Comparison of survey techniques for monitoring interior least tern and piping plover productivity

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ABSTRACT

Within central North America, interior least tern (*Sternula antillarum athalassos*; here after, least tern) and piping plover (*Charadrius melodus*) abundance and productivity has been monitored throughout their ranges and utilized to track these metrics through time and to compare regional differences and population trends. Several methods have been employed to monitor and estimate least tern and piping plover abundance and productivity throughout their range. However, little attention has been given to differences in methods used to collect these data. We implemented four years of season-long, inside (i.e., grid searches) and outside (i.e., monitoring with binoculars and/or spotting scopes from outside the nesting colony) monitoring efforts at off-channel least tern and piping plover nesting sites along the central Platte River to compare these monitoring techniques and their influence on productivity estimates. We found inside monitoring efforts resulted in more nests and early-development chicks being detected so excluding these from nest and chick survival analyses would result in estimates of nest and chick survival rates that are biased high. However, more chicks ≥15 days old were observed by outside monitoring crews. While fledgling counts between methods were similar for piping plovers, more least tern fledglings were observed from outside the nesting colony which, when combined with lower breeding pair counts, would result in higher productivity measures such as fledge ratios. The most appropriate method of survey appears to depend on the objectives of the study and availability of resources. Monitoring from within the nesting colony provides the most precise estimates of abundance, productivity, and daily nest and chick survival rates; however, it requires additional labor and thus monetary resources. If resources are limited, monitoring from outside the colony results in reasonable estimates of abundance and productivity measures provided the majority of the area can be observed from outside the nesting colony.

KEY WORDS: *Charadrius melodus*, interior least tern, monitoring techniques, piping plover, productivity, *Sternula antillarum athalassos*

INTRODUCTION

Extensive monitoring of avian species has occurred throughout the world for a multitude of reasons. Waterbirds, in particular, have been the subjects of successful population monitoring due their locations of breeding activities, colonial nature and role as indicators of ecosystem health (Kushlan 1993; Diamond and Devlin 2003). Within central North America, interior least tern (*Sternula antillarum athalassos*; here after, least terns) and piping plover (*Charadrius melodus*) breeding productivity has been monitored throughout their ranges and utilized to compare regional differences and population trends (Larson et al. 2000; Haig et al. 2005; Lott et al. 2013; Catlin et al. 2016). However, until recently little attention has been given to differences in methods used to collect productivity and abundance data (Shaffer et al. 2013).

Proximity of observers to nests and nesting colonies is an important consideration between monitoring techniques for least terns and piping plovers. Survey proximity has been investigated for only the most extreme differences. Aerial surveys tend to underestimate least tern numbers compared to nesting site (i.e., inside) searches (Savereno 1992). At a more local, site-level scale, least tern and piping plover monitoring is most often accomplished as surveys from a distance (outside) or within (inside) the nesting colony (Hillman et al. 2013; Roche et al. 2016). Inside surveys can gather extensive productivity information unattainable by outside surveys such as egg floating for nest initiation dates and chick banding for individual survival estimations (Roche et al. 2016; Baasch and Keldsen 2018). However, inside surveys require short-term colony disturbances which have been linked to higher nest failure rates and decreased reproductive success of colonial nesting species (Carney and Sydeman 1999; Blackmer et al.

2004; Carey 2009). Consideration of introducing additional stressors and suppressing productivity through investigators entering nesting sites is especially important for threatened and endangered species. Outside monitoring can greatly decrease investigator disturbance but the comparable accuracy to inside methods is less well understood (Hillman et al. 2013).

On the central Platte River, monitoring from outside the nesting colony (generally 20 m – 200 m away from nests) has been used to evaluate least tern and piping plover productivity since the early 1990s (Jenniges and Plettner 2008). Nesting has primarily been documented on off-channel sandpits created by sand and gravel mining operations and through efforts to construct similar, peninsula-type nesting habitat through excavation activities (Jenniges and Plettner 2008; Baasch et al. 2017; Baasch and Keldsen 2018; Farrell et al. 2018). These habitats are highly accessible to investigators, but only outside surveys were conducted for several decades (Jenniges and Plettner 2008) to minimize potential effects of investigator presence on least tern and piping plover nesting sites.

From 2009-2016 the U.S. Geological Survey - Northern Prairie Wildlife Research Center (USGS) assisted the Platte River Recovery Implementation Program (PRRIP) with, among other things, implementing a study protocol that included grid-search surveys from within the nesting colony (inside monitoring) and to band and resight least tern and piping plover adults and chicks at nesting sites within the PRRIP Associated Habitat Area (PRRIP 2015). During 2013 – 2016, surveys from both inside and outside nesting colonies were conducted independently at all sites with nesting least terns or piping plovers. Duplicating monitoring efforts allowed us to compare estimates of reproductive measures between techniques. The objective of this study was to quantify differences in least tern and piping plover productivity metrics including: 1) observed nest period duration; 2) nest and chick counts; 3) breeding pair and fledgling counts; and 4) nest and brood survival. Our findings allowed us to better understand the influence of survey techniques on estimates of productivity and abundance.

STUDY AREA

The Associated Habitat Reach for the PRRIP is a 145-km reach extending from Lexington, Nebraska, downstream to Chapman, Nebraska, USA, and encompasses central Platte River channels and off-channel habitats (sandpits and constructed off-channel sand and water sites) within 5.6 km of the river (Figure 1). PRRIP and Nebraska Public Power District maintained eight managed, off-channel nesting sites through 2016 that incorporated both inside and outside monitoring techniques and were utilized for this study. Management activities at each site included predator fencing and trapping, pre-emergent herbicide application, and tree removal.

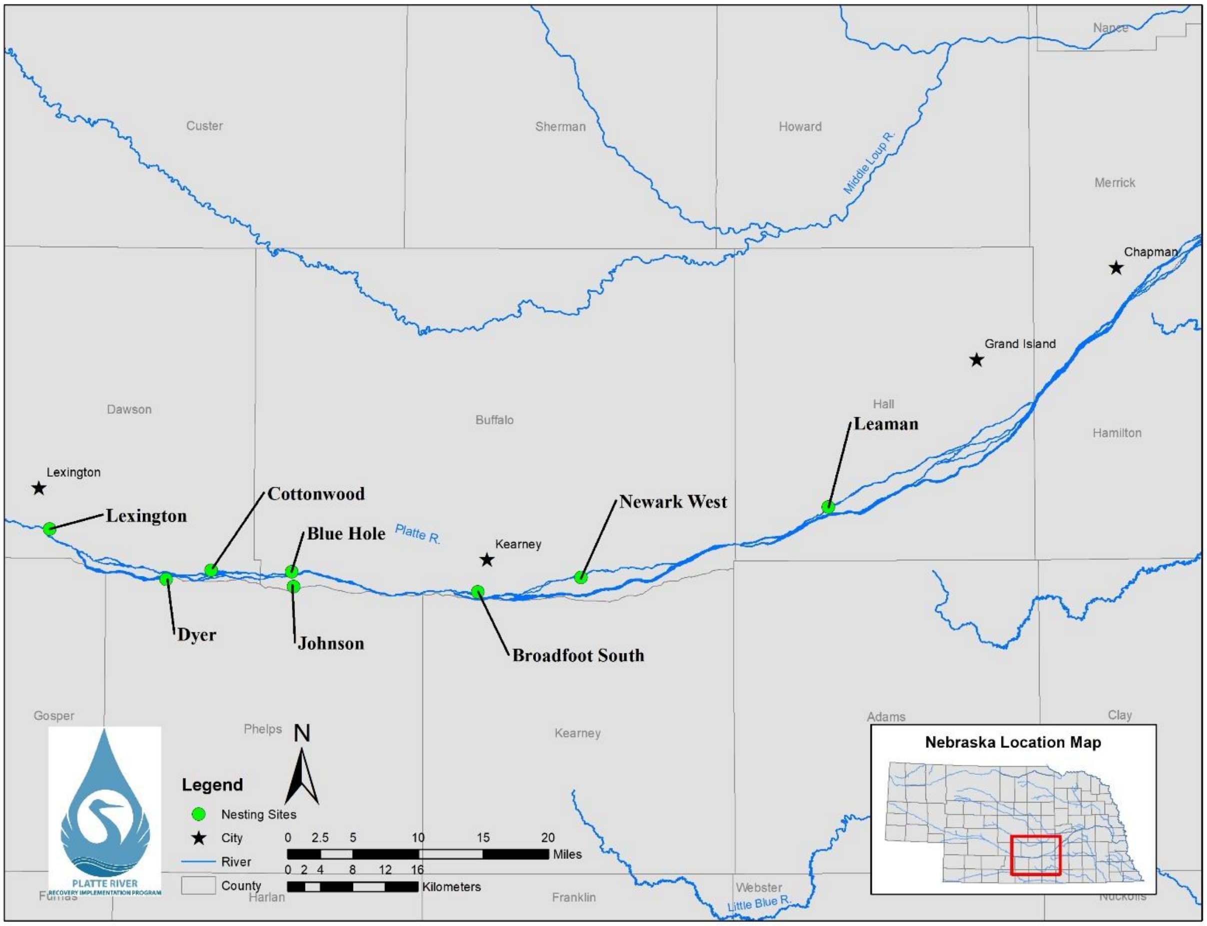

Figure 1. Associated Habitat Reach of the central Platte River extending from Lexington, NE downstream to Chapman, NE including eight managed, off-channel nesting sites that were included in the productivity monitoring analyses.

METHODS

Data

During the nesting seasons of 2013 through 2016, managed off-channel nesting sites where nesting was documented was monitored from inside as well as outside the nesting area intensively (i.e., at least twice per week) through early September or until the cessation of nesting or brood-rearing activities of both species. Given the intensity of survey effort for both techniques, inside and outside surveys generally occurred on the same day or within one day of each other. Piping plovers initiate nests earlier in the year (late April) than least terns (mid- to late May) in our study area and monitoring season duration was set to capture all breeding activities of the two species (PRRIP 2015; Baasch and Keldsen 2018). Monitoring objectives included locating and documenting least tern and piping plover adults, nests, chicks, fledglings, and breeding pairs. Inside surveys involved systematic, 10-m grid searches with 4-6 evenly spaced investigators entering colony sites and walking through nesting areas to identify nest locations and chicks at least twice per week (2013–2016; PRRIP 2015; Keldsen and Baasch 2017). Outside surveys were performed at least twice per week by a single observer for at least 30 minutes with binoculars and spotting scopes at a distance of greater than 50 m from outside the nesting sites. During each outside survey, sites were visually scanned at least 5 times from multiple locations. Outside nests were identified by the presence of an incubating adult as outside monitoring personnel only entered the nesting colony to confirm nest fates when needed. When an active nest was located by either survey method, the date was recorded as "first observed" and a GPS point was recorded for the location. Active nests were defined as any scrape containing 1 or more viable eggs. Active nests were monitored at least twice per week until successful (≥1 chick observed hatched), failed (evidence of nest destruction or abandonment), or unknown fates (no evidence present) were determined. If a brood was observed, but the associated nest was not, the brood was included in our analysis. Broods were considered fledged when chicks were observed in sustained flight or were observed at 21 (least tern) or 28 (piping plovers) days of age. Nests or broods with unknown fates were considered as hatched or fledged if observed as active for at least 21 (least tern) or 28 (piping plovers) days during either reproductive stage. Breeding pair estimates were obtained using methods outlined in Baasch et al. (2015).

Statistical Analyses

To evaluate nest and brood direct measures of productivity (i.e., breeding pair, chick, and fledgling counts), we used 2-sample t-tests and an alpha level of 0.05. To evaluate indirect measures of productivity (i.e., nest and brood survival), we used several pieces of survey information including: 1) the day the nest or brood was found; 2) the last day the nest or brood was active; 3) the day the nest or brood was fated as successful or failed; and 4) nest or brood fate (successful or fledged=0, respectively, or failed=1). Days were standardized to only include the entire breeding season for both least terns and piping plovers, which we designated as 15 April to 15 September.

We calculated nest and brood daily survival rate (DSR) and the incubation and brooding period survival rates (DSR^n) separately for each species where n was 21 days for least tern nests and broods and 28 days for piping plover nests and broods. Logistic regression models were developed with a logit link function using the nest survival models in package RMARK in Program R for both nest and brood survival analyses using each monitoring technique (Rotella et al. 2000; Dinsmore et al. 2002; Laake 2013; R Development Core Team 2015). To test for statistical differences between monitoring techniques, chi-square tests were performed within the nest survival modeling framework in Program MARK and we reported only significant test results (White and Burnham 1999).

Results

Least tern and piping plover inside monitoring nest and chick counts were generally greater than outside monitoring nest and chick counts in any given year from 2013 to 2016 (Table 1). Least tern nests were observed 0.1 days earlier by outside survey crews, but inside surveys crews observed nests 0.8 days longer overall than outside survey crews. Least tern chicks were observed 0.9 days earlier by inside survey crews, but outside surveys crews observed chicks 1.4 days longer overall. Least tern nest exposure days were similar between survey methods, but outside survey crews observed least tern chicks significantly longer than inside survey crews ($t = -2.2879$, $p = 0.023$). Inside survey crews observed more least tern chicks than outside survey crews. The average least tern brood contained 1.32 chicks that were <15 days old as observed by inside survey crews and 1.16 chicks that were <15 days old as observed by outside survey crews. However, outside survey crews observed more least tern chicks ≥15 days old and fledglings than inside survey crews. The average least tern brood contained 0.56 chicks ≥15 days old as observed by inside survey crews and 0.82 chicks ≥15 days old as observed by outside surveys and results were significantly different ($t = -3.754$, $p = <0.001$). The average least tern brood contained 0.47 fledglings as observed by inside survey crews and 0.72 fledglings as observed by outside survey crews and results were significantly different ($t = -3.748$, $p = <0.001$).

Table 1. Comparison of monitoring techniques from inside and outside the nesting colony for interior least tern (top) and piping plover (bottom) breeding pairs, nests, chicks <15 days old (chicks <15D), chicks ≥15 days old (chicks ≥15D), fledglings (interior least tern = 21 days old; piping plover = 28 days old), and nest and brood exposure periods.

Interior Least Tern

Species	Breeding Pairs	Nests	Broods	Chicks <15 D	Chicks ≥15 D	Fledglings	Nest Exposure Days	Brood Exposure Days
Inside	289	420	257	576	244	206	16.8	14.7
Outside	264	364	203	422	299	262	16.0	16.1

Piping Plover

Species	Breeding Pairs	Nests	Broods	Chicks <15 D	Chicks ≥15 D	Fledglings	Nest Exposure Days	Brood Exposure Days
Inside	116	156	113	373	208	140	24.0	19.7
Outside	103	144	96	283	166	115	19.5	18.6

Inside survey crews observed more piping plover nests than outside survey crews (Table 1). Piping plover nests were observed 4.2 days earlier and 4.5 days longer overall by inside survey crews while chicks were observed 2.0 days earlier and 1.1 days longer overall by inside monitoring crews than outside monitoring crews. Inside survey crews observed piping plover nests significantly longer than outside survey crews (t = 4.663, p = < 0.001), but piping plover brood exposure days were similar between survey methods. Contrary to least terns, inside survey crews counted more piping plover chicks and piping plover chicks per brood than outside survey crews regardless of chick age (Table 1). The average piping plover brood contained 2.45 chicks that were <15 days old as observed by inside survey crews and only 2.01 chicks that were <15 days old were observed by outside survey crews and results were significantly different (t = 2.349, p = 0.020). The average piping plover brood contained 1.37 chicks ≥15 days old as observed by inside survey crews and 1.18 chicks ≥15 days old were observed by outside survey crews, but results were not significantly different (t = 1.137, p = 0.256). The average piping plover brood contained 0.92 fledglings as observed by inside survey crews and 0.82 fledglings were observed by outside survey crews, but again, results were not significantly different (t = 0.743, p = 0.458).

Annual breeding pair estimates obtained from within the nesting area, calculated following methods outlined in Baasch et al. (2015), were generally greater than those obtained from outside the colony whereas fledgling counts were more varied (Table 1; Figure 2). Outside monitoring of piping plover fledgling counts were lower for three of four years, but the opposite was observed for least terns, where outside monitoring crew fledgling counts were much greater in three of four years (Figure 2). Combining breeding pair and fledgling estimates, annual least tern fledglings per breeding pair obtained from within the nesting area were lower than estimates obtained by outside survey crews while annual piping plover fledglings per breeding pair was highly variable, but statistically similar between survey methods (Figure 3).

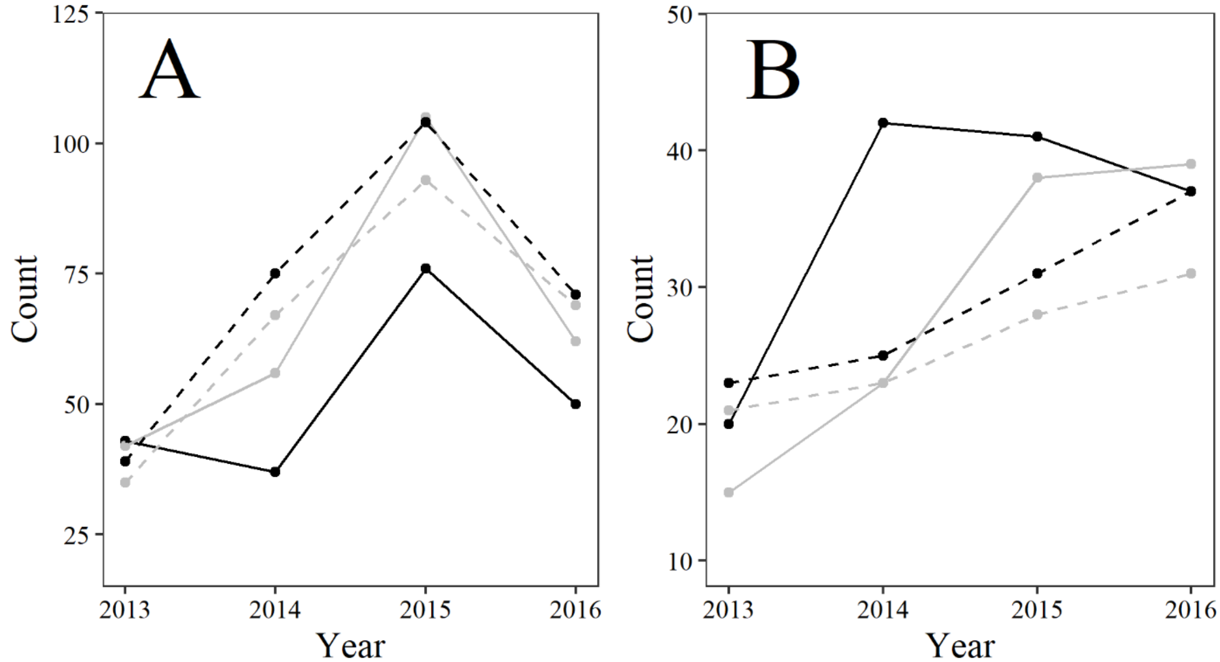

Figure 2. Annual estimates of interior least tern (A) and piping plover (B) breeding pairs (dashed lines) and fledglings (solid lines) using inside (black) and outside (gray) monitoring techniques from 2013 to 2016.

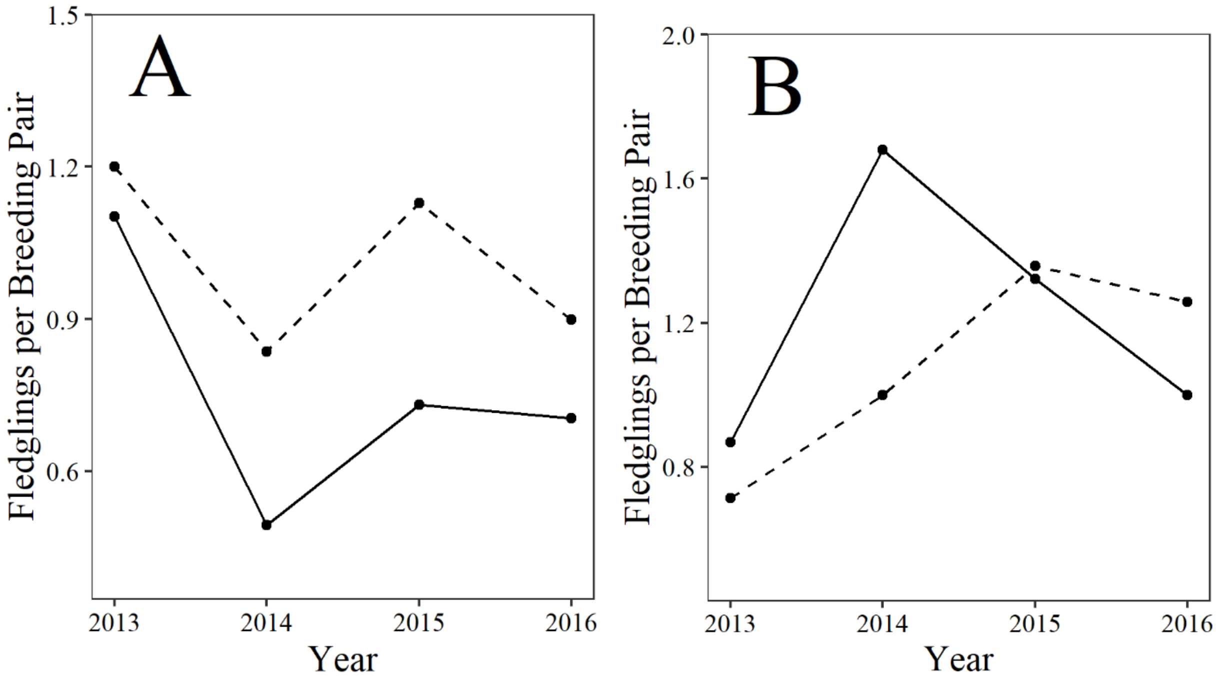

Figure 3. Annual interior least tern (A) and piping plover (B) fledglings per breeding pair estimates using inside (black) and outside (dashed line) monitoring techniques from 2013 to 2016.

We observed variable results in our nest and brood survival estimates between inside and outside monitoring of least terns and piping plovers. Average incubation period survival estimates were higher for inside survey crews than outside survey crews, especially for piping plovers (χ^2 = 4.850, p = 0.0276; Figure 4). Least tern average brooding period survival rate was much higher for outside monitoring (χ^2 = 13.546, p = 0.002), but somewhat lower for piping plovers (Figure 4).

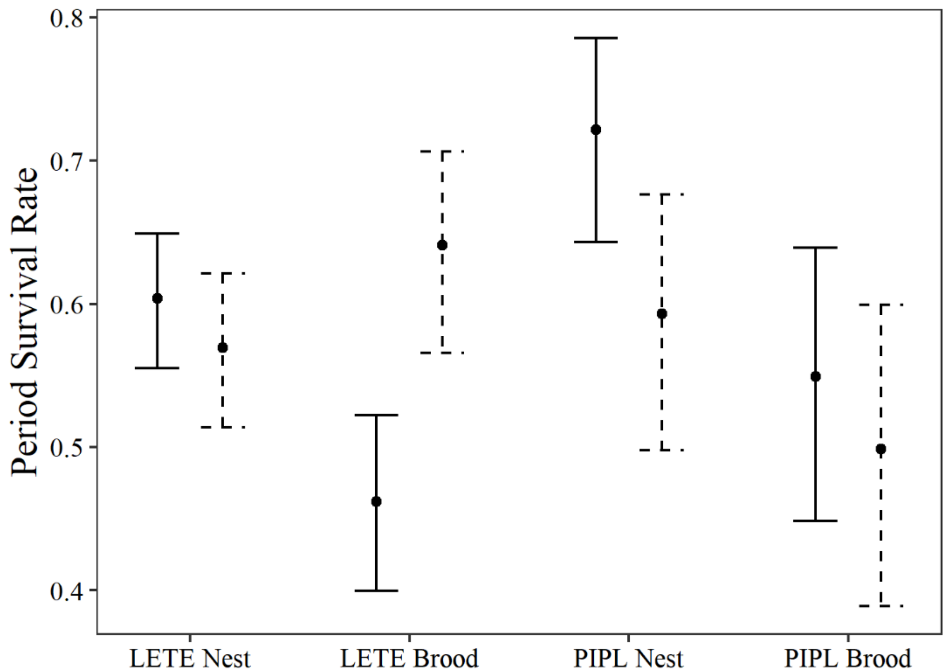

Figure 4. Estimated incubation- and brooding-period survival rates, with 95% confidence intervals, obtained by monitoring from inside (black) and outside (dashed line) the nesting colony for interior least tern (LETE) and piping plover (PIPL) nests and broods.

Discussion

Off-channel sites have accounted for >95% of nests and broods along the central Platte River since 2001 and productivity at these sites is highly important to the local least tern and piping plover populations (Baasch et al. 2017). Four years of intensive monitoring at off-channel nesting sites provided sufficient data to compare inside and outside monitoring techniques and their influence on central Platte River least tern and piping plover productivity estimates. We found many similarities between inside and outside monitoring techniques at nesting sites along the central Platte River. Inside monitoring efforts resulted in more nests and early-development chicks being detected so excluding these nests and chicks from survival analyses would result in estimates of survival from outside the nesting area that were biased high. The reduced detection of nests from outside the nesting colony was likely related to an inability to observe nests due to visual obstruction of the terrain and not observing nests during early the initiation phase when adults were not tending nests regularly which can lead to biases for several productivity measures (Shaeffer et al. 2013). However, the difference between survey methods resulted in lower direct productivity measures derived from inside surveys for least terns which was likely due to fewer nests and chicks being observed from outside the nesting area. Though colony disturbance has been linked to higher nest failure rates and decreased reproductive success of colonial nesting species (Carney and Sydeman 1999; Blackmer et al. 2004; Carey 2009), we did not observe a noticeable decrease in productivity associated with inside monitoring efforts which is similar to findings of Roche et al. (2014) on the Missouri River. While fledgling counts between methods were similar for piping plovers, more least tern fledglings were observed from outside the nesting colony, which would result in higher direct productivity measures such as fledge ratios (i.e., fewer nests or breeding pairs + higher fledgling counts = higher fledge ratios). While there were some differences between monitoring techniques, both techniques described direct productivity on the central Platte River as near or above the proposed productivity estimates for species recovery in the region (Lutey 2002).

Least tern and piping plover nest and young chick counts were lower along the Missouri River when survey duration was protracted (Shaffer et al. 2013). Shaffer et al. (2013) reported detectability of least tern chicks increased with age, but detectability of piping plover chicks was more constant as chicks aged due to precocial development and behavior. Differences in detectability of older least tern chicks due to behaviors of older chicks (hiding under objects and in depressions) and adults (flying, dive-bombing, etc.) as investigators entered the nesting area likely explain the lower estimates of brood survival for inside crews in our study as well. Our results indicate monitoring of breeding development through early chick rearing stage is similar between methods. Even though we found no difference between exposure days and survey technique, inside survey chick detectability was lower relative to outside survey detectability for older chicks close to fledging. Lower detectability may have led to inside surveys fating chicks capable of sustained flight prior to 21 days as unknown or failed when outside surveys fated these younger chicks as successful.

More least tern fledglings were counted by outside surveys in our study for several possible reasons. When investigators enter nesting sites, adults take flight and mobile chicks flee observers or move to safety to avoid perceived threats (Conover and Miller 1979; Burger 1982). Adult least terns may even mob investigators, adding additional sensory complications for inside survey investigators (Burger 1989). Chicks at fledging age may take flight when investigators enter the nesting site, further complicating inside survey counts when many fledglings are observed together. Another event that is known to occur is often times fledglings leave their natal areas possibly in search of nesting habitat for subsequent years; a behavior that has been termed "prospecting" (Friedrich et al. 2015; Davis et al. 2017). This prospecting behavior by fledglings could potentially result in fledglings being counted at multiple sites from outside the survey area when band combinations cannot be read and correctly associated with a nest. These least tern behaviors can result in decreased estimates of fledglings perceived by inside surveys and results in lower direct productivity measures as compared to outside surveys.

Regardless of monitoring technique, least tern productivity was similar to past productivity measures on the central Platte River when only outside monitoring occurred (Jenniges and Plettner 2008, Roche et al. 2016). From 1979 to 2003, 1.13 least tern fledglings per nest were observed at managed, off-channel nesting sites on the central Platte River (Jenniges and Plettner 2008). We observed similar least tern fledglings per breeding pair, but studies from other areas were dissimilar. On the lower Platte River during 1987–1990, overall least tern fledglings per breeding pair was only 0.47 and no annual fledge ratio on sandpits exceeded 0.64 for least terns (Kirsch 1996). However, more recent fledge ratios on off-channel sites on the lower Platte River were similar to what we observed (Brown and Jorgenson 2008, 2009, 2010; Brown et al. 2011). Extensive management of off-channel nesting sites in the central Platte River could account for increased productivity observed in the region (Jenniges and Plettner 2008). Limited on-site disturbance, predator trapping, moating of the nesting area, and fences to limit land-access to nesting areas for mammalian predators are all utilized in the central Platte River to increase breeding productivity of least terns and piping plovers and may account for the increased productivity compared to other areas including the adjacent lower Platte River (Baasch et al. 2017; Farrell et al. 2018). Management activities at lower Platte River off-channel nesting sites include nesting site perimeter flagging and individual nest enclosures for piping plover nests, where the latter appears to result in productivity levels that are similar to what has been observed along the central Platte River (Kirsch 1996; Brown and Jorgenson 2008, 2009, 2010; Brown et al. 2011).

Several methods have been employed to estimate least tern and piping plover abundance and productivity throughout their range including single mid-June surveys as has occurred on the Mississippi River (Lott 2006), periodic inside and/or outside monitoring as has occurred on the lower Platte River (Brown et al. 2017), season-long periodic inside monitoring as has occurred on the Missouri River (Shaffer et al. 2013), and season-long inside and/or outside monitoring as has been implemented on the central Platte River since 2001 and more recently on the Missouri River (PRRIP 2015; Andes et al. 2018). It appears all monitoring efforts that employ multiple surveys, especially during June, would provide reasonable estimates for tracking long-term trends in population abundance, but some methods appear to provide better estimates of nest and chick survival parameters. Andes et al. (2018) found inside monitoring on a 3-day return interval resulted in reliable estimates of fate and causes of nest loss. While we found similar results, it is important to note that monitoring from outside the nesting area can result in reliable estimates of productivity as well, so long as the nesting areas can be adequately observed. The best method of survey to employ is highly dependent on the objectives of the study, availability of resources, and access to the nesting sites. Inside monitoring efforts seem to provide the most precise estimates of abundance and daily nest and chick survival; however, the techniques used in the our study required 4-6 times the labor force and associated costs as outside monitoring efforts which also resulted in reasonable estimates of abundance and productivity measures when sites were viewable from multiple angles from outside the nesting colony. Understanding breeding productivity based on varying monitoring techniques is important for species with wide breeding distributions and several distinct, but interconnected populations (Roche et al. 2010; Lott et al. 2013). By accounting for differences among techniques, more appropriate comparisons of least tern and piping plover productivity would allow conservation organizations to make better decisions to reach recovery goals over large spatial areas.

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