Platte River Recovery Implementation Program

2016 Interior Least Tern and Piping Plover Monitoring and Research Report for the Central Platte River, Nebraska.

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Governance Committee

Prepared by:
Executive Director's Office

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PLATTE RIVER
RECOVERY IMPLEMENTATION PROGRAM

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2016 Interior Least Tern and Piping Plover Monitoring and Research Report for the Central Platte River, Nebraska

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PREFACE

This is a report of the Platte River Recovery Implementation Program's (Program) monitoring and research efforts for interior least terns (least tern) and piping plovers during 2015. 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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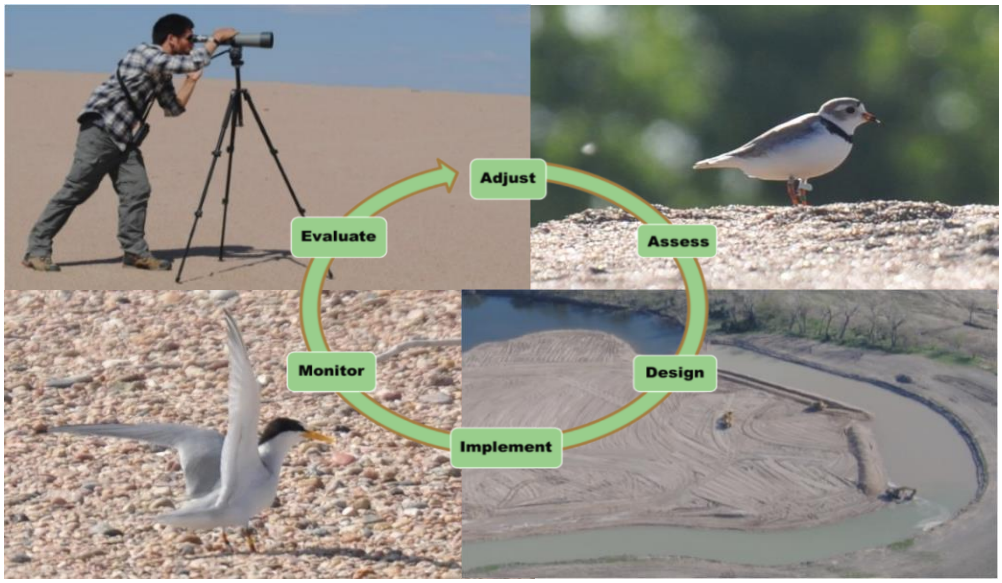

INTRODUCTION

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 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 renesting attempts by adults with failed nests. As such, banding and resighting least tern and piping plover adults and chicks has continued for seven consecutive years on the central Platte River (2009–2016). We plan to continue band resighting for two additional years. We anticipate a final report documenting results of those efforts will be available on the Program's online Public Library in 2019. Monitoring and research during 2016 was a collaborative effort between personnel of Headwaters Corporation (EDO or Program staff), Central Platte Natural Resources District (CPNRD), Nebraska Public Power District (NPPD), United States Fish and Wildlife Service (USFWS), and United States Geologic Survey-Northern Prairie Wildlife Research Center (USGS-NPWRC). Past data and analyses are reported in annual reports produced by West Incorporated (2001−2007) and Program staff (2008−2014) and are

available in the Program's online Public Library. Least tern and piping plover activity and reproductive success during 2016 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.

2016 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.

Crew member using a canoe to search for birds

April to early-May daily flows were slightly higher than normal during 2016. Flows from May to mid-July were higher than normal (Figure 2). The peak flow of the 2016 season at the Overton, Kearney, and Grand Island gages was just over 8,400 cubic feet per second (cfs). This was half the flow as compared to 2015. Much of the constructed habitat was lost due to lateral erosion during 2015. The habitat that was available experienced more erosion and vegetation which resulted in limited use in 2016.

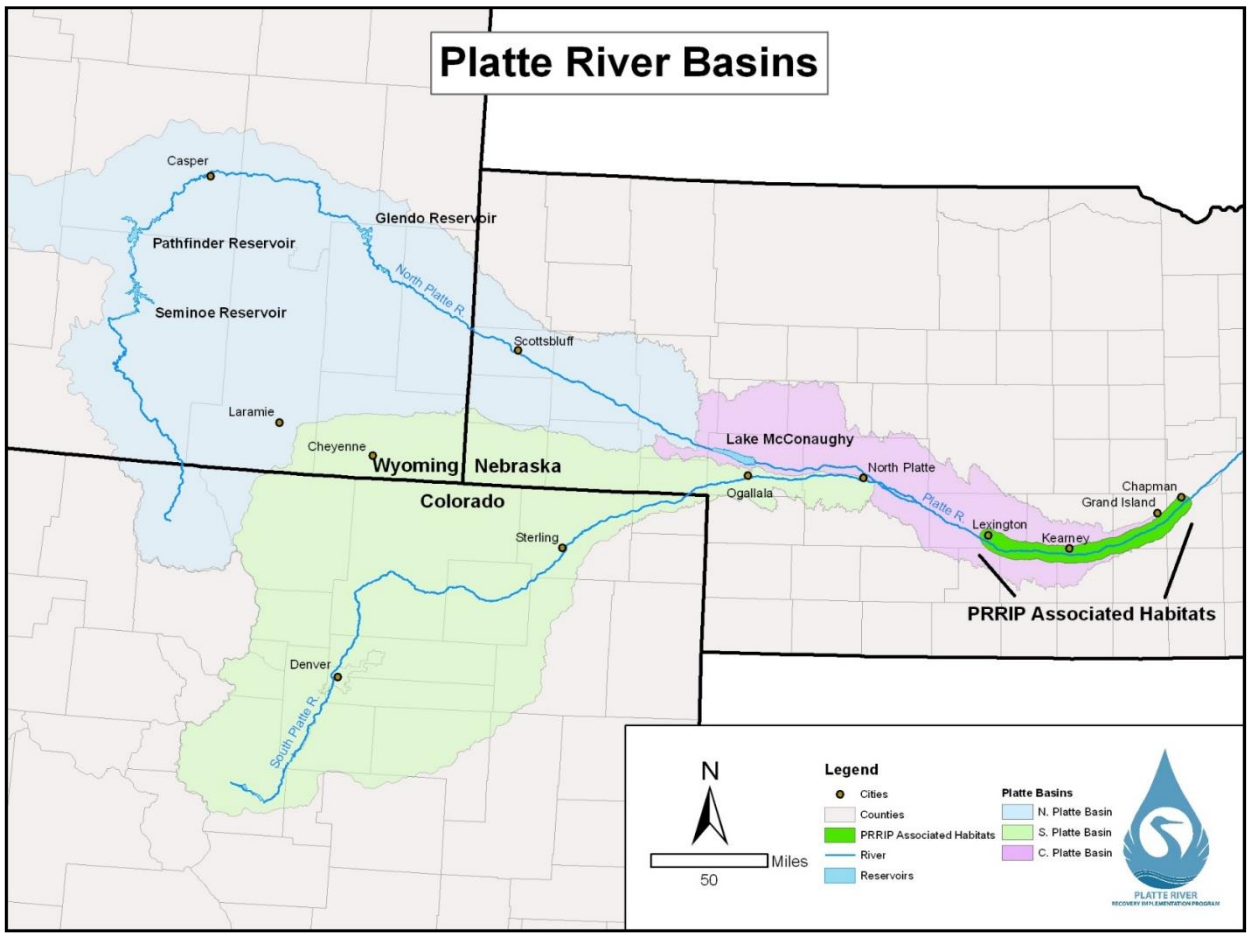

Figure 1. Platte River Basins extending from Colorado and Wyoming through Nebraska. The study area for our least tern and piping plover monitoring and research efforts was the PRRIP Associated Habitats region of the Platte River located between Lexington and Chapman, Nebraska.

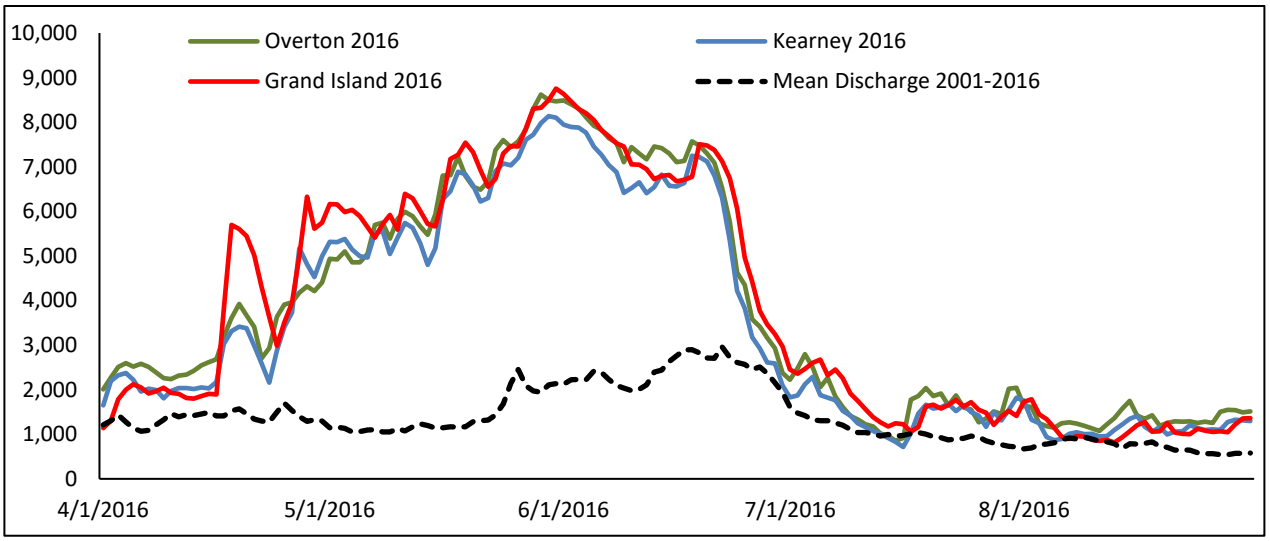

Figure 2. Mean daily discharge (ft^3/second; cfs) from Overton (USGS gage 06768000), Kearney (USGS gage 06770200), and Grand Island, Nebraska (USGS gage 06770500) for 2016. Average across 2001–2016 from Kearney (USGS gage 06770200). See Figure 3 for the location of gage stations within our study area. 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 2015 and spring 2016. 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, 2007−2016

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. All of this habitat remained available at the start of the 2015 nesting season. However, much of it was lost due to erosion during the 2015 high flow event occurring from mid-May through mid-July. There were only two on-channel habitat sites available for nesting; Cottonwood Ranch Complex and Shoemaker Island. On channel habitat construction by other conservation organizations has been very limited since 2007.

Table 1. Constructed on- and off-channel habitat in the Associated Habitat Reach by year, 2007−2016.

	On-Channel Habitat (ac)			Off-Channel Habitat (ac)		
Year	**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	61	149
Mean	**12.5**	**7.0**	**19.5**	**48.8**	**49.9**	**98.7**

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 off-channel habitat in the AHR increased to 138 acres during the period of 2009−2015 as the Program constructed and/or restored 90 acres of habitat. The Program may possibly acquire one or more additional off-channel sites prior to the end of the First Increment. One existing off-channel site (Follmer Alda) was modified to create a portion of suitable habitat and was monitored during the 2015 nesting season. Mining at this site as well as the Newark East site is still under way and more habitat will become available during the 2017 nesting season.

SANDPIT SITES:

Thirteen of the 14 off-channel sites monitored during 2016 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 2016, the woven-wire predator fence with offset electric wires along the west side of the nesting areas was maintained, and predator trapping occurred during 2016. No sand and gravel mining occurred during 2016.
- ^{PM} ***Dyer Pit*** – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2015. A pre-emergent herbicide was applied during spring 2016, a permanent 4-foot tall woven wire predator fences with offset electric wires across the south ends of each peninsula were electrified and predator trapping occurred during 2016. No sand and gravel mining occurred during 2016.
- ^{PM} ***Cottonwood Ranch OCSW*** – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2015, a pre-emergent herbicide was applied, and predator trapping occurred during 2016. A permanent 4-foot tall woven wire predator fence with offset electric wires was maintained in 2016. No sand and gravel mining occurred; this site was constructed with dozers and scrapers.
- ^{M} ***Blue Hole*** – A pre-emergent herbicide was applied during spring 2016, the existing permanent predator fence was maintained, a temporary 4-foot tall electrified predator fence was installed along the southwest edge of the peninsula and electrified, and predator trapping occurred during 2016.
- ^{M} ***Johnson Pit*** – A pre-emergent herbicide was applied during spring 2016, 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 2016. No sand and gravel mining occurred during 2016.
- ^{PM}***Broadfoot South - Kearney*** – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2015 and a pre-emergent herbicide was applied to the nesting area during spring 2016. A temporary 4-foot tall electrified predator fence was installed

across the east end of the main peninsula, and predator trapping occurred during 2016. Sand and gravel mining occurred northwest of the main peninsula during 2016.

Broadfoot South Non-access Islands

[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 2016. 6 acres were available for least tern or piping plover nesting for 2016.

[PM] ***Newark West*** – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2015. A pre-emergent herbicide was applied during spring 2016, 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 2016. No sand and gravel mining occurred during 2016.

[PM] ***Broadfoot Newark East*** – A contact herbicide was applied to kill existing vegetation primarily along the waterline during fall 2015. 2.6 acres of new nesting habitat was constructed with excavators on the northwest portion of the sandpit during fall 2015. A pre-emergent herbicide was applied during spring 2016. 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 2016.

Newark East Nesting Areas

[PM] ***Leaman East OCSW*** – A contact herbicide was applied to kill existing vegetation along the waterline during fall 2015. A pre-emergent herbicide was applied to the nesting area during spring 2016 and predator trapping occurred during 2016. A permanent, 4-foot tall woven wire predator fence with offset electric wires was maintained in 2016. No sand and gravel mining occurred; this site was constructed with dozers and scrapers.

[PM] ***Follmer-Alda Pit*** – A contact herbicide was applied to kill existing vegetation along the waterline during fall 2015. A pre-emergent herbicide was applied to the nesting area during spring 2016. A temporary 4-foot tall electrified predator fence was installed across the west

end of the main peninsula and predator trapping occurred during 2016. Sand and gravel mining occurred east of the main peninsula during 2016.

[M] ***Trust Wild Rose East*** – The nesting areas were disked during 2016. No sand and gravel mining occurred during 2016.

DeWeese-Alda – Not managed. Sand and gravel mining occurred during 2016.

Hooker Brothers - GI East – Not managed. Sand and gravel mining occurred during 2016.

Hooker Brothers - GI South East – Not managed. Sand and gravel mining occurred during 2016.

Lilley - Wood River – Not managed. Sand and gravel mining occurred during 2016.

RIVERINE SITES:

Only two on-channel riverine sites had nesting habitat available during the 2016 monitoring season. The available on-channel riverine sites 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}).

[PM] ***Cottonwood Ranch Complex Islands*** – When designed in 2013, this complex encompassed three nesting islands that were approximately 2, 4, and 4.5 acres in size and were designed as to not be overtopped by flow (i.e., higher than the elevation of the adjacent bank lines). Due to high flows in 2015 and erosion, only 2 acres were available for the 2016 nesting season. Predator trapping occurred during 2016.

[PM] ***Shoemaker Complex Islands*** – Predator trapping occurred during 2016.

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.

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 2016. We derived least tern and piping plover breeding pair estimates (BPE; Baasch et al. 2016) 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 2010−2015); 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 2010−2015); 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 2015 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, and USGS personnel, conducted semi-monthly river surveys between the J2 Return and the Chapman Bridge on 2-4 May; 12 and 17-18 May; 1-2 June; 14-15 June; 29-30 June; 14 July; and 2-3 August during 2016. 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, nests, chicks, and fledglings located within this reach of river. Due to high flows, canoes and/or kayaks were used to perform some of the river surveys (Table 2). Program staff and USGS personnel conducted semi-monthly river surveys between the J2 Return and the Chapman Bridge for all surveys.

Table 2. Boat type used and conducting personnel for semi-monthly river surveys conducted on the Central Platte River in 2016.

Survey Period	PRRIP Boat Type/ River Stretch
1-May	Airboat: J2-Overton Bridge; Canoe Overton-Chapman Bridge
15-May	Airboat: J2-Overton Bridge; Canoe: Overton-Chapman Bridge
1-Jun	Airboat: J2-Overton Bridge; Canoe: Overton-Chapman Bridge
15-Jun	Airboat: J2-Overton Bridge; Canoe: Overton-Chapman Bridge
1-Jul	Airboat: J2-Chapman Bridge
15-Jul	Airboat: J2-Alda Bridge*
1-Aug	Airboat: J2-Chapman Bridge

**Due to inclement weather on 7/15/16, Alda-Chapman Bridge stretch was not completed.*

Semi-monthly Sandpit Surveys – We conducted semi-monthly surveys from outside the nesting colony at 14 sandpit sites as well as from within the nesting area at 9 of these sites to count individual birds and document least tern and piping plover nests, chicks, and fledglings during 2016. Semi-monthly sandpit surveys were conducted outside the nesting area on 2-5 and 8 May; 12-13 and 15-17 May; 30-31 May; 13 and 15-17 June; 1-2 July, 12-14 and 19 July; and 28 July, 1 and 4 August during 2016. Semi-monthly sandpit surveys were conducted inside the nesting area on 2-4 May; 17-18 May; 31 May, 1 and 3 June; 13-17 June; 28-30 June and 1 July; 12-14 and 18 July; and 1-4 August during 2016. Program staff, technicians and personnel from Program staff, USGS, CPNRD, and NPPD conducted semi-monthly sandpit surveys during 2016.

Semi-monthly Survey Totals – To obtain an estimate of numbers of least tern and piping plover adults, nests, chicks, and fledglings within the Program Associated Habitat Area throughout the 2016 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 2016 required 1–3 days to conduct. We observed the most least tern adults (39) on the river during the 1-August river survey and the most least tern breeding pairs (2) during the 1-July river survey. The most piping plover adults (9) were observed on the river during the 1-May river surveys and the most piping plover breeding pairs (1) were observed during the 1 and 15-June and 1 and 15-July river surveys in 2016 (Table 3). We observed 1 piping plover breeding pair and nest within the Cottonwood Ranch Complex and Shoemaker Island Complex. Of the two chicks that hatched from the Shoemaker Island nest one survived to fledge. The totals for the river islands were, 2 piping plover breeding pairs and 1 piping plover nest as well as 2 least tern breeding pairs and 2 least tern nests were observed in this area. The breeding pair estimates do not match nest counts because breeding pair estimates were determined on specific dates, whereas nest counts were determined on the dates that surveys actually occurred. All other least tern and piping plover adults and fledglings observed during semi-monthly river surveys in 2016 were either known (banded) or were presumed (near areas with sandpits that fledged chicks) to be associated with nearby sandpit nesting sites.

Table 3. 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 2016.

	Interior Least Tern					Piping Plover				
Survey	**Adults**	**Pair***	**Nests**	**Chicks**	**Fledglings**	**Adults**	**Pair***	**Nests**	**Chicks**	**Fledglings**
1-May	0	0	0	0	0	9	0	0	0	0
15-May	20	0	0	0	0	6	0	1	0	0
1-Jun	16	0	0	0	0	1	1	0	0	0
15-Jun	15	1	1	0	0	3	1	1	0	0
1-Jul	28	2	2	0	0	3	1	0	2	1
15-Jul	16	0	0	0	5	1	1	0	0	1
1-Aug	39	0	0	0	39	4	0	0	0	5

** 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 inside and outside the nesting area required 4–7 days to conduct in 2016. 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. We did, however, observe 3 least tern breeding pairs and 3 least tern nests at the unmanaged Hooker Brothers South East sandpit that all hatched, but no chicks fledged. We also observed 2 piping plover breeding pair and 4 nests at the Trust sandpit that was only disked prior to the 2016 nesting season; all nests failed prior to hatching. We observed the most adult least terns during the 1-July (129) sandpit survey and the most least tern breeding pairs (82) during the 15-June sandpit survey, in which there were 67 active

nests (Table 4). We observed the most piping plover adults (62) during the 1-June sandpit survey and the most piping plover breeding pair (35) during the 1-June sandpit survey, when there were 25 active nests and 20 chicks present across all sandpit sites. The most piping plover active nests (26) occurred during the 15-June sandpit survey. A total of 14 sites were monitored during each of the semi-monthly survey periods.

Table 4. Number of least tern and piping plover adults, breeding pairs (pair), nests, chicks, and fledglings documented from inside or outside the nesting area during semi-monthly sandpit surveys in 2016.

	Interior Least Tern					Piping Plover				
Survey	**Adults**	**Pair***	**Nests**	**Chicks**	**Fledglings**	**Adults**	**Pair***	**Nests**	**Chicks**	**Fledglings**
1-May	0	0	0	0	0	33	2	10	0	0
15-May	20	0	0	0	0	46	22	23	0	0
1-Jun	65	34	26	0	0	62	35	25	20	0
15-Jun	128	82	67	0	0	61	29	26	34	0
1-Jul	129	81	23	59	0	50	14	11	24	8
15-Jul	100	69	19	38	29	40	5	4	25	9
1-Aug	22	52	3	4	8	7	0	0	11	4

** 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 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 2016 nesting season. Inside and outside sandpit surveys generally overlapped or occurred within 1–5 days of river surveys. A combined total of 16 sites. In 2016 we observed 67 active least tern nests during the 15-June survey when 143 adults and 83 breeding pairs were observed (Table 5). We observed 29 least tern fledglings during the 15-July survey. In 2016, we observed 26 active piping plover nests during the 15-June survey when 64 adults and 42 breeding pairs were observed. We also observed 9 fledglings during the 15-July survey. A total of 16 sites were surveyed for each semi-monthly survey (Table 5).

Table 5. 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 2016.

	Interior Least Terns					Piping Plovers				
Survey	**Adults**	**Pair***	**Nests**	**Chicks**	**Fledglings**	**Adults**	**Pair***	**Nests**	**Chicks**	**Fledglings**
1-May	0	0	0	0	0	42	5	10	0	0
15-May	32	0	0	0	0	52	24	23	0	0
1-Jun	81	34	26	0	0	63	36	25	20	0
15-Jun	143	83	67	0	0	64	42	26	34	0
1-Jul	157	83	23	59	0	53	35	11	24	8
15-Jul	116	69	19	38	29	41	21	4	25	9
1-Aug	61	52	3	4	8	11	11	0	11	4

** 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.*

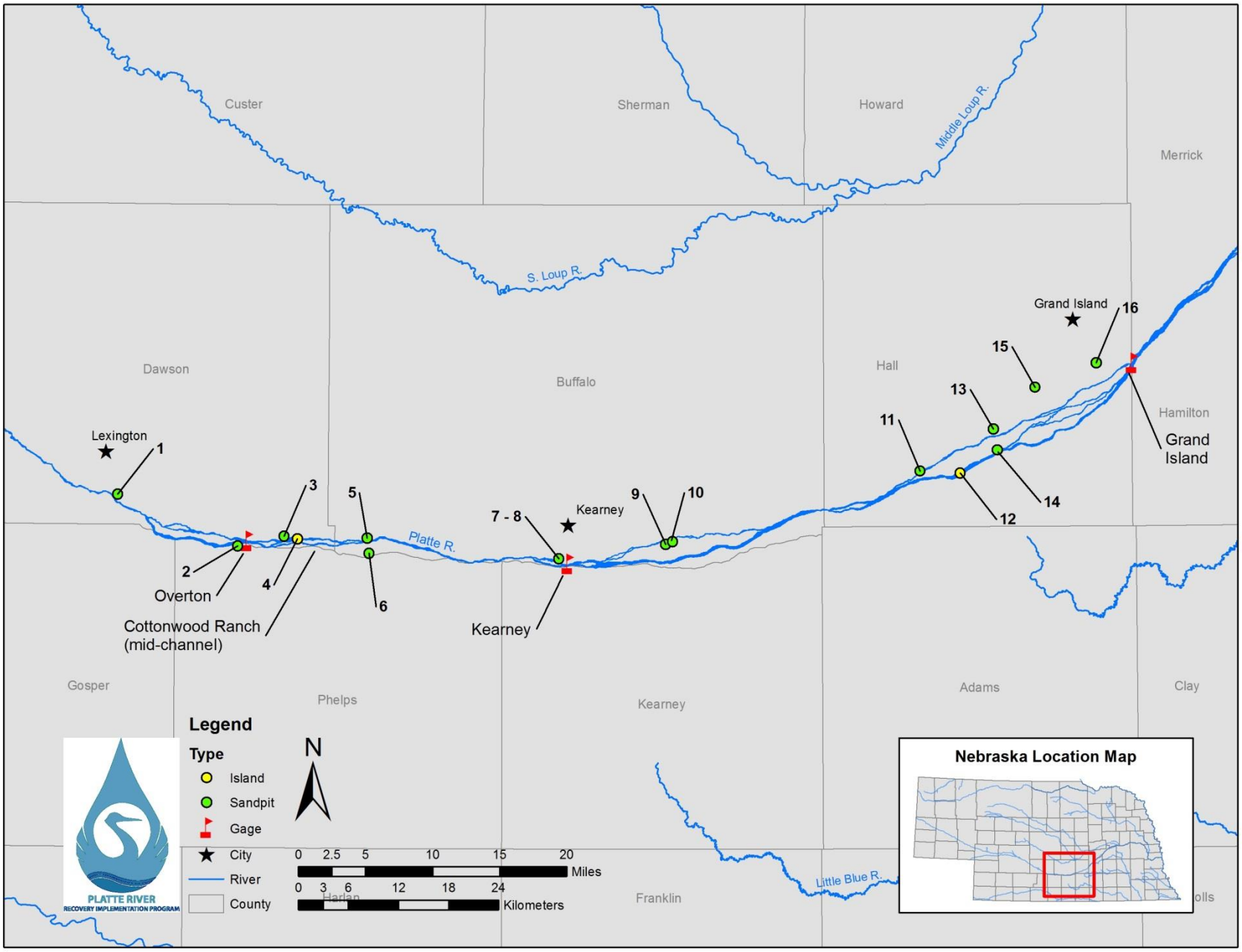

Figure 3. Study area including sandpits and constructed or managed river island sites monitored for least tern and piping plover nesting and foraging activities during 2015. Names of sites are located in Table 8.

MID-MONTH AND SEMI-MONTHLY SURVEYS

River Surveys, 2001–2016: We observed slight use of the river by least terns and piping plovers throughout the nesting season including nesting by both species (Figure 4). Counts of least tern and piping plover adults observed during river surveys in 2016 were generally similar to numbers observed prior to Program implementation (2001–2006). The trend in numbers of adult least terns and piping plovers observed during mid-month river surveys of the central Platte River has increased slightly during the 2001–2016 timeframe. It is important to note, however, that several surveys were not completed because of low or no flow conditions in the river. The increase in numbers of least tern and piping plover adults observed during the river surveys can likely be attributed to an overall increase in numbers of adults and breeding pairs observed within the Program Associated Habitat Area.

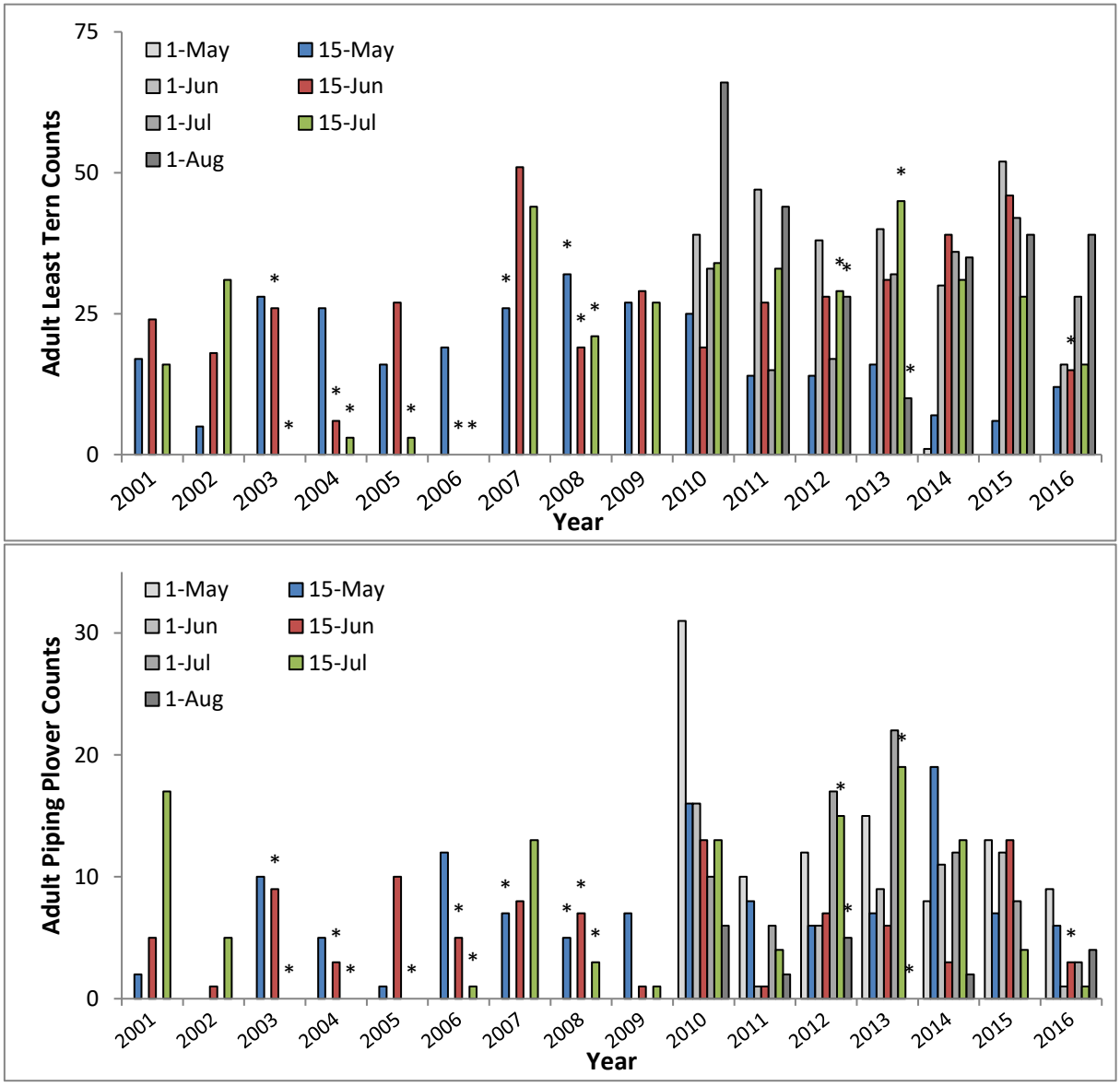

Figure 4. Numbers of least tern (top) and piping plover (bottom) adults observed during mid-month and semi-monthly surveys of the Platte River between Lexington and Chapman, Nebraska, 2001-2016. * indicates minimum numbers present as several river surveys were not completed due to a lack of flow in the channel.

Sandpit Surveys, 2001–2016: Other than in 2015 we observed as many or more piping plover adults on sandpits within the Program Associated Habitat Area in 2016 than we had in the previous nine years of Program implementation (Figure 5). Least tern counts on sandpit sites during 2016 was down from counts observed in 2015, however, they were generally higher than what had been observed prior to 2015. We observed the most adult least terns (128 and 129) during semi-monthly sandpit surveys that occurred during the 15-June and 1-July survey, respectively. We observed the most adult piping plovers (62) during the 1-June semi-monthly sandpit survey.

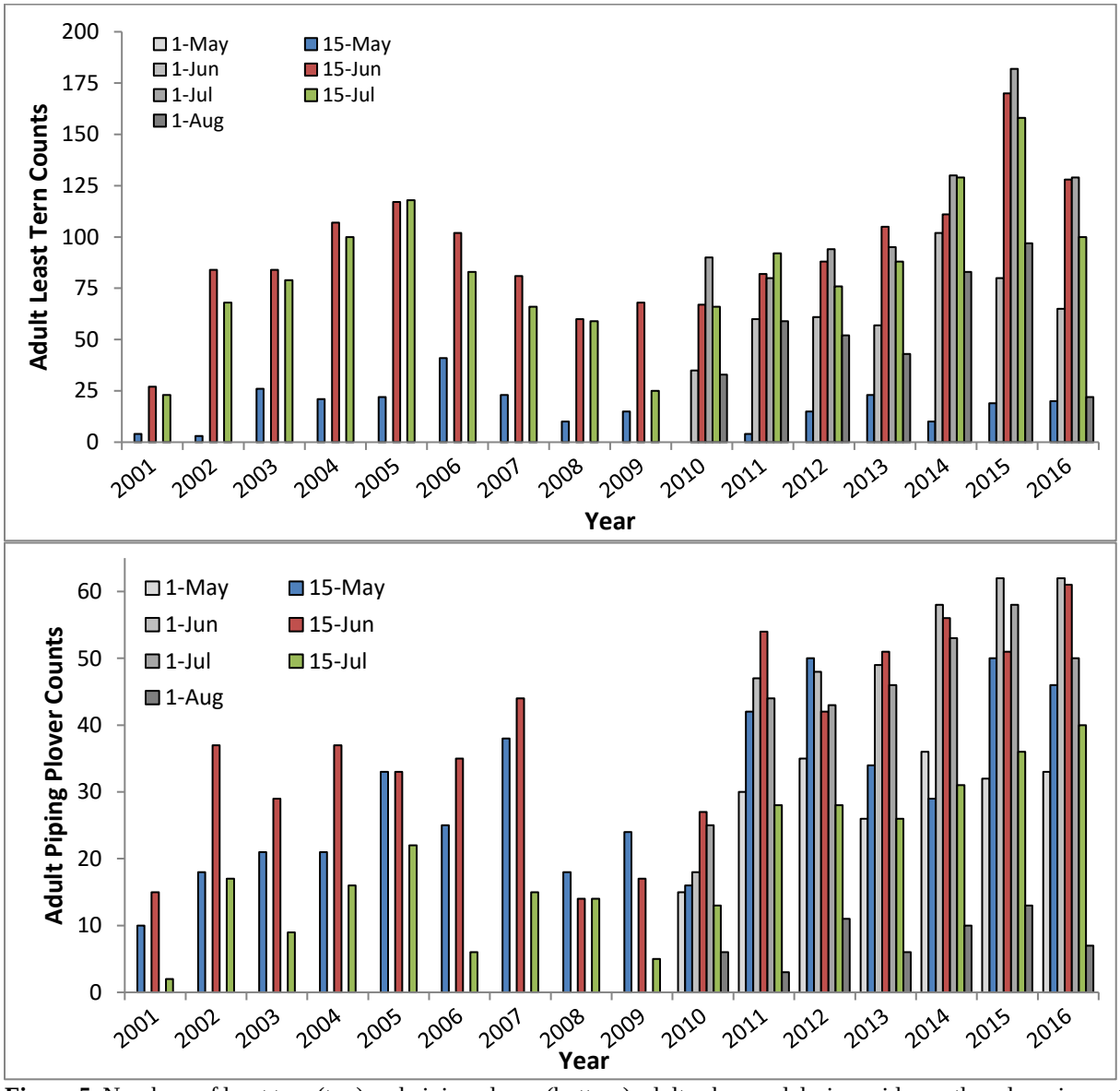

Figure 5. Numbers of least tern (top) and piping plover (bottom) adults observed during mid-month and semi-monthly surveys of sandpits along the Platte River between Lexington and Chapman, Nebraska, 2001–2016.

Sandpit-River Surveys, 2001–2016: During 2016, we observed similar numbers of piping plover adults and least tern adults within the Program Associated Habitat Area in 2016 as in the past 6 years (Figure 6). We observed the most adult least terns (157) and piping plovers (64) during semi-monthly sandpit and river surveys that occurred during early-July and mid-June, respectively. We

observed a decrease in nesting on the riverine habitat in 2016 as compared to 2015 (2 piping plover nests and 2 least tern nests). Similar to past years the river was used most intensively for foraging by both species only. One of the piping plover nests was successful and fledged a chick. A total of 117 (98%) least tern nests and 58 (96%) piping plover nests were located on off-channel sandpits.

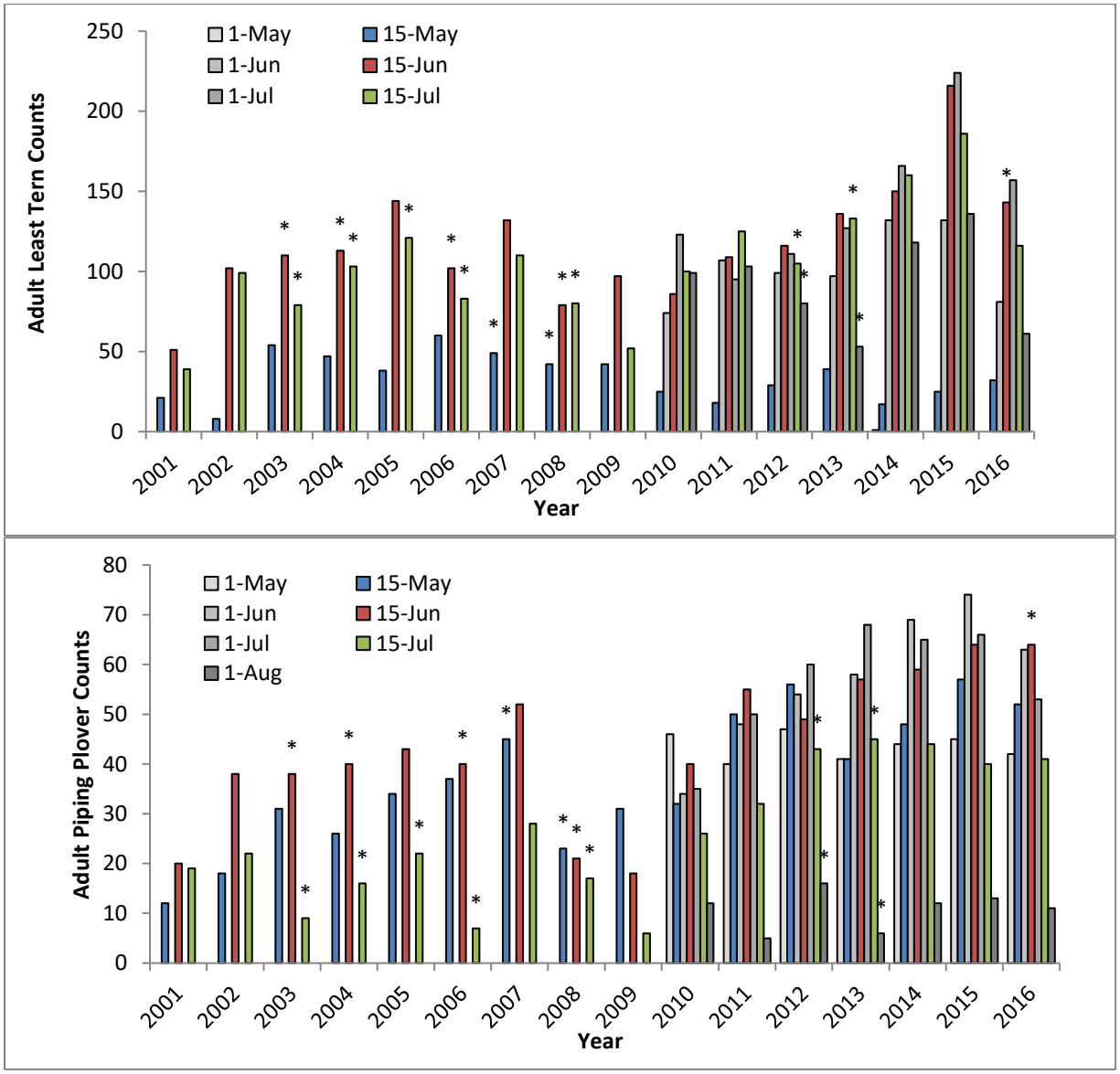

Figure 6. Numbers of adult least tern (top) and piping plover (bottom) adults observed during mid-month and semi-monthly surveys of sandpits and the central Platte River channel between Chapman and Lexington, Nebraska, 2001–2015. Counts represent minimum numbers present as several river surveys were 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 2016 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 habitat available.

Fledgling Least Tern

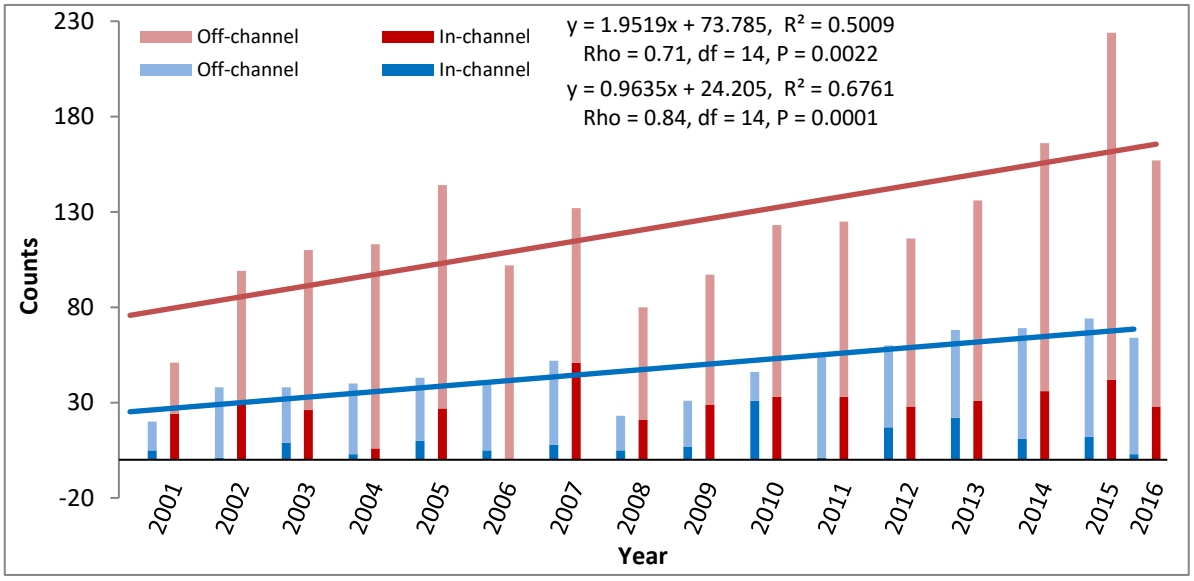

Figure 7. Trends (lines) in peak counts of least tern (red bars) and piping plover (blue bars) adults observed during mid-month and semi-monthly surveys of sandpits (light blue and light red bars) and the Platte River (dark blue and dark red bars) between Lexington and Chapman, Nebraska, 2001-2016.

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 both outside and within the nesting area, and attempted to conduct these surveys during the same day. Program staff and technicians and Program partners monitored nesting sites from outside the nesting colonies and Program staff and USGS field crews conducted nest and brood searches from within the nesting colonies during 2015. Observations of adults, nests, chicks, and fledglings collected from outside and inside the nesting area were documented on separate data sheets; final counts contained herein represent maximum numbers counted by either method of observation during each site visit.

We recorded date, temperature, 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. During the initial observation of each nest, we counted the number of eggs present, estimated nest-initiation date, took a photograph of the nest, and collected habitat measures believed to influence nest placement and productivity (vegetation height, canopy cover, and distance to vegetation ≥6 inches tall within a 1-yd^2 area centered on the nest; classified bare-sand area of nesting sites; documented presence/absence of nest furniture; determined distances to predator perch and nearest waterline; and used a GIS to determine elevation of each nest above the waterline). We recorded maximum vegetation height and percent canopy cover within a 1-yd^2 area centered on each nest and classified percent bare-sand area at the nesting site during subsequent observations of each nest. 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. We delineated exposed bare-sand areas present within CIR imagery captured 31 July–1 August, 2015 when flows at Overton, Kearney, and Grand Island ranged from 611 cfs to 1,790 cfs. Summaries of the habitat metrics for Off-Channel and On-Channel least tern and piping plover nests from 2007–2016 can be found in Tables 14-15 under the Research portion of this paper. This data can also be found in the habitat selection study that is currently underway and will be finalized in 2016.

Crew member observing birds

Outside Monitoring – Outside surveys were performed from the ground or boats 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. From outside the nesting colony, nests and chicks were often located by observing adult birds.

Inside Monitoring – A systematic grid-search pattern was used to conduct inside surveys (Figure 8). To initiate this search method, investigators formed a straight line on the edge of and parallel to the side of the sandpit pond. Investigators were evenly spaced and the spacing was adjusted to ensure all nests and chicks were detected; the distance between individuals did not exceed 10 yards unless chicks were detected at which point the spacing was widened to allow the chicks to pass between observers to prevent driving chicks out of their natal territory. When visibility was low due to vegetation or because the substrate was similar in size and shape to the eggs, then the distance between technicians was decreased.

Crew members nest searching

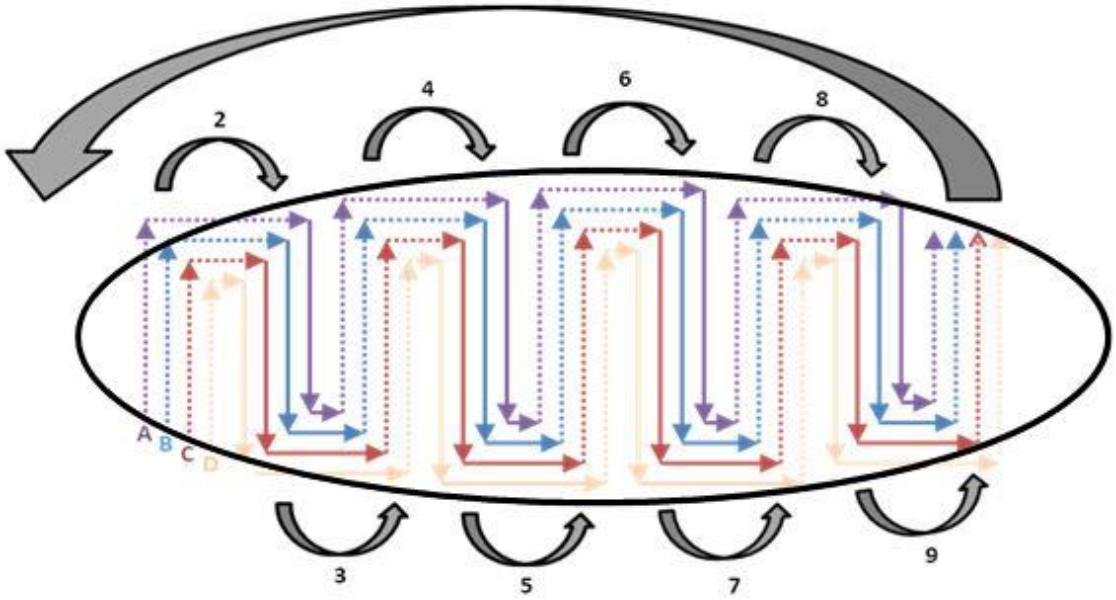

Figure 8. Systematic grid-search pattern used to locate nests and broods while conducting inside surveys of sandpit sites.

We calculated daily and incubation-period nest survival rates using Program MARK (Version 5.1). We included nests located at sandpit and riverine sites that were monitored during 2015 by Program staff, USGS field crews, 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 Program MARK 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.

We also calculated Mayfield estimates of daily and incubation-period or brooding-period survival rates for all least tern and piping plover nests and broods because, only Mayfield estimates were reported in the past (2001–2007). We calculated Mayfield estimates of daily nest survival (S) using: $S = 1 - N_f / E_S$, where N_f is the number of nests that failed and E_S is exposure days or number of days that elapsed between when the nest was first observed and when it was observed to have hatched or failed; losses occurring between visits were assumed to have occurred at the midpoint between visits. We calculated incubation-period survival rates for nests by raising the daily survival rate to the 21st or 28th power for least tern and piping plover nests, respectively. For example, if the daily survival rate for least tern nests was 0.97, the incubation-period survival rate would be approximately 0.53 (0.97^{21}). The same process was used to obtain estimates of daily and brooding-period survival rates for least tern and piping plover broods and chicks. We calculated standard errors (SE_S) and 95% confidence intervals (CI_{95}) for survival estimates using: $SE_S = ([S-S^2]/E_S)^{1/2}$ where E_S was the total number of exposure days used to calculate S and $CI_{95} = S \pm 1.96(SE_S)$. The 95% confidence intervals for the corresponding Mayfield incubation-period and brood-rearing period estimates were calculated by raising the confidence limits for S to the power of 21 or 28 for least terns and piping plovers, respectively.

RESULTS:

Mortality: We had one incident of research-related mortality during 2016. One least tern egg was accidentally stepped on during nest searching activities. This incident was reported to USFWS. Weather was attributed as the cause of 2 piping plover nest (6%) and 3 least tern nest (10%) failures during 2016. Predation was documented as the cause of loss for 6 piping plover nests (26%) and 12 least tern nests (30%) as well suspected in the loss of several additional least tern and piping plover nests and chicks during 2016. Eighteen least tern (40%) and 8 piping plover (40%) nest failures were attributed to unknown causes and the fate of 2 least tern nests were unknown as the nest bowls were empty on or near the expected hatch date, but no chicks were observed and associated with the nests. Ten least tern (22%) and 4 piping plover nests (20%) were abandoned. We found 2 dead piping plover chicks and 18 dead least tern chicks in 2016. Many of these deaths could have been attributed to weather and/or predation related events, but most of the evidence was either inconclusive or no evidence was present.

Partially buried least tern chick

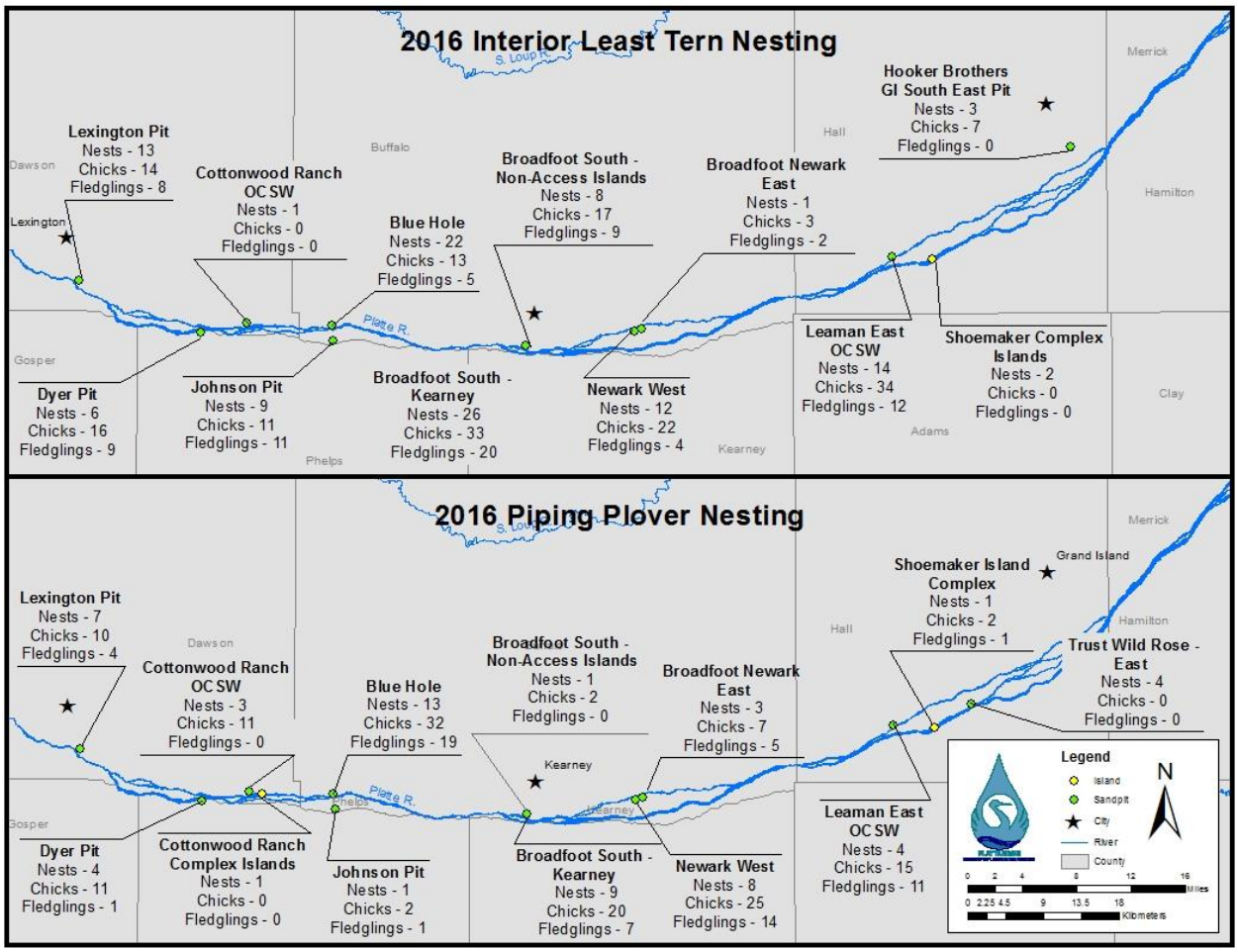

Figure 9. Distribution and numbers of least tern and piping plover nests, chicks, and fledglings observed within Program associated habitats during 2016 surveys of sandpits and managed, constructed, or naturally occurring river islands. Least tern nests were observed and monitored at 11 of the 14 sandpits and 1 of the riverine sites monitored during 2016. Piping plover nests were observed and monitored at 11 of the 14 sandpits and 2 of the riverine sites monitored during 2016.

Least Terns: Least tern nests were observed and monitored at 12 of the 14 sandpits and 1 of the 2 riverine sites monitored during 2016 (Table 8, Figure 9). All counts of adults, nests, chicks, and fledglings reported in Table 8 represent maximum numbers observed from inside or outside the nesting colony during all surveys. The first observation of a least tern nest occurred on 30 May, 2016 and the last nest was first observed on 22 July, 2016. The first observation of a least tern chick occurred on 20 June, 2016 and the last nest known to hatch did so on 3 August, 2016. At least 1 egg from 62% (74/119) of least tern nests hatched which resulted in 170 chicks and an overall nest-success rate of 1.43 chicks/nest or 1.93 chicks/breeding pair (170 chicks/88 breeding pairs) during 2016 (Table 6). Average daily survival rate of least tern nests during 2016 was 0.9840 (range = 0.4754–1.0000; Appendices 1 & 9) with at least one significant difference observed between sites [$\chi^2(7, N = 121) = 22.463$; $p = 0.002$]; average survival rate over the 21-day incubation period was 0.7128 (range = 0.0000–1.0000). We observed the first least tern fledgling on 11 July, 2016 and the last known least tern chick to fledge did so on 15 August, 2016. Apparent fledge success at all sites monitored was 0.67 fledglings/nest (80 fledglings/119 nests) or 0.91 fledglings/breeding pair (80 fledglings/88 breeding pairs) with all but 2 nests occurring on sandpit sites during 2016. Average daily survival rates for least tern broods across all sites during 2016 was 0.9765 (range = 0.9122–1.0000; Appendices 2 & 10) with no significant difference observed between sites [$\chi^2(8, N = 76) = 13.557$; $p = 0.0941$]; average brooding-period survival rate across all sites was 0.6074 (range = 0.1451–1.0000).

We tested for an effect of ownership (i.e., Program or other) on nest and brood survival rates during 2016. Least tern incubation period survival was lower at non-Program sites than at Program owned and/or managed nesting areas, 0.5888, 0.7834 respectively [$\chi^2(1, N = 119) = 4.273$; $p = 0.0387$; Appendices 5 & 13]. Brooding period survival rates were generally slightly lower at non-Program sites than at Program owned and/or managed nesting areas least terns, 0.5135, 0.6441 respectively, but the difference was not significant at $\alpha=0.05$ level (Appendices 6 & 14).

Banded least tern adult

Table 6. Summary of least tern reproductive success at sandpit and river-island sites on the central Platte River in Nebraska, 2007–2016. Site-specific details on numbers of adults, nest, chicks, and fledglings observed during 2016 are provided in Table 8. Habitat- and site-specific details of daily, incubation- and brooding-period survival rates for 2016 are provided in Appendices 1-2 and 5-6 (Program Mark estimates) and Appendices 9-10 and 13-14 (Mayfield estimates).

	Least Tern									
Reproductive Parameter	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Maximum Adults Observed	132	80	97	123	125	116	136	166	224	157
Breeding Pairs	39	37	42	53	60	64	58	98	141	88
Total Nests Observed	53	64	60	76	90	88	95	145	188	119
Successful Nests (≥1 egg hatched)	22	27	37	43	52	63	51	80	116	74
Apparent Nest Success	0.42	0.42	0.62	0.57	0.58	0.72	0.54	0.55	0.62	0.62
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
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
Chicks Observed (<15D)	50	54	71	105	124	144	118	180	258	170
Hatch Ratio (Chicks/Nest)	0.94	0.84	1.18	1.38	1.38	1.64	1.24	1.24	1.37	1.43
Hatch Ratio (Chicks/Breeding Pair)	1.28	1.46	1.69	1.98	2.07	2.25	2.03	1.84	1.83	1.93
Chicks (≥15D)	40	44	48	67	98	95	70	104	158	91
Fledglings (21D)	-----[A]	-----	----	64	89	84	64	91	146	80
Historic Fledge Ratio (15D Chicks/Nest)	0.75	0.69	0.80	0.88	1.09	1.08	0.74	0.72	0.84	0.76
Fledge ratio (21D Chicks/Nest)	-----	-----	----	0.84	0.99	0.95	0.67	0.63	0.78	0.67
Historic Fledge Ratio (15D Chicks/Breeding Pair)	1.03	1.19	1.14	1.26	1.63	1.48	1.21	1.06	1.12	1.03
Fledge Ratio (21D Chicks/Breeding Pair)	-----	-----	----	1.21	1.48	1.31	1.10	0.93	1.04	0.91
Daily Brood Survival Rate (All sites)	-----	0.98	0.98	0.98	0.99	0.99	0.97	0.98	0.98	0.98
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

[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 11 of 14 sandpits and two river sites monitored during 2016 (Table 8; Figure 9). The first observation of a piping plover nest was made on 26 April, 2016 and the last nest was first observed on 1 July, 2016. The first observation of a piping plover chick occurred on 28 May, 2016 and the last successful nest observed hatched on 19 July, 2016. At least one egg from 67% (40/60) of piping plover nests hatched, which resulted in 120 chicks and an overall nest-success rate of 2.00 chicks/nest or 2.79 chicks/breeding pair (120 chicks/43 breeding pairs) during 2016 (Table 7). Two of these nests were located on river islands in 2016. One of the island nests was located within the Shoemaker island complex and hatched 2 chicks and fledged one. The other nest was located on the Cottonwood Ranch Complex and was believed to be abandoned when found. Piping plover daily nest survival rate across all sites during 2016 was 0.9868 (range = 0.4753–1.0000; Appendices 3 & 11) with at least one difference observed between sites [$\chi^2(4, N = 60) = 24.239$; $p = 0.0001$]; average incubation-period survival rate was 0.6884 (range = 0.1434–1.0000). We first observed a piping plover fledgling on 20 June, 2016 and the last known piping plover chick to fledge did so on 11 August, 2016. We observed an apparent nest-based fledging rate of 0.92 (55 fledglings/60 nests) and a pair-based fledging rate of 1.28 (55 fledglings/43 breeding pairs) at all sites monitored during 2016 (Table 7). Average daily survival rates for piping plover broods across all sites during 2016 was 0.9790 (range = 0.8966–1.0000; Appendices 4 & 12) with at least one significant difference observed between sites [$\chi^2(7, N = 40) = 17.993$; $p = 0.0120$]; average brooding-period survival rate across all sites was 0.5526 (range = 0.0470–1.0000).

Banded adult piping plover on nest

We tested for an effect of ownership (i.e., Program or other) on nest and brood survival rates during 2016. Piping plover incubation period survival rates were lower at non-Program sites than at Program owned and/or managed nesting areas, 0.4337, 0.9010 respectively [$\chi^2(1, N = 60) = 14.891$; $p = 0.0001$; Appendices 7 & 15]. Piping plover brooding period survival rates were generally lower at Program sites than at non-Program owned and/or managed nesting areas, 0.6476, 0.5233 respectively, but the difference was not significant at $\alpha=0.05$ level (Appendices 8 & 16).

Table 7. Summary of piping plover reproductive success at sandpit and river-island sites along the central Platte River in Nebraska, 2007–2016. Site-specific details on numbers of adults, nest, chicks, and fledglings observed during 2015 are provided in Table 8. Site-specific details of daily, incubation- and brooding-period survival rates for 2015 are provided in Appendices 3-4 and 11-12 (Program Mark estimates) and Appendices 7-8 and 15-16 (Mayfield estimates).

	Piping Plover									
Reproductive Parameter	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Adults Observed	52	23	31	46	55	60	68	69	74	64
Breeding Pairs	19	13	12	20	27	30	27	30	39	43
Total Nests Observed	27	21	15	33	34	46	31	43	54	60
Successful Nests (≥1 egg hatched)	15	8	9	21	27	32	23	34	34	40
Apparent Nest Success	0.56	0.38	0.60	0.64	0.79	0.70	0.74	0.79	0.63	0.68
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
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
Chicks Observed (<15D)	44	26	27	76	87	99	80	116	119	120
Hatch Ratio (Chicks/Nest)	1.63	1.24	1.80	2.30	2.56	2.15	2.58	2.70	2.2	2.00
Hatch Ratio (Chicks/Breeding Pair)	2.32	1.24	2.25	3.80	3.22	3.30	2.96	3.87	3.05	2.79
Chicks (≥15D)	27	10	18	53	61	68	43	67	73	70
Fledglings (28D)	-----[A]	-----	-----	42	45	59	28	55	52	55
Historic Fledge Ratio (15D Chicks/Nest)	1.00	0.48	1.20	1.61	1.79	1.48	1.39	1.56	1.35	1.17
Fledge ratio (28D Chicks/Nest)	-----	-----	-----	1.27	1.32	1.28	0.90	1.28	0.96	0.92
Historic Fledge Ratio (15D Chicks/Breeding Pair)	1.42	0.77	1.50	2.65	2.26	2.27	1.59	2.23	1.87	1.63
Fledge Ratio (28D Chicks/Breeding Pair)	-----	-----	-----	2.01	1.67	1.97	1.04	1.83	1.33	1.28
Daily Brood Survival Rate (All sites)	-----	0.94	0.98	0.99	0.99	0.99	0.98	0.99	0.99	0.98
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

[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 8. Site-specific numbers of adults, nests, chicks, and fledglings observed while monitoring sandpits and constructed or managed river islands for least tern and piping plover reproduction during 2016. 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.

					Least tern								Piping plover							
Site #/Name	Habitat Type [A]	Management [A]	Surveys	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.	Fledglings
1 Lexington Pit	SP	FTP	78	109	7	10	15	13	7	14	8	8	2	7	10	7	4	10	4	4
2 Dyer Pit	SP	HFTP	75	78	7	8	14	6	6	16	10	9	4	4	11	4	5	11	1	1
3 Cottonwood Ranch OCSW	OC	HFTP	46	40	0	1	4	1	0	0	0	0	1	3	6	3	3	11	0	0
4 Cottonwood Ranch Complex Islands	RI	HTP	9	4	0	0	2	0	0	0	0	0	0	1	6	1	0	0	0	0
5 Blue Hole [C]	SP	FTP	87	153	6	11	18	22	7	13	5	5	8	8	21	13	5	32	23	19
6 Johnson Pit	SP	PFT	49	46	6	9	20	9	6	11	11	11	1	1	4	1	1	2	2	1
7 Broadfoot South - Kearney	SP	HFTP	82	126	23	23	37	26	17	33	20	20	6	7	13	9	6	20	9	7
8 Broadfoot South - Non-Access Islands	SP	FM	60	8	7	8	20	8	8	17	10	9	1	1	2	1	1	2	2	0
9 Newark West	SP	HFTP	78	90	10	10	21	12	10	22	7	4	6	6	10	8	7	25	19	14
10 Broadfoot Newark East [D]	SP	HFTPM	58	31	1	1	7	1	1	3	2	2	3	3	6	3	3	7	7	5
11 Leaman East OCSW	OC	HFTP	71	84	12	13	24	14	12	34	17	12	4	4	8	4	4	15	12	11
12 Shoemaker Island Complex	RI	TP	10	7	2	2	8	2	0	0	0	0	1	1	3	1	1	2	1	1
13 Follmer-Alda Pit	SP	HFTPM	7	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14 Trust Wild Rose East	OC	GHP	22	21	0	0	10	0	0	0	0	0	0	2	5	4	0	0	0	0
15 Deweese – Alda Pit	SP	N	7	4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
16 Hooker Brothers – GI South East Pit	SP	NM	15	7	2	3	0	3	3	7	0	0	0	0	2	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 2015 nesting season and prior to the 2016 nesting season could include: mowed (M), burned (B), disked (D), graded (G), tree/vegetation removal (R), or contact herbicide (H) during fall 2015; pre-emergent herbicide (P), predator fencing (F), predator trapping (T), or Nest Furniture Distribution (S) during spring 2016; active sand/gravel mining within primary nesting peninsula (M), 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 determined on 7 July for least terns and 25 June 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, regardless of Breeding Pair peak dates. Adults (Max) represent the maximum number adults observed during any single survey at the site.

[C] Includes 1 Least Tern nest was outside the managed nesting areas and thus not surrounded by electrified fence and water. The nest was determined to be failed.

[D] Includes 1 Piping Plover nest that was outside the managed nesting areas and thus not surrounded by electrified fence and water. The nest was determined successful and fledged two chicks.

SURVEY METHODOLOGY STUDY

Outside monitoring

Inside-Outside Monitoring – Monitoring efforts were made by inside and outside crews to determine least tern and piping plover counts at eight sandpits in 2016. Similarly, Johnson Sandpit was not monitored independently by the inside crew, but was primarily visited for banding operations. Data collected on these banding visits was supplemented into the outside monitoring data collection. Quantities listed for Broadfoot Kearney South only include the main peninsula that was monitored by both the inside and outside monitoring crews. The non-access islands were monitored solely by the outside monitoring crew and are included in the quantities listed in Table 8. Similar to past observations, outside monitoring generally resulted in fewer young chick and nest observations. However, the outside observers were able to observe a greater quantity of fledglings during 2016.

Banded piping plover chick observed from inside the colony

Inside and outside counts of nests, chicks, and fledglings were obtained at sandpit sites and river island sites from 2011–2016. Outside monitoring at Program-owned sites was insufficient during 2011–2012, therefore comparisons for those years are not available. To compare the counts produced by these two methods, we present the counts for each year by site (Table 9). Our results show annual totals of inside counts of nests, and chicks were always greater than annual totals of outside counts. The annual total of outside counts of fledglings for 2016 were greater than annual totals of inside counts.

Table 9. Cumulative number of nests, chicks, and fledglings counted from outside (Outside Counts) and within (Inside Counts) sites monitored at 10 sites in 2013−2016.

Year	Site	Inside	Outside	Inside	Outside	Inside	Outside
2013	Cottonwood Ranch OCSW	10	10	6	4	0	0
2013	Dyer	17	17	35	20	8	5
2013	Lexington Pit	6	5	12	4	0	0
2013	Blue Hole	25	22	43	31	27	20
2013	Johnson	NA	NA	NA	NA	NA	NA
2013	Newark-West	3	3	10	9	4	4
2013	Broadfoot South-Kearney	37	26	41	23	11	15
2013	Leaman OCSW	7	6	9	11	4	4
2013	**Totals**	**105**	**89**	**156**	**102**	**54**	**48**
2014	Cottonwood Ranch OCSW	15	14	35	26	8	9
2014	Dyer	6	6	12	9	1	0
2014	Lexington Pit	5	5	12	8	1	0
2014	Blue Hole	50	32	65	50	23	34
2014	Johnson	7	7	4	2	0	1
2014	Newark-West	18	18	26	18	10	10
2014	Broadfoot South-Kearney	21	16	33	16	10	2
2014	Leaman OCSW	41	30	46	35	21	17
2014	**Totals**	**166**	**131**	**241**	**167**	**80**	**73**
2015	Cottonwood Ranch	9	9	19	11	7	6
2015	Dyer	10	10	25	23	6	6
2015	Lexington Pit	7	7	17	15	6	8
2015	Blue Hole	40	33	71	54	35	45
2015	Johnson*	8	8	14	13	2	6
2015	Newark-West	33	31	59	38	15	31
2015	Broadfoot South-Kearney*	26	23	30	17	16	6
2015	Leaman OCSW	48	43	70	58	31	33
2015	**Totals**	**181**	**164**	**305**	**229**	**118**	**141**
2016	Cottonwood Ranch OCSW	4	3	11	1	0	0
2016	Dyer	13	13	26	25	4	9
2016	Lexington Pit	19	17	23	17	7	12
2016	Blue Hole	32	27	29	19	9	16
2016	Johnson*	9	10	11	13	7	12
2016	Newark-West	20	17	47	39	17	17
2016	Broadfoot South-Kearney*	34	28	53	38	25	24
2016	Leaman OCSW	18	18	48	47	18	11
2016	**Totals**	**149**	**133**	**248**	**199**	**87**	**101**

[1] Cottonwood Ranch OCSW were monitored jointly by the inside and outside crews due to high river flows which limited the access to this site.

[2] Johnson Sandpit was not monitored as frequently or intensively by the inside crew as other sites were; data collected during these visits was used to supplement outside monitoring data collection.

[3] Broadfoot South-Kearney is a comparison of only the main peninsula and does not include data observed by the outside monitoring crew taken from the non-access islands.

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 day of the nesting season (Baasch et al. 2015). Least tern breeding pair counts peaked at 88 pairs on 29 June, 2016. Piping plover breeding pair counts peaked at 43 pairs 14 June, 2016; these dates were earlier than what we observed in 2015. Similar to nest and adult counts, least tern breeding pair counts have increased steadily since 2001 (Figure 10). Piping plover breeding pair counts increased slightly from 2001−2007, declined during 2008 and 2009, and have since increased (Figure 11). We did observe a decrease in least tern breeding pairs in 2016; however these counts are still above the years prior to the Program implementation. Though nesting has occurred on riverine sandbars, with an increase during 2015, off-channel sandpits have provided the most consistent nesting habitat for both species to date.

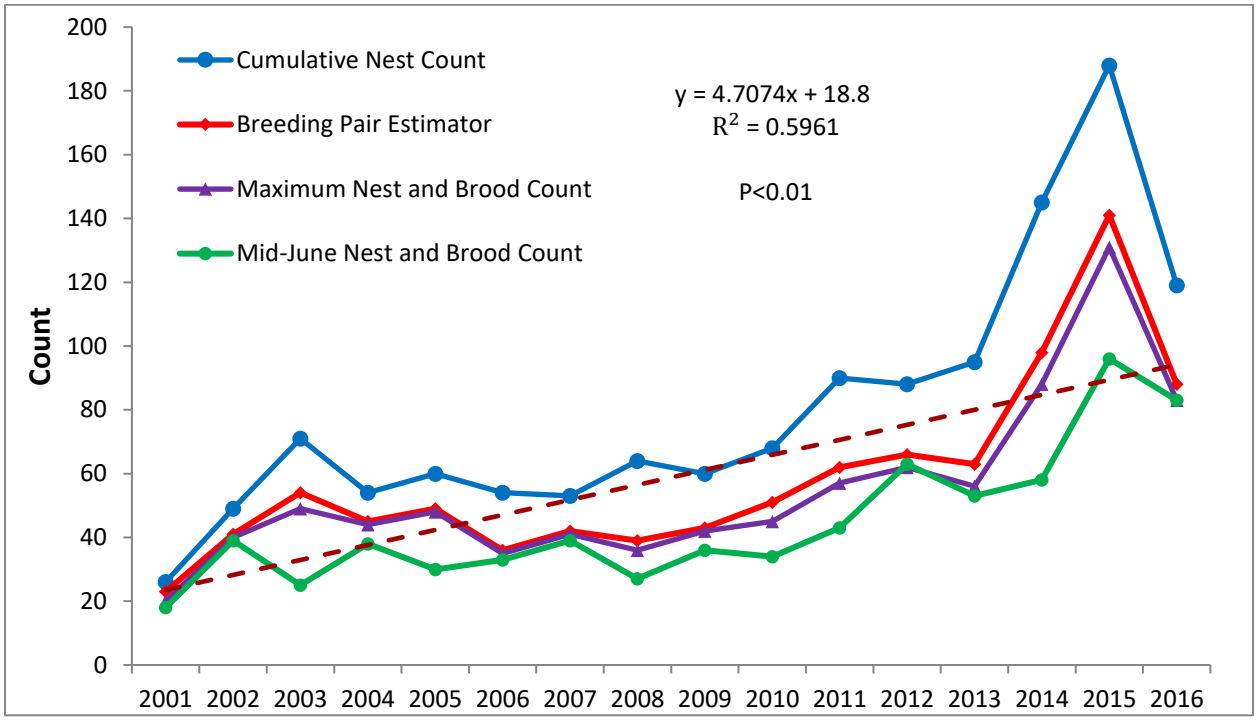

Figure 10. Comparison of numbers of least tern cumulative nests, Program defined breeding pairs, maximum nest and brood quantities, and the mid-June nest and brood quantities observed within the Program Associated Habitat Area, 2001-2016.

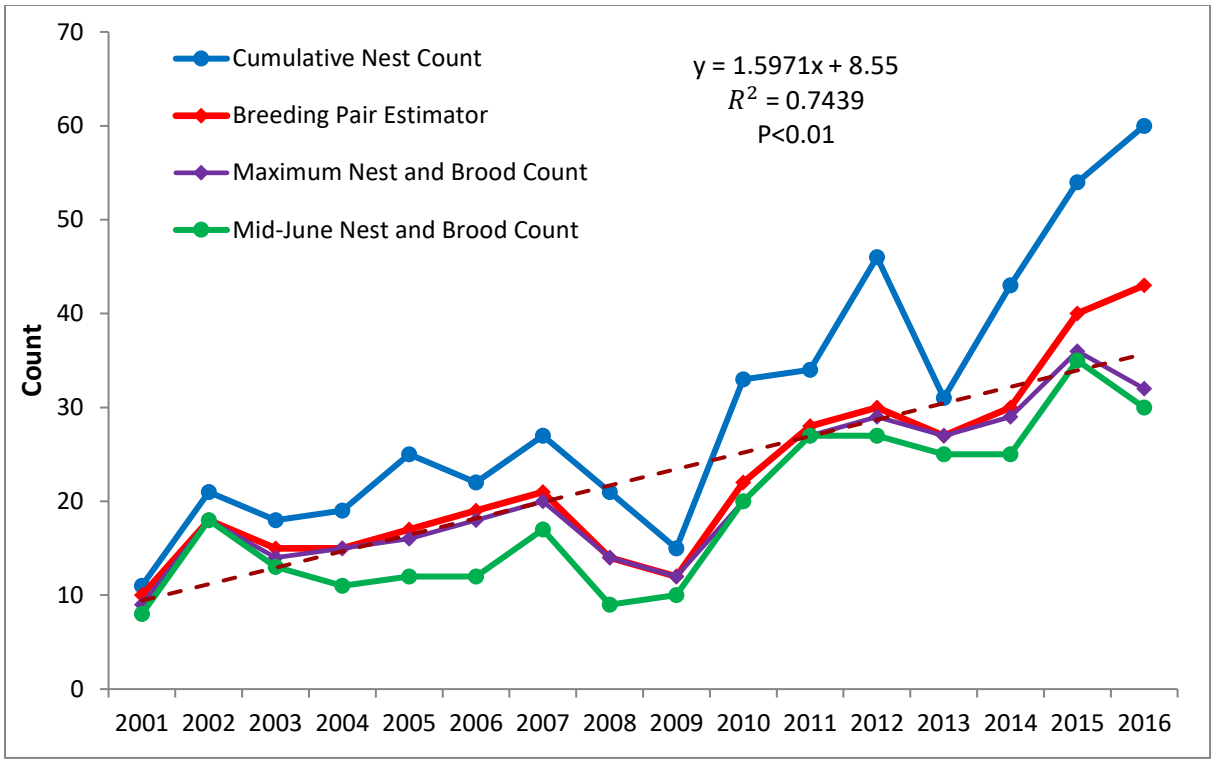

Figure 11. Comparison of numbers of piping plover cumulative nests, Program defined breeding pairs, maximum nest and brood quantities, and the mid-June nest and brood quantities observed within the Program Associated Habitat Area, 2001−2016.

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 10). In 2016, a total of 88 breeding pairs of terns and 43 breeding pairs of plovers were observed in the AHR. Most of the nesting in the AHR during the First Increment of the Program has occurred on managed off-channel habitats (Tables 10 and 11). The limited amount of on-channel nesting observed at the beginning of the First Increment declined as on-channel habitat was lost during high flow events (Tables 1 and 3). The species did respond to subsequent Program habitat construction efforts in 2014 (Table 11) during the 2015 season. Despite an increase in on-channel nesting, productivity remained low as many of the nests located on islands were lost due to habitat erosion during high flow occurrences that happened throughout the season. In 2016 we observed this decrease of in-channel use with only 2 piping plover nests and 2 least tern nests. 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 12). Overall, the Program has observed a species response to off-channel habitat construction, while the species response to on-channel habitat construction is still undetermined.

Sun breaking through on an active mine site

Table 10. Least tern and piping plover nesting incidence by year, 2007−2016.

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
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
Mean	**69.3**	**98.2**	**54.0**	**74.8**	**1.1**	**26.6**	**36.4**	**23.5**	**39.1**	**1.4**

Table 11. Least tern and piping plover on-channel nesting incidence and productivity by year, 2007−2016.

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
2008	10	20	7	9	0.9	3	5	1	3	1
2009	3	8	5	4	1.33	2	2	1	1	0.5
2010	0	0	0	0	0	4	11	4	10	2.5
2011	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	1	1	1	4	4
2013	0	0	0	0	0	0	0	0	0	0
2014	0	2	0	0	0	1	2	1	4	4
2015	8	14	3	0	0	5	7	1	1	0.2
2016	2	2	0	0	0	2	2	1	1	0.5
Mean	**3.4**	**5.9**	**1.7**	**1.5**	**0.2**	**1.9**	**3.4**	**1.2**	**3.1**	**2.0**

*Breeding pairs within the table represent numbers of breeding pairs present on river islands the day breeding pairs within the system were maximized; therefore, nests and fledglings per breeding pair are occasionally disproportionately large. See Table 8 for maximum in-channel breeding pairs by site.

Table 12. Least tern and piping plover off-channel nesting incidence and productivity by year, 2007−2016.

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
Mean	**65.9**	**92.3**	**52.3**	**73.3**	**1.10**	**24.8**	**33.0**	**22.3**	**36.0**	**1.40**

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

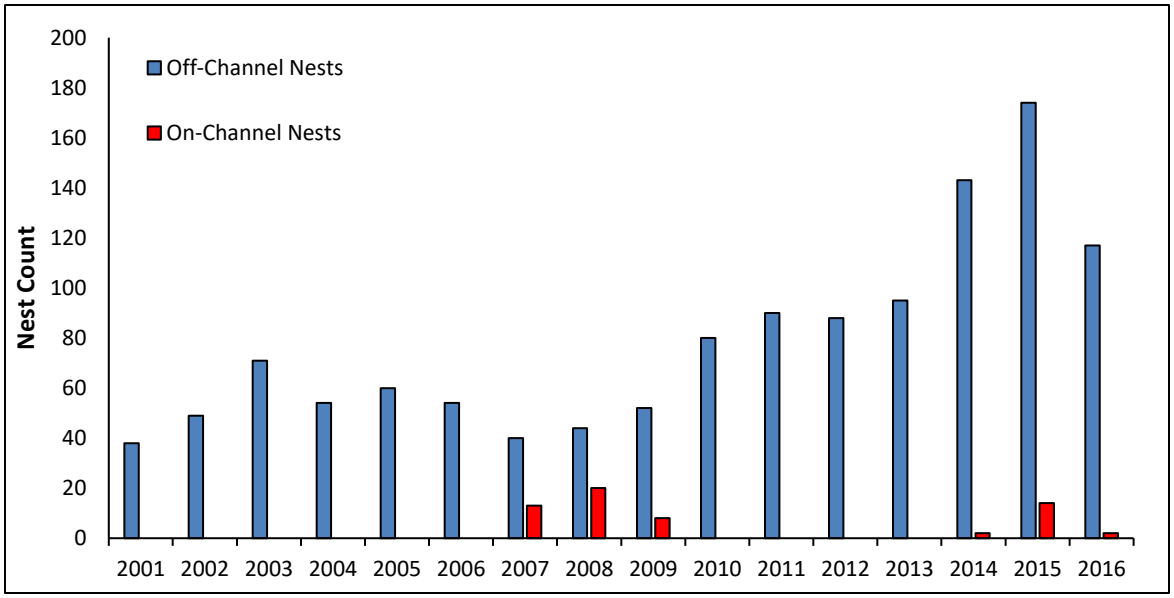

Figure 12. Comparison of least tern off-channel (blue bars) on-channel (red bars) nests within the Program Associated Habitat Area, 2001-2016.

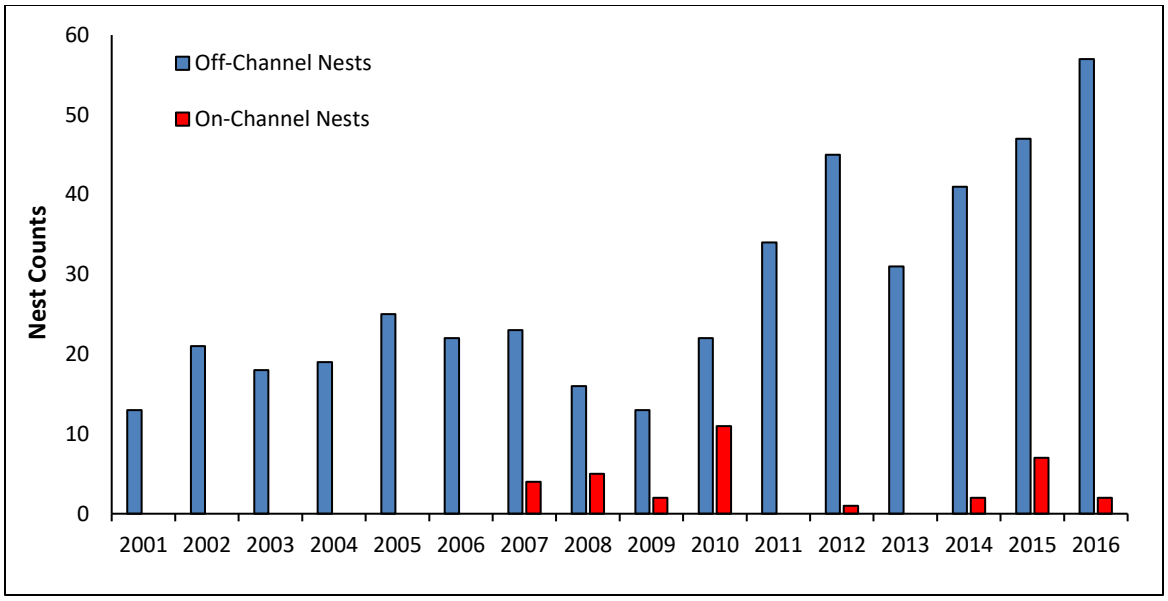

Figure 13. Comparison of piping plover off-channel (blue bars) and the on-channel (red bars) nests within the Program Associated Habitat Area, 2001-2016.

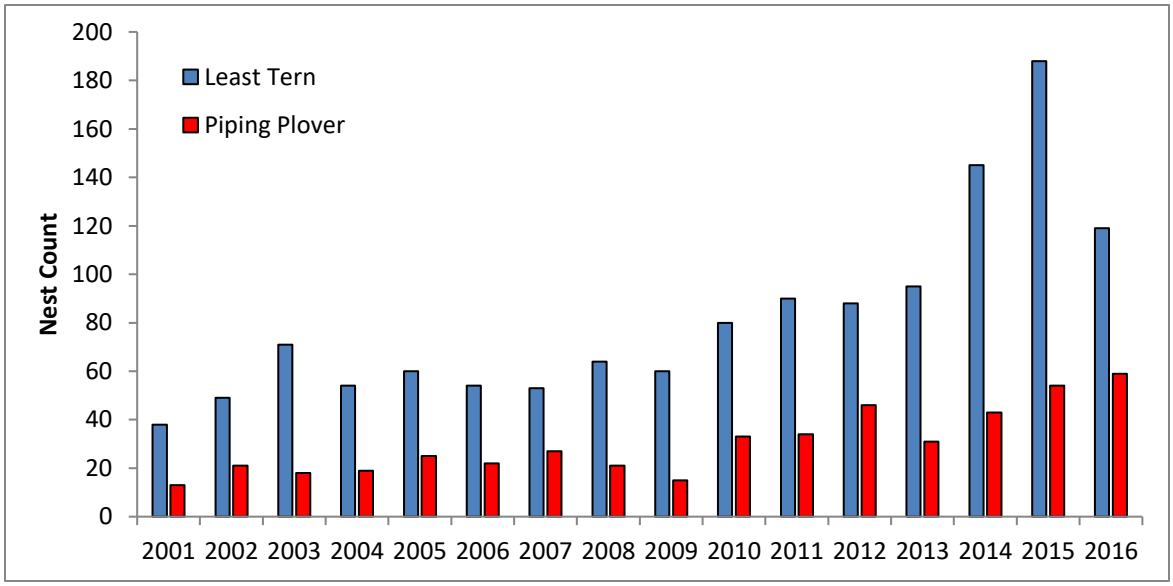

Figure 14. Comparison of total piping plover (red bars) and least tern (blue bars) nests within the Program Associated Habitat Area, 2001-2016.

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. Over the next several years, activities will include research on least tern and piping plover habitat colonization, dispersal rates, re-nesting events, and comparisons of use and reproductive success on riverine versus off-channel sand and water habitat. Design and implementation of this research will be guided by the ED Office, the TAC, and Program partners and will be reviewed by the Program's Independent Scientific Advisory Committee (ISAC).

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 will address three specific objectives that will contribute to the understanding of habitat use by least terns and piping plovers in the CPRV:

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 is 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 that will include banding and resighting data from continued efforts performed during 2009–2018.

Piping plover that nested at Broadfoot-South sandpit that was originally banded in North Dakota

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 have been banded along the central Platte River to date (Table 13).

Table 13. Summary of numbers of interior 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 eight years of banding 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); however, all banded piping plover chicks observed to date that returned to nest have nested at non-natal sites. On multiple occasions we observed least tern and piping plover fledglings at non-natal sites late in the nesting season, which may be an indication that fledglings begin selecting nesting habitat for the subsequent year prior to departing for the winter grounds. A detailed summary of what has been observed and learned from banding efforts will be available in 2019.

NEST DATA

Over the past ten 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, and we documented the presence of nest furniture at each nest location. Summaries of the habitat metrics for on- and off-channel least tern and piping plover nests from 2016 are presented in Tables 14 & 15.

Table 14. Average of on-channel and off-channel least tern nest elevations above water in inches, distances to edge of water (yards), distances to predator perch (yards), and number of least tern nests with nest furniture present by site during 2016.

Interior Least Terns

Site Name	Year	On or Off Chan.	Avg. Elev. Above Water	Avg. Dist. To Edge of Water	Avg. Dist. To Pred. Perch	Nests With Nest Furn. Present
Lexington Sandpit	2016	Off	108	35	153	8
Dyer Sandpit	2016	Off	75	35	204	5
Cottonwood Ranch Sandpit	2016	Off	158	30	318	1
Blue Hole	2016	On	59	28	193	8
Johnson Sandpit	2016	Off	74	27	247	6
Broadfoot - Kearney South	2016	Off	96	27	275	8
Broadfoot South - Non-Access Islands	2016	Off	NA	14	417	NA
Newark West	2016	Off	75	22	228	6
Broadfoot Newark East	2016	Off	113	30	342	0
Leaman East OCSW	2016	Off	61	39	239	1
Shoemaker Island	2016	Off	33	11	316	0
Hooker Brothers – GI South East	2016	Off	NA	173	292	1

Table 15. Average of On-Channel and Off-Channel piping plover elevations above water in inches, distances to edge of water, distances to predator perch in yards, and number of least tern nests with nest furniture present by site during 2016.

Piping Plover

Site Name	Year	On or Off Chan.	Avg. Elev. Above Water	Avg. Dist. To Edge of Water	Avg. Dist. To Pred. Perch	Nests With Nest Furn. Present
Lexington Pit	2016	Off	6	53	159	3
Dyer Sandpit	2016	Off	74	45	252	1
Cottonwood Ranch OCSW	2016	Off	213	45	229	0
Blue Hole	2016	Off	41	27	198	7
Johnson	2016	Off	49	28	243	1
Broadfoot - Kearney South	2016	Off	92	30	326	3
Broadfoot South - Non-Access Islands	2016	Off	NA	12	416	NA
Newark West	2016	Off	78	28	190	2
Broadfoot - Newark East	2016	Off	54	12	503	0
Leaman East OCSW	2016	Off	63	46	233	0
Shoemaker Island Complex	2016	On	34	15	279	0
Trust Wildrose - East	2016	Off	53	31	165	1
Cottonwood Ranch PRRIP Island	2016	On	49	0	179	0

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 interior least terns and piping plovers on off-channel nesting sites (PRRIP unpublished report). We found nest site selection by interior 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. We found inter- and intra-specific interactions influenced nest site selection by both species. Being nongregarious, piping plovers avoid nesting in close proximity to each other whereas interior least terns, being colonial, select nest sites in close proximity to each other. We also found probability of interior least tern and piping plover use was maximized when distance to nearest forest was ≥150 m, distance to water was ≥30 m, and elevation above waterline was ≥3 m. As such, habitat management activities implemented at off-channel sites should include the removal of potential predator perches ≤150–200 m from off-channel nesting areas and design plans should attempt to provide maximal amounts of elevated nesting habitat distant to water.

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ACKNOWLEDGEMENTS

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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, DeWeese Sand and Gravel Inc., and Hooker Brothers Sand and Gravel.

Appendices

Program Mark Survival Estimates

Appendix 1. Daily and incubation-period survival rates for least tern nests monitored on sandpits and 1 river island site during 2016. 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 Nest Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Blue Hole	23	15	302	0.9550	0.0127	0.9225	0.9743	0.3804	0.2024	0.5975
Johnson	9	3	158	0.9801	0.0114	0.9400	0.9936	0.6551	0.3216	0.8839
Lexington	13	6	213	1.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000
Dyer	8	2	159	0.9923	0.0077	0.9475	0.9989	0.8503	0.4046	0.9794
Broadfoot South	26	9	488	0.9856	0.0058	0.9683	0.9935	0.7376	0.5263	0.8767
Broadfoot South Non-access	9	1	151	0.9930	0.0069	0.9522	0.9990	0.8634	0.4345	0.9811
Newark West	12	2	232	0.9910	0.0064	0.9646	0.9977	0.8262	0.5091	0.9561
Newark East	1	0	22	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Leaman OCSW	14	2	258	0.9918	0.0057	0.9680	0.9980	0.8418	0.5407	0.9601
Cottonwood Ranch OCSW	1	1	1	0.4754	0.0000	0.4754	0.4754	0.0000	0.0000	0.0000
Hooker Brothers SE	3	0	65	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Shoemaker Island	2	2	35	0.9391	0.0425	0.7824	0.9851	0.2673	0.0279	0.8224
All Sites	121	43	2,084	0.9840	0.0029	0.9771	0.9889	0.7128	0.6177	0.7922

Appendix 2. Daily and brooding-period survival rates for least tern broods (1 or more chicks) monitored on sandpits during 2016. Brooding-period brood survival rate = (daily brood survival rate)^{21}.

Site	# Broods	# Broods Lost	Exposure Days	Daily Brood Survival Rate	Daily Brood Survival SE	Daily Brood Survival Rate 95% CI		Brooding Period Survival Rate	Brooding Period Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Blue Hole	7	5	70	0.9369	0.0305	0.8437	0.9761	0.2547	0.0535	0.6739
Johnson	6	1	116	0.9909	0.0090	0.9386	0.9987	0.8262	0.3556	0.9762
Lexington	7	3	109	0.9708	0.0166	0.9133	0.9906	0.5369	0.2021	0.8415
Dyer	6	1	116	0.9909	0.0091	0.9383	0.9987	0.8254	0.3542	0.9761
Broadfoot South	17	5	277	0.9886	0.0066	0.9652	0.9963	0.7855	0.5061	0.9290
Broadfoot South Non-access	7	3	110	0.9713	0.0164	0.9147	0.9907	0.5422	0.2067	0.8433
Newark West	10	8	117	0.9453	0.0218	0.8834	0.9752	0.3068	0.1014	0.6344
Newark East	1	0	18	1.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000
Leaman OCSW	12	4	227	0.9815	0.0092	0.9518	0.9930	0.6758	0.3893	0.8721
Hooker BSE	3	3	15	0.9122	0.0843	0.5689	0.9879	0.1451	0.0020	0.9357
All Sites	76	33	1,175	0.9765	0.0045	0.9658	0.9840	0.6074	0.4870	0.7160

Appendix 3. Daily and incubation-period survival rates for piping plover nests monitored on sandpits and 2 river island sites during 2016. Incubation-period nest survival rate = (daily nest survival rate)[28].

Site	# Nests	# Nests Lost	Exposure Days	Daily Nest Survival Rate	Daily Nest Survival SE	Daily Nest Survival Rate 95% CI		Incubation Period Survival Rate	Incubation Period Nest Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Blue Hole	13	8	237	0.9649	0.0122	0.9314	0.9823	0.3675	0.1625	0.6352
Johnson	1	0	29	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Lexington	7	3	181	0.9829	0.0098	0.9483	0.9945	0.6170	0.2789	0.8703
Dyer	5	0	142	1.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000
Broadfoot South	9	3	207	0.9898	0.0072	0.9602	0.9975	0.7509	0.3797	0.9369
Broadfoot South Non-access	1	0	1	0.4753	0.0000	0.4753	0.4753	0.0000	0.0000	0.0000
Newark West	8	1	201	0.9948	0.0052	0.9643	0.9993	0.8649	0.4382	0.9813
Newark East	3	0	77	1.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000
Leaman OCSW	4	0	114	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Cottonwood Ranch OCSW	3	0	78	1.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000
Cottonwood Ranch Islands	1	1	1	0.4753	0.0000	0.4753	0.4753	0.0000	0.0000	0.0000
Trust Wild Rose East	4	4	48	0.9330	0.0375	0.8114	0.9783	0.1434	0.0126	0.6869
Shoemaker Island	1	0	22	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
All Sites	60	20	1,338	0.9868	0.0032	0.9788	0.9917	0.6884	0.5555	0.7961

Appendix 4. Daily and brooding-period survival rates for piping plover broods (one or more chicks) monitored on sandpits and 1 river island site during 2016. 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
Blue Hole	5	1	119	0.9913	0.0087	0.9406	0.9988	0.7822	0.2824	0.9704
Johnson	1	0	28	1.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000
Lexington	4	2	57	0.9625	0.0261	0.8616	0.9906	0.3425	0.0514	0.8336
Dyer	5	4	42	0.8966	0.0492	0.7540	0.9608	0.0470	0.0021	0.5375
Broadfoot South	6	3	108	0.9709	0.0166	0.9135	0.9906	0.4370	0.1281	0.8039
Broadfoot South Non-access	1	1	26	0.9608	0.0385	0.7682	0.9945	0.3261	0.0182	0.9265
Newark West	7	2	176	0.9882	0.0083	0.9542	0.9971	0.7179	0.3330	0.9284
Newark East	3	0	78	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Leaman OCSW	4	1	103	0.9899	0.0101	0.9318	0.9986	0.7526	0.2424	0.9666
Cottonwood Ranch OCSW	3	3	41	0.9309	0.0476	0.7594	0.9829	0.1346	0.0060	0.7996
Shoemaker Island	1	0	29	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
All Sites	40	17	807	0.9790	0.0052	0.9661	0.9871	0.5526	0.3921	0.7029

Appendix 5. Daily and incubation-period survival rates for least tern nests monitored on Program and non-Program sites during 2016. 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 Brood Survival Rate 95% CI		Incubation Period Survival Rate	Brooding Period Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Non-Program	47	24	738	0.9751	0.0064	0.9591	0.9849	0.5888	0.4273	0.7332
Program	72	19	1,345	0.9884	0.0031	0.9806	0.9931	0.7834	0.6671	0.8671
All Sites	119	43	2,083	0.9840	0.0029	0.9771	0.9889	0.7128	0.6177	0.7922

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

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

Appendix 6. Daily and brooding-period survival rates for least tern broods (1 or more chicks) monitored on Program and non-Program sites during 2016. Brooding-period brood survival rate = (daily brood survival rate)[21].

Site	# Broods	# Broods Lost	Exposure Days	Daily Brood Survival Rate	Daily Brood Survival SE	Daily Brood Survival Rate 95% CI		Brooding Period Survival Rate	Brooding Period Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Non-Program	23	12	310	0.9688	0.0103	0.9410	0.9837	0.5135	0.3012	0.7211
Program	53	21	865	0.9793	0.0050	0.9669	0.9871	0.6441	0.5013	0.7651
All Sites	76	33	1,175	0.9765	0.0045	0.9658	0.9840	0.6074	0.4870	0.7160

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

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

Appendix 7. Daily and incubation-period survival rates for piping plover nests monitored on Program and non-Program sites during 2016. 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 Brood Survival Rate 95% CI		Incubation Period Survival Rate	Brooding Period Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Non-Program	25	15	495	0.9706	0.0077	0.9510	0.9825	0.4337	0.2612	0.6239
Program	35	5	843	0.9963	0.0021	0.9885	0.9988	0.9010	0.7343	0.9677
All Sites	60	20	1,338	0.9868	0.0032	0.9788	0.9917	0.6884	0.5555	0.7961

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

Non-Program sites: Lexington, Blue Hole, Johnson, & Trust Wild Rose East

Appendix 8. Daily and brooding-period survival rates for piping plover broods (1 or more chicks) monitored on Program and non-Program sites during 2016. Brooding-period brood 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
Non-Program	10	5	200	0.9846	0.0088	0.9534	0.9950	0.6476	0.3128	0.8813
Program	30	13	599	0.9771	0.0063	0.9610	0.9867	0.5233	0.3440	0.6968
All Sites	40	18	799	0.9790	0.0052	0.9661	0.9871	0.5526	0.3921	0.7029

Program sites: Dyer, Broadfoot South, Broadfoot South Non-access, Newark West, Newark East, Leaman OCSW & Shoemaker Island

Non-Program sites: Lexington, Blue Hole, & Johnson

Mayfield Survival Estimates

Appendix 9. Daily and incubation-period survival rates for least tern nests monitored on sandpits and 1 river island site during 2016. 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 Nest Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Blue Hole	23	15	302	0.9503	0.0125	0.9258	0.9748	0.3431	0.1573	0.5288
Johnson	9	3	158	0.9810	0.0109	0.9597	1.0023	0.6686	0.3640	0.9732
Lexington	13	6	213	0.9718	0.0113	0.9496	0.9941	0.5488	0.2853	0.8123
Dyer	8	2	159	0.9874	0.0088	0.9701	1.0047	0.7666	0.4842	1.0490
Broadfoot South	26	9	488	0.9816	0.0061	0.9696	0.9935	0.6764	0.5037	0.8492
Broadfoot South Non-access	9	1	151	0.9934	0.0066	0.9804	1.0063	0.8698	0.6319	1.1076
Newark West	12	2	232	0.9914	0.0061	0.9795	1.0033	0.8338	0.6237	1.0438
Newark East	1	0	22	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Leaman OCSW	14	2	258	0.9922	0.0055	0.9815	1.0029	0.8492	0.6569	1.0416
Cottonwood Ranch OCSW	1	1	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hooker Brothers SE	3	0	65	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Shoemaker Island	2	2	35	0.9429	0.0392	0.8660	1.0198	0.2906	-0.2072	0.7885
All Sites	121	43	2,084	0.9794	0.0031	0.9733	0.9855	0.6454	0.5610	0.7299

Appendix 10. Daily and brooding-period survival rates for least tern broods (1 or more chicks) monitored on sandpits during 2016. Brooding-period brood survival rate = (daily brood survival rate)^{21}.

Site	# Broods	# Broods Lost	Exposure Days	Daily Brood Survival Rate	Daily Brood Survival SE	Daily Brood Survival Rate 95% CI		Brooding Period Survival Rate	Brooding Period Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Blue Hole	7	5	70	0.9286	0.0308	0.8682	0.9889	0.2109	-0.0769	0.4987
Johnson	6	1	116	0.9914	0.0086	0.9746	1.0082	0.8338	0.5366	1.1309
Lexington	7	3	109	0.9725	0.0157	0.9418	1.0032	0.5565	0.1874	0.9256
Dyer	6	1	116	0.9914	0.0086	0.9746	1.0082	0.8338	0.5366	1.1309
Broadfoot South	17	5	277	0.9819	0.0080	0.9663	0.9976	0.6821	0.4534	0.9109
Broadfoot South Non-access	7	3	110	0.9727	0.0155	0.9423	1.0032	0.5595	0.1918	0.9272
Newark West	10	8	117	0.9316	0.0233	0.8859	0.9774	0.2260	-0.0070	0.4589
Newark East	1	0	18	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Leaman OCSW	12	4	227	0.9824	0.0087	0.9653	0.9995	0.6884	0.4365	0.9403
Hooker BSE	3	3	15	0.8000	0.1033	0.5976	1.0024	0.0092	-0.0398	0.0582
All Sites	76	33	1,175	0.9719	0.0048	0.9625	0.9814	0.5498	0.4376	0.6620

Appendix 11. Daily and incubation-period survival rates for piping plover nests monitored on sandpits and two river island sites during 2016. Incubation-period nest survival rate = (daily nest survival rate)^{28}.

Site	# Nests	# Nests Lost	Exposure Days	Daily Nest Survival Rate	Daily Nest Survival SE	Daily Nest Survival Rate 95% CI		Incubation Period Survival Rate	Incubation Period Nest Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Blue Hole	13	8	237	0.9662	0.0117	0.9433	0.9892	0.4862	0.2432	0.7292
Johnson	1	0	29	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Lexington	7	3	181	0.9834	0.0095	0.9648	1.0020	0.7040	0.4244	0.9836
Dyer	5	0	142	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Broadfoot South	9	3	207	0.9855	0.0083	0.9692	1.0018	0.7360	0.4806	0.9913
Broadfoot South Non-access	1	0	1	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Newark West	8	1	201	0.9950	0.0050	0.9853	1.0048	0.9006	0.7157	1.0854
Newark East	3	0	77	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Leaman OCSW	4	0	114	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Cottonwood Ranch OCSW	3	0	78	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Cottonwood Ranch Island	1	1	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Trust Wild Rose East	4	4	48	0.9167	0.0399	0.8385	0.9949	0.1609	-0.1273	0.4490
Shoemaker Island	1	0	22	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
All Sites	60	20	1,338	0.9851	0.0033	0.9786	0.9916	0.7289	0.6278	0.8299

Appendix 12. Daily and brooding-period survival rates for piping plover broods (1 or more chicks) monitored on sandpits and 1 river island site during 2016. 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
Blue Hole	5	1	119	0.9916	0.0084	0.9752	1.0080	0.8376	0.5467	1.1285
Johnson	1	0	28	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Lexington	4	2	57	0.9649	0.0244	0.9171	1.0127	0.4723	-0.0187	0.9634
Dyer	5	4	42	0.9048	0.0453	0.8160	0.9935	0.1222	-0.1296	0.3741
Broadfoot South	6	3	108	0.9722	0.0158	0.9412	1.0032	0.5534	0.1829	0.9240
Broadfoot South Non-access	1	1	26	0.9615	0.0377	0.8876	1.0355	0.4388	-0.2696	1.1473
Newark West	7	2	176	0.9886	0.0080	0.9730	1.0043	0.7866	0.5250	1.0483
Newark East	3	0	78	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Leaman OCSW	4	1	103	0.9903	0.0097	0.9714	1.0092	0.8147	0.4876	1.1419
Cottonwood Ranch OCSW	3	3	41	0.9268	0.0407	0.8471	1.0065	0.2028	-0.1635	0.5690
Shoemaker Island	1	0	29	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
All Sites	40	17	807	0.9789	0.0051	0.9690	0.9888	0.6395	0.5036	0.7754

Appendix 13. Daily and incubation-period survival rates for least tern nests monitored on Program and non-Program sites during 2016. 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 Brood Survival Rate 95% CI		Incubation Period Survival Rate	Brooding Period Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Non-Program	47	24	738	0.9675	0.0065	0.9547	0.9803	0.4994	0.3607	0.6382
Program	72	19	1,345	0.9859	0.0032	0.9796	0.9922	0.7417	0.6421	0.8414
All Sites	119	43	2,083	0.9794	0.0031	0.9733	0.9855	0.6453	0.5608	0.7298

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

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

Appendix 14. Daily and brooding-period survival rates for least tern broods (1 or more chicks) monitored on Program and non-Program sites during 2016. Brooding-period brood survival rate = (daily brood survival rate)[21].

Site	# Broods	# Broods Lost	Exposure Days	Daily Brood Survival Rate	Daily Brood Survival SE	Daily Brood Survival Rate 95% CI		Brooding Period Survival Rate	Brooding Period Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Non-Program	23	12	310	0.9613	0.0110	0.9398	0.9828	0.4365	0.2317	0.6412
Program	53	21	865	0.9757	0.0052	0.9655	0.9860	0.5968	0.4651	0.7286
All Sites	76	33	1,175	0.9719	0.0048	0.9625	0.9814	0.5498	0.4376	0.6620

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

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

Appendix 15. Daily and incubation-period survival rates for piping plover nests monitored on Program and non-Program sites during 2016. 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 Brood Survival Rate 95% CI		Incubation Period Survival Rate	Brooding Period Survival Rate 95% CI	
						Lower	Upper		Lower	Upper
Non-Program	25	15	495	0.9697	0.0077	0.9546	0.9848	0.5240	0.3527	0.6954
Program	35	5	843	0.9941	0.0026	0.9889	0.9993	0.8826	0.7859	0.9792
All Sites	60	20	1,338	0.9851	0.0033	0.9786	0.9916	0.7289	0.6278	0.8299

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

Non-Program sites: Lexington, Blue Hole, Johnson, & Trust Wild Rose East

Appendix 16. Daily and brooding-period survival rates for piping plover broods (1 or more chicks) monitored on Program and non-Program sites during 2016. Brooding-period brood 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
Non-Program	10	3	204	0.9853	0.0084	0.9688	1.0018	0.7326	0.4747	0.9906
Program	30	14	602	0.9767	0.0061	0.9647	0.9888	0.6101	0.4522	0.7680
All Sites	40	17	806	0.9789	0.0051	0.9690	0.9888	0.6391	0.5031	0.7751

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

Non-Program sites: Lexington, Blue Hole, & Johnson