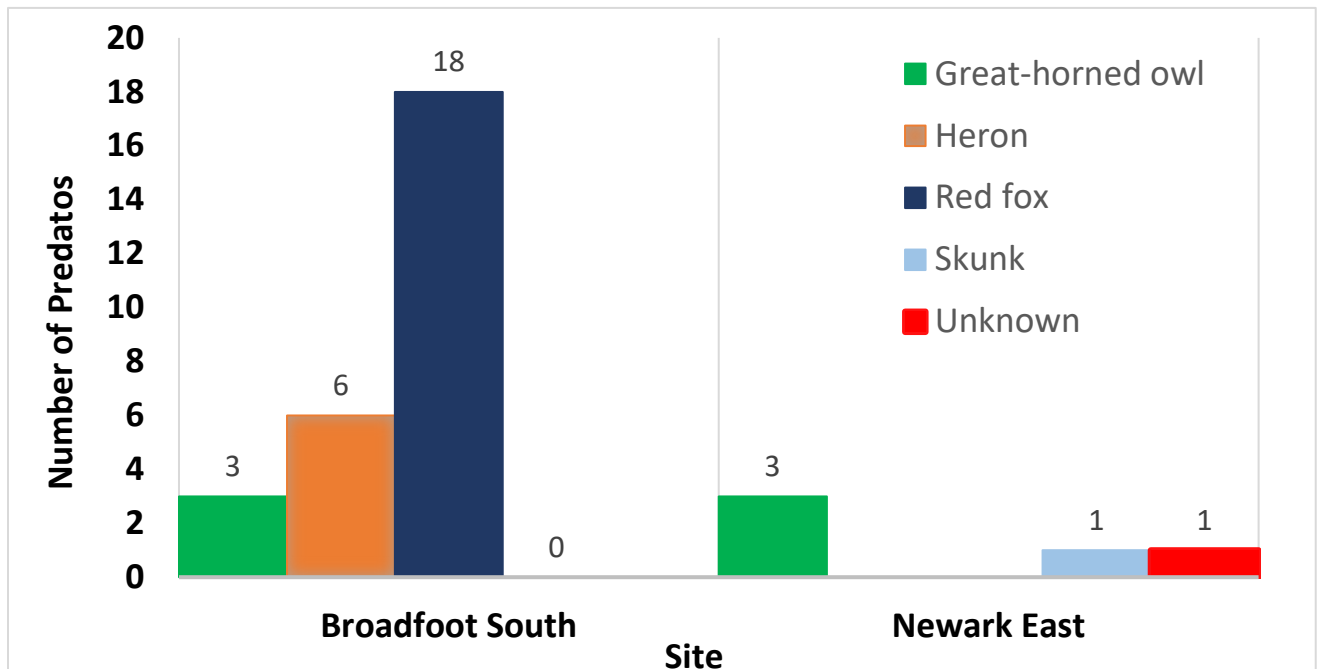


Figure 21. Predators captured on camera at least tern and piping plover nests on Broadfoot South and Newark East Sandpits

TRAPPING DATA

2019 marked the 8th year of predator trapping on Program-owned off-channel nesting sites. Though the number of Program-owned off-channel nesting sites has increased during this time, the average number of predators caught at each site increased in 2019 as compared to the previous year (Figure 22).

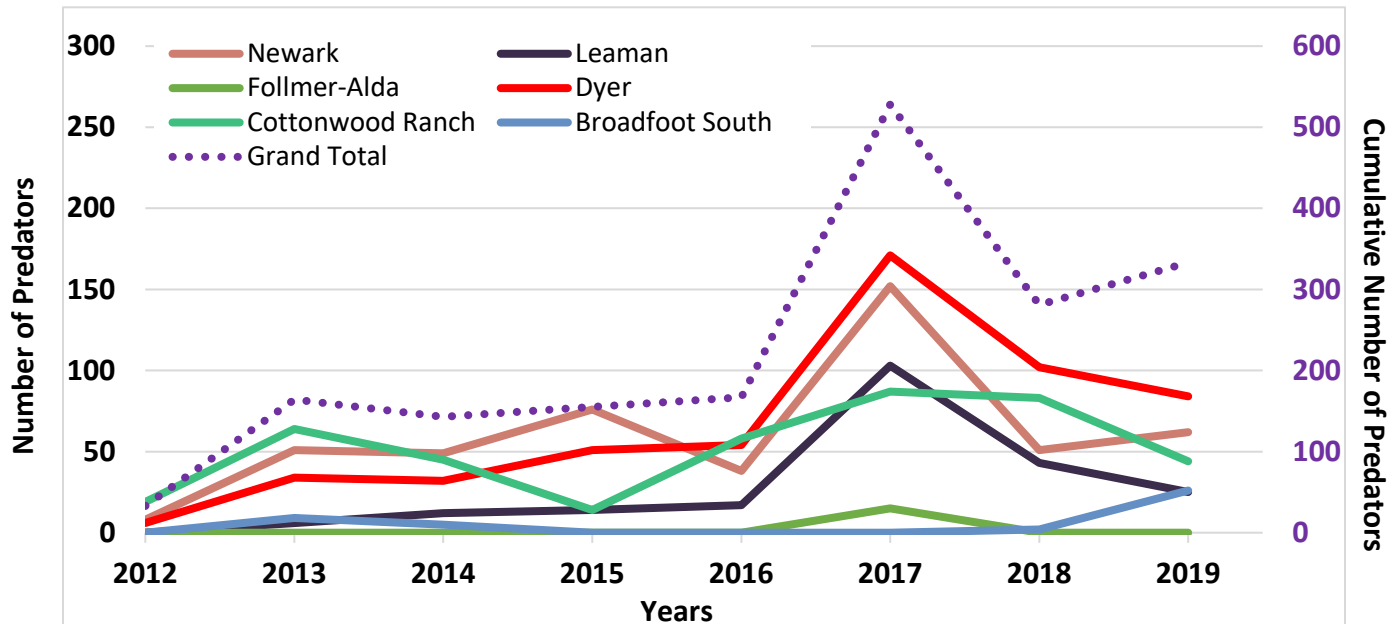


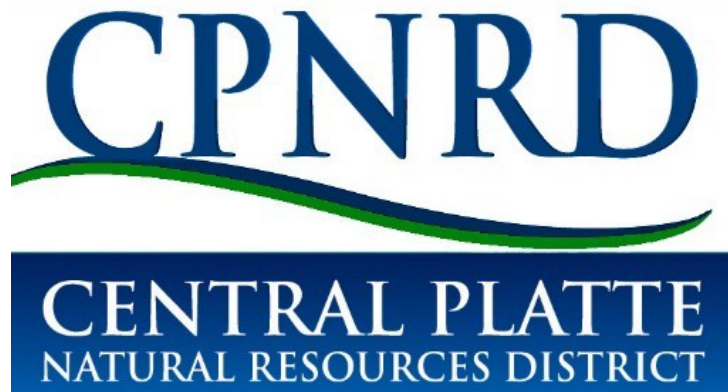
Figure 22. Numbers of predators trapped at program-owned off-channel nesting sites, 2012–2019. Predators trapped include bull snake, raccoon, weasel, opossum, skunk, fox, coyote, and bobcat. Predator trapping efforts at off-channel sites increased substantially in 2017. Trapping did not occur at Broadfoot South during 2012 or at Follmer-Alda during 2012–2014 or 2018–2019.

REFERENCES CITED

- Baasch D.M., P.D. Farrell, J.M Farnsworth, and C.S. Smith. 2017. Interior least tern and piping plover nest site selection at managed sandpit sites along the central Platte River, Nebraska, USA. *Journal of Field Ornithology* DOI: [10.1111/jof.12206](https://doi.org/10.1111/jof.12206).
- Baasch D.M., T.J. Hefley, S.D. Cahis. 2015. A comparison of breeding population estimators using nest and brood monitoring data. *Ecology and Evolution*. 4197:4209. Available at: <http://onlinelibrary.wiley.com/doi/10.1002/ece3.1680/epdf>.
- Farrell P.D., D.M. Baasch, J.M Farnsworth, and C.S. Smith. 2018. Least tern and piping plover nest success and brood survival at off channel sites in the Central Platte River. *Avian Conservation and Ecology* 13:1. <https://doi.org/10.5751/ACE-01133-130101>.
- Lutey, J.M. 2002. Species Recovery Objectives for Four Target Species in the Central and Lower Platte River (Whooping Crane, Interior Least Tern, Piping Plover, Pallid Sturgeon). United States Fish and Wildlife Service.
- Platte River Recovery Implementation Program. 2017. 2017 Central Platte River Tern and Plover Monitoring and Research Protocol. Available at: <https://www.platteriverprogram.org/PubsAndData/ProgramLibrary/PRRIP%202017%20Central%20Platte%20River%20Tern%20and%20Plover%20Monitoring%20and%20Resear%20Protocol.pdf>.

ACKNOWLEDGEMENTS

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



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.



Appendices

Program RMark Survival Estimates

Appendix 1. Daily and incubation-period survival rates for least tern nests monitored on sandpit sites during 2019. Incubation-period nest survival rate = (daily nest survival rate)²¹.

Site	# Nests	# Nests Lost	Exposure Days	Daily Brood Survival	Daily Brood Survival	Daily Brood Survival Rate 95% CI		Brooding Period Survival	Brooding Period Survival Rate 95% CI	
				Rate	SE	Lower	Upper	Rate	Lower	Upper
Lexington Sandpit	17	7	322.5	0.9782	0.0082	0.9549	0.9896	0.6288	0.3793	0.8021
Dyer Sandpit	20	2	380.0	0.9945	0.0039	0.9783	0.9986	0.8909	0.6313	0.9716
Blue Hole	9	8	90.5	0.9136	0.0294	0.836	0.9563	0.1498	0.0233	0.3917
Johnson Sandpit	1	1	2.0	0.0000	0.0014	0.0000	1.0000	0.0000	0.0000	1.0000
Broadfoot - Kearney South	25	19	381.5	0.9509	0.0110	0.9243	0.9685	0.3475	0.1914	0.5105
Newark West	16	6	297.0	0.9795	0.0083	0.9552	0.9908	0.6479	0.382	0.8233
Newark East	35	6	627.0	0.9900	0.0041	0.9779	0.9955	0.8098	0.6259	0.9097
Leaman East (Sandpit) OCSW	6	2	102.5	0.9806	0.0136	0.9256	0.9951	0.6623	0.1974	0.9027
Hooker Brothers - South East	3	0	47.0	1.0000	0.0000	1.0000	1.0000	1.0000	0.9998	1.0002
All Sites	132	51	2,250.0	0.9769	0.0032	0.9697	0.9824	0.612	0.5242	0.6887

Appendix 2. Daily and brooding-period survival rates for observed least tern broods (1 or more chicks) monitored on sandpit sites during 2019. Brooding-period brood survival rate = (daily brood survival rate)²¹.

Site	# Broods	# Broods Lost	Exposure Days	Daily Brood Survival	Daily Brood Survival	Daily Brood Survival Rate 95% CI		Brooding Period Survival	Brooding Period Survival Rate 95% CI	
				Rate	SE	Lower	Upper	Rate	Lower	Upper
Lexington	9	4	78.0	0.9436	0.0274	0.8592	0.9787	0.2956	0.0413	0.6361
Dyer	16	4	254.5	0.9830	0.0084	0.9557	0.9936	0.6983	0.3861	0.8743
Blue Hole	1	0	16.0	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Broadfoot South	3	1	41.0	0.9750	0.0247	0.8426	0.9965	0.5875	0.0274	0.9288
Newark West	8	4	103.0	0.9584	0.0204	0.8943	0.9843	0.4101	0.0958	0.7178
Newark East	27	10	381.0	0.9724	0.0086	0.9495	0.9851	0.5560	0.3370	0.7297
Hooker Brothers South	3	0	51.5	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
All Sites	67	23	925.0	0.9735	0.0055	0.9604	0.9823	0.5685	0.4279	0.6874

Appendix 3. Daily and incubation-period survival rates for piping plover nests monitored on sandpit sites during 2019. Incubation-period nest survival rate = (daily nest survival rate)²⁸.

Site	# Nests	# Nests Lost	Exposure Days	Daily Nests Survival	Daily Nests Survival	Daily Nests Survival Rate 95% CI		Incubation Period Survival	Incubation Period Survival Rate 95% CI	
				Rate	SE	Lower	Upper	Rate	Lower	Upper
Lexington Sandpit	5	0	117.0	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Dyer Sandpit	14	2	277.5	0.9923	0.0055	0.9696	0.9981	0.8045	0.4213	0.9472
Cottonwood Ranch OCSW	2	0	43.0	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Blue Hole	4	1	67.0	0.9847	0.0152	0.8994	0.9979	0.6499	0.0514	0.9416
Ed Broadfoot and Sons	1	1	24.5	0.9600	0.0393	0.7641	0.9944	0.3184	0.0000	0.8544
Broadfoot - Kearney South	18	16	314.0	0.9498	0.0123	0.9195	0.9690	0.2362	0.0955	0.4144
Non-Access Islands Broadfoot	1	1	4.0	0.7598	0.2193	0.2307	0.9709	0.0000	0.0000	0.4375
Newark West	3	0	61.0	1.0000	0.0000	1.0000	1.0000	1.0000	0.9999	1.0001
Newark East	7	2	165.0	0.9873	0.0089	0.9507	0.9968	0.6992	0.2425	0.9147
Leaman East (Sandpit) OCSW	5	4	82.5	0.9523	0.0233	0.8795	0.982	0.2543	0.0275	0.6012
All Sites	60	27	1,155.5	0.976	0.0046	0.9652	0.9835	0.5062	0.3708	0.6272

Appendix 4. Daily and brooding-period survival rates for observed piping plover broods (1 or more chicks) monitored on sandpit sites during 2019. 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
Lexington	5	0	106.5	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Dyer	12	5	229.5	0.9769	0.0102	0.9458	0.9904	0.5204	0.2100	0.7627
Cottonwood Ranch OCSW	2	2	35.0	0.9439	0.0387	0.8006	0.9860	0.1987	0.0020	0.6744
Blue Hole	2	0	39.0	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Broadfoot South	2	2	11.5	0.8379	0.1057	0.5294	0.9596	0.0071	0.0000	0.3151
Newark West	3	2	50.5	0.9599	0.0278	0.8532	0.9900	0.3180	0.0117	0.7540
Newark East	4	3	70.5	0.9568	0.0244	0.8742	0.9860	0.2901	0.0232	0.6739
Leaman East OCSW	1	1	2.0	0.5773	0.3333	0.0858	0.9521	0.0000	0.0000	0.2529
All Sites	31	15	544.5	0.9713	0.0073	0.953	0.9826	0.4427	0.2595	0.6124

Appendix 5. Daily and incubation-period survival rates for least tern nests monitored on Program and non-Program sites during 2019. Incubation-period nest survival rate = (daily nest survival rate)²¹.

Site	# Nests	# Nests Lost	Exposure Days	Daily Nest Survival	Daily Nest Survival	Daily Nest Survival Rate 95% CI		Incubation Period Survival	Brooding Period Survival Rate 95% CI	
				Rate	SE	Lower	Upper	Rate	Lower	Upper
Non-Program	30	16	462.0	0.9651	0.0086	0.9437	0.9785	0.4739	0.2963	0.6335
Program	102	35	1,788.0	0.9800	0.0034	0.9722	0.9856	0.6540	0.5538	0.7374
All Sites	132	51	2,250.0	0.9769	0.0032	0.9697	0.9824	0.6120	0.5242	0.6887

Program sites: Dyer, Broadfoot South, Newark West, Newark East, & Leaman OCSW.

Non-Program sites: Lexington, Blue Hole, Johnson, & Hooker Brothers.

Appendix 6. Daily and brooding-period survival rates for least tern broods (1 or more chicks) monitored on Program and non-Program sites during 2019. Brooding-period brood survival rate = (daily brood survival rate)²¹.

Site	# Broods	# Broods Lost	Exposure Days	Daily Brood Survival	Daily Brood Survival	Daily Brood Survival Rate 95% CI		Brooding Period Survival	Brooding Period Survival Rate 95% CI	
				Rate	SE	Lower	Upper	Rate	Lower	Upper
Non-Program	13	4	145.5	0.9697	0.0149	0.9220	0.9886	0.5240	0.1818	0.7857
Program	54	19	779.5	0.9741	0.0059	0.9598	0.9835	0.5769	0.4227	0.7044
All Sites	67	23	925.0	0.9735	0.0055	0.9604	0.9823	0.5685	0.4279	0.6874

Program sites: Dyer, Broadfoot South, Newark West, Newark East, & Leaman OCSW.

Non-Program sites: Lexington, Blue Hole, Johnson, & Hooker Brothers.

Appendix 7. Daily and incubation-period survival rates for piping plover nests monitored on Program and non-Program sites during 2019. Incubation-period nest survival rate = (daily nest survival rate)²⁸.

Site	# Nests	# Nests Lost	Exposure Days	Daily Nest Survival	Daily Nest Survival	Daily Nest Survival Rate 95% CI		Incubation Period Survival	Incubation Period Survival Rate 95% CI	
				Rate	SE	Lower	Upper	Rate	Lower	Upper
Non-Program	10	2	208.5	0.9901	0.0070	0.9614	0.9975	0.7573	0.3320	0.9331
Program	50	25	947.0	0.9729	0.0054	0.9601	0.9816	0.4629	0.3202	0.5946
All Sites	60	27	1,155.5	0.9760	0.0046	0.9652	0.9835	0.5062	0.3708	0.6272

Program sites: Dyer, Cottonwood Ranch OCSW, Broadfoot South, Broadfoot South Non-access, Newark West, Newark East, & Leaman OCSW.

Non-Program sites: Lexington, Blue Hole, & Ed Broadfoot & Sons.

Appendix 8. Daily and brooding-period survival rates for piping plover broods (1 or more chicks) monitored on Program and non-Program sites during 2019. Brooding-period brood survival rate = (daily brood survival rate)²⁸.

Site	# Broods	# Broods Lost	Exposure Days	Daily Brood Survival	Daily Brood Survival	Daily Brood Survival Rate 95% CI		Brooding Period Survival	Brooding Period Survival Rate 95% CI	
				Rate	SE	Lower	Upper	Rate	Lower	Upper
Non-Program	7	0	145.5	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Program	24	15	399.0	0.9612	0.0098	0.9366	0.9765	0.3303	0.1600	0.5138
All Sites	31	15	544.5	0.9713	0.0073	0.9530	0.9826	0.4427	0.2595	0.6124

Program sites: Dyer, Cottonwood Ranch OCSW, Broadfoot South, Newark West, Newark East, & Leaman OCSW.

Non-Program sites: Lexington & Blue Hole