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Reducing Effort When Monitoring Shorebird Productivity

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Abstract.—While several methods have been employed to estimate shorebird abundance and productivity, little attention has been given to differences in methods used to collect these data. Within central North America, Interior Least Tern (*Sternula antillarum athalassos*; hereafter, Least Tern) and Piping Plover (*Charadrius melodus*) monitoring is often accomplished through surveys from a distance or within the nesting colony. Four years (2013-2016) of season-long monitoring (April- mid-September) were implemented from inside and outside nesting colonies at off-channel nesting sites along the central Platte River, Nebraska, USA to compare estimates of resulting productivity components. Each method was found to have observational strengths and weaknesses, depending on the species and reproductive component. Outside Least Tern monitoring resulted in higher fledgling counts (256 total fledglings) and lower breeding pair estimates (242 total pairs), resulting in higher fledge ratios compared to inside monitoring (192 total fledglings, 261 total pairs). Differences in Piping Plover fledge ratios were annually variable (total pairs: inside estimate = 116, outside estimate = 103; total fledglings: inside estimate = 142, outside estimate = 117). Overall, both inside and outside monitoring can produce reasonable estimates of species abundance and productivity despite substantial differences in monitoring effort and cost. *Received 9 April 2019, accepted 14 February 2020.*

Key words.—*Charadrius melodus*, Interior Least Tern, monitoring technique, Piping Plover, productivity, shorebird, *Sternula antillarum athalassos*

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Extensive monitoring of avian species has occurred throughout the world for a multitude of reasons. Shorebirds have been the subjects of successful population monitoring due to the location of breeding activities, their colonial nature, and their role as indicators of ecosystem health (Kushlan 1993; Diamond and Devlin 2003). Within central North America, Interior Least Tern (*Sternula antillarum athalassos*; hereafter, Least Tern) and Piping Plover (*Charadrius melodus*) breeding productivity has been monitored and utilized to compare regional differences and population trends (Haig *et al.* 2005; Lott *et al.* 2013; Catlin *et al.* 2016). Several methods have been employed to estimate Least Tern and Piping Plover abundance and productivity, including: single mid-June surveys on the Mississippi River (Lott 2006); periodic inside the nesting area (hereafter, inside) and/or outside the nesting area from a distance (hereafter, outside) monitoring on the lower Platte River (Brown *et al.* 2017); season-long periodic inside monitoring on the Missouri River (Shaffer *et al.* 2013); and season-long inside and/or outside monitoring on the central Platte River and more recently on the Missouri River (PRRIP 2015; Andes *et al.* 2018). Even though many different monitoring protocols have been practiced, 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 important to consider when deciding between monitoring techniques for shorebirds. Survey proximity has been investigated for only the most extreme differences. Aerial surveys tend to underestimate abundance compared to nesting site searches (i.e., inside; Savereno 1992). Inside surveys can also result in 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; Seefelt and Farrell 2018). Consideration of additional stressors and reduced productivity due to investigators entering nesting sites is especially important for threatened and endangered species. Outside monitoring can greatly decrease disturbance, but the accuracy of observations compared to inside methods is less well understood (Hillman *et al.* 2013).

Least Tern and Piping Plover monitoring has been accomplished through both inside and outside methods (Hillman *et al.* 2013; Roche *et al.* 2016). On the central Platte River, monitoring from outside the nesting colony (generally 20-200 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 to minimize potential effects of investigator presence on Least Tern and Piping Plover productivity (Jenniges and Plettner 2008).

From 2009-2016 the U.S. Geological Survey - Northern Prairie Wildlife Research Center (USGS) assisted the Platte River Recovery Implementation Program (PRRIP) with implementing a study protocol that included grid-search surveys from within the nesting colony (inside monitoring) and to band and re-sight Least Tern and Piping Plover adults and chicks at nesting sites within the PRRIP Associated Habitat Reach (PRRIP 2015). During 2013-2016, survey techniques were implemented from both inside and outside nesting colonies at all sites with nesting Least Terns or Piping Plovers. Duplicating monitoring efforts allowed us to obtain and compare independent estimates of reproductive measures between techniques by not sharing knowledge of breeding activities between crew members performing each monitoring technique. 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 effort on estimates of abundance and productivity.

Methods

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 eight PRRIP and Nebraska Public Power District managed, off-channel habitats (sandpits and constructed off-channel sand and water sites) within 5.6 km of the river (Fig. 1). Management activities at each site included predator fencing and trapping, pre-emergent herbicide application, and tree removal.

During the 2013-2016 nesting seasons, the nesting sites were monitored from inside as well as outside the nesting area intensively (i.e., at least twice per week) from April through early September or until the cessation of nesting or brood-rearing activities of both species. We implemented the study so neither the inside nor the outside survey crews were aware of observations made by the other crew. 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). Given inside surveys were conducted with numerous combinations of 8 individuals where 4-6 people were generally used during each inside survey of each site, comparisons between observers collecting data simultaneously on the same 10-m grid was not possible. In addition, fledglings were documented by inside survey crews based on band combinations observed during river and other survey efforts.

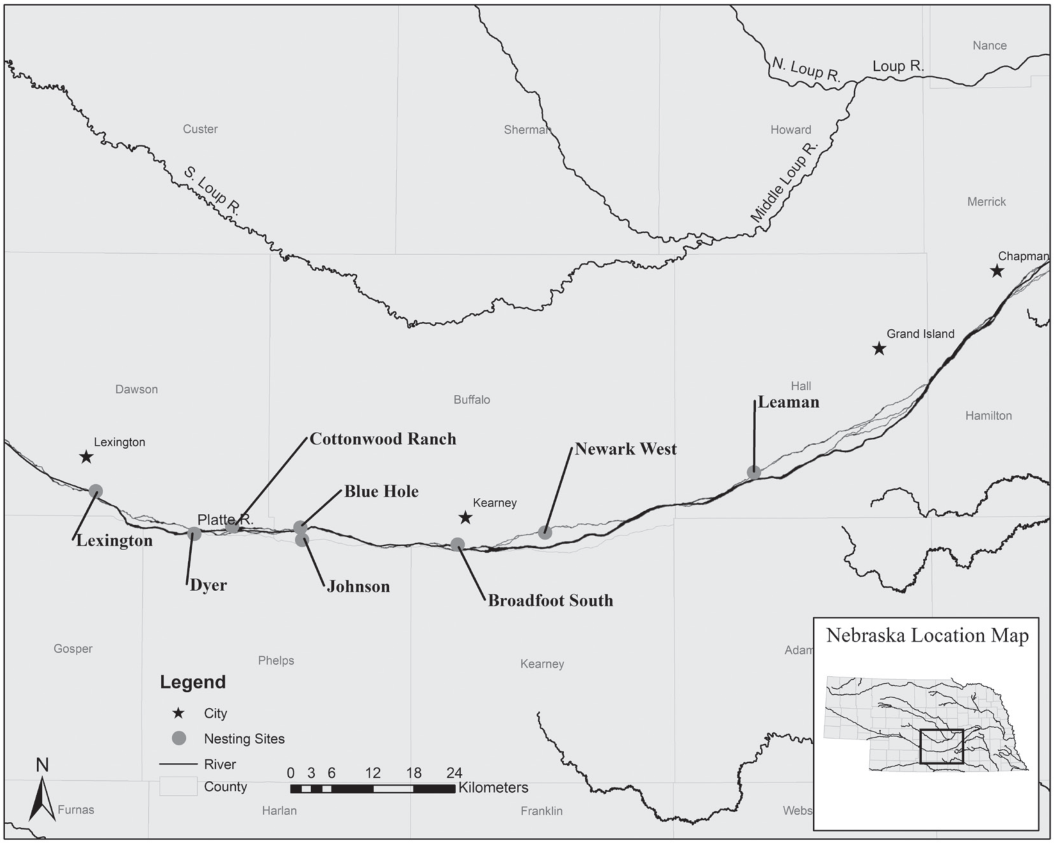

Figure 1. Associated Habitat Reach of the central Platte River extending from Lexington, Nebraska, USA downstream to Chapman, Nebraska, USA, including eight managed, off-channel nesting sites of Piping Plover and Interior Least Terns that were included in the productivity monitoring (Apr-Sept 2013-2016) analyses.

Outside surveys were performed at least twice per week for at least 30 minutes with binoculars and spotting scopes at a distance >50 m from outside the nesting sites. On days inside surveys preceded outside surveys at a site, an interval of at least 1 hour was enforced between the end of inside and beginning of outside surveys to allow displaced adults and chicks to settle into pre-survey behavior patterns. Only 1 outside surveyor was used at each site annually, so comparisons between observers was not possible. During each outside survey, sites were visually scanned at least 5 times from multiple locations, and nests were identified by the presence of an incubating adult.

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 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 (PRRIP 2015). Nests or broods with unknown fates were considered to have 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).

We compared inside and outside monitoring survey components, including number of days a nest was observed (nest exposure days), number of days a brood was observed (brood exposure days), number of chicks <15 days old per brood, average number of chicks ≥15 days old per brood, and number of fledglings per brood. Nest exposure days were fit with linear mixed effects models, while chick counts were fit with Poisson mixed effects models. Year and nest site within year were included as random effects due to nesting sites being represented within each year in the experimental design. Fixed effects included monitoring technique as a categorical variable. Zero inflation in chick count data was checked using the R package performance. If zero-inflation was present in the chick count data, models were fit with a negative binomial distribution with quadratic parameterization (Hardin *et al.* 2007). Exposure days and chick count models were executed in R package glmmTMB (Brooks *et al.* 2017). Nest and brood direct measures of productivity (i.e., overall and annual breeding pair and fledgling counts) were visually inspected and interpreted annually. 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) to obtain 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. Mixed effect nest or brood fate logistic exposure models were developed, with a logit function developed to account for individual nest exposure days in package lme4 in Program R (Shaffer 2004; R Development Core Team 2020). Monitoring technique was included as a fixed effect, whereas year and sites within year were accounted for with random effects. If singular model fit occurred, due to overly complex model parameterization, the highest level random variable component (year) was removed from the model. This ensured the random structure was still accounting for experimental design, while avoiding non-singular fits (Barr *et al.* 2013). Additionally, we performed our nesting and brood-rearing period survival modeling to obtain estimates of nest and brood survival using each survey technique and presented results with bootstrapped 95% confidence intervals. All significance tests were evaluated at an alpha level of 0.05.

RESULTS

Nest and chick counts for Least Terns and Piping Plovers were generally greater based on inside versus outside monitoring in any given year from 2013 to 2016 (Table 1). Least Tern nests and chicks were observed, on average, for a similar number of exposure days regardless of technique (Table 2). Overall, outside survey crews observed fewer young Least Tern chicks than inside survey crews and averaged 0.86 (95% CI: 0.76-0.99) times as many young chicks per brood as inside crews (P = 0.034; Table 2). However, outside survey crews observed more Least Tern chicks ≥15 days old and fledglings. Outside survey crews averaged 1.52 (95% CI: 1.21-2.02) as many chicks ≥15 days old per brood (P < 0.001) and 1.59 (95% CI: 1.19-2.11) as many fledglings per brood (P < 0.001) than inside survey crews.

Inside survey crews observed more Piping Plover nests and broods than outside survey crews (Table 1). Piping plover nests were observed, on average, 4.44 (95% CI: 2.66-6.22) days longer by inside survey crews than outside survey crews on average (P < 0.001), whereas Piping Plover brood exposure days were similar between survey methods (Table 2). Contrary to Least Terns, inside survey crews counted more overall Piping Plover chicks and fledglings. Outside survey crews observed, on average, 0.80 (95% CI: 0.69-0.94) as many <15 days old chicks per brood than outside survey crews (P = 0.007), but both techniques observed a similar number of ≥15 days old chicks and fledglings per brood (Table 2).

Annual breeding pair estimates obtained from inside survey data, calculated following methods outlined in Baasch *et al.* (2015), were higher than those obtained from outside the colony for Least Terns and Piping Plovers (Table 1; Fig. 2). Outside monitoring of Piping Plover fledgling counts was lower, which is largely attributable to observations of fledglings off their natal site during river and other survey efforts (Fig. 2D).

Table 1. Comparison of total counts from inside and outside monitoring of nesting colonies for Interior Least Tern (top) and Piping Plover (bottom) breeding pairs, nests, chicks <15 days old (<15 D), chicks ≥15 days old (≥15 D), and fledglings (Interior Least Tern ≥ 21 days old; Piping Plover ≥ 28 days old). Monitoring was conducted Apr-Sept 2013-2016 at off-channel nesting sites along the central Platte River, Nebraska, USA.

Technique	Breeding Pairs	Nests	Broods	<15 D	≥15 D	Fledglings
Interior Least Tern						
Inside	261	424	251	554	230	192
Outside	242	357	201	409	294	256
Piping Plover						
Inside	116	156	113	380	206	142
Outside	103	143	95	285	166	117

Table 2. Model results for comparison of monitoring techniques from inside and outside the nesting colony for Interior Least Tern (top) and Piping Plover (bottom) monitoring conducted Apr-Sept 2013-2016 at off-channel nesting sites along the central Platte River, Nebraska, USA. Productivity measurement model results include intercept (β_0), effect of monitoring technique ($\beta_{technique}$), monitoring technique standard error (SE), *Z*-value (*Z*), *P*-value, random effects included in model, and type of model used to evaluate differences for each Least Tern and Piping Plover productivity measurement.

Measurement	β_0	$\beta_{technique}$[a]	SE	*Z*	*P*-value	Random Effects	Model
Interior Least Tern							
Nest Exposure Days	16.89	-0.54	0.46	-1.17	0.24	Year, Site	Linear
Brood Exposure Days	14.90	1.03	0.57	1.80	0.07	Year, Site	Linear
<15day Chicks	0.24	-0.14	0.07	-2.11	0.03	Year, Site	Negative Binomial
>15day Chicks	-0.66	0.42	0.10	3.97	<0.001	Year, Site	Negative Binomial
Fledglings	-0.86	0.46	0.12	3.96	<0.001	Year, Site	Negative Binomial
Nest Survival	4.00	0.03	0.12	0.30	0.77	Year, Site	Logistic Exposure
Brood Survival	3.45	0.67	0.16	4.12	<0.001	Site	Logistic Exposure
Piping Plover							
Nest Exposure Days	24.38	-4.44	0.91	-4.88	<0.001	Year, Site	Linear
Brood Exposure Days	19.51	-1.32	1.06	-1.25	0.21	Year, Site	Linear
<15day Chicks	0.91	-0.21	0.08	-2.67	0.01	Year, Site	Negative Binomial
>15day Chicks	0.08	-0.14	0.13	-1.08	0.28	Year, Site	Negative Binomial
Fledglings	-0.38	-0.14	0.16	-0.87	0.39	Year, Site	Negative Binomial
Nest Survival	4.89	-0.35	0.22	-1.60	0.11	Site	Logistic Exposure
Brood Survival	4.12	-0.06	0.23	-0.28	0.78	Site	Logistic Exposure

[a] Inside monitoring technique was the reference group in all models.

Inside survey crews documented 3, 8, 4, and 5 fledglings via band combinations during river surveys in 2013–2016, respectively, and other observations likely occurred off site as well. The opposite was observed for Least Terns, where outside monitoring crew fledgling counts were higher for all years (Fig. 2B). 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 comparison of annual Piping Plover fledglings per breeding pair was variable (Fig. 3). Given the stable differences in annual breeding pair estimates obtained from surveys conducted inside and outside the nesting colonies (Fig. 2A, 2C), we applied an adjustment factor to breeding pair counts to display a more realistic estimate for fledglings per breeding pair for outside survey crews. We calculated the difference between breeding pair estimates obtained during inside and outside surveys and divided this by the number of breeding pairs observed by inside survey crews to estimate the proportion of breeding pairs not documented by outside survey crews. We estimated outside survey crews failed to observe 7.9% of Least Tern and 12.6% of Piping Plover breeding pairs. This resulted in applying breeding pair adjustment factors of 1.079 for Least Tern and 1.126 for Piping Plover breeding pairs, which resulted in a reduction of outside survey fledge ratios by 7.3% and 11.2%, respectively (Fig. 3).

We observed variable results in our nest and brood survival estimates between inside and outside monitoring of Least Terns and Piping Plovers. Average Piping Plover nest survival estimates were higher for inside survey crews than outside survey crews, but results were not statistically significant ($P = 0.109$; Fig. 4; Table 2). Least Tern broods observed by outside survey crews were, on average, 1.95 (95% CI: 1.42-2.72) times as likely to survive per day compared to inside surveys, which resulted in higher brood survival rates ($P < 0.001$; Fig. 4).

DISCUSSION

Our study comparing methods for estimating shorebird abundance and productiv-

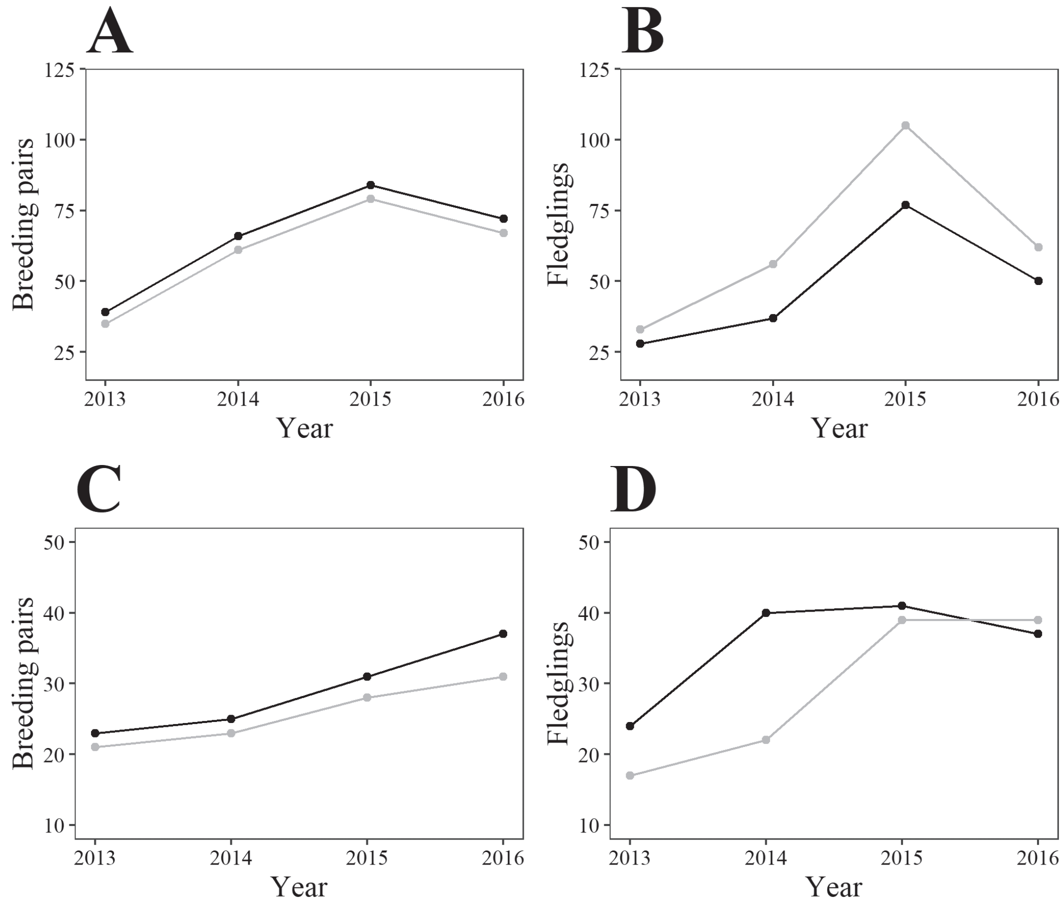

Figure 2. Annual estimates of Interior Least Tern (top) and Piping Plover (bottom) breeding pairs (A, C) and fledglings (B, D) observed using inside (black) and outside (gray) monitoring techniques on eight central Platte River off-channel nesting sites, 2013-2016.

ity demonstrates that early Least Tern reproductive stages and all Piping Plover stages are better detected at close range, whereas lower investment and lower impact distance monitoring is effective and accurate for late Least Tern reproductive stages. Inside monitoring efforts resulted in more nests and early-development chicks being detected, so excluding these nests and chicks from survival analyses resulted in higher estimates of survival from outside the nesting area. 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 the early initiation phase when adults were not tending nests regularly, which can lead to biases for several productivity measures (Shaffer *et al.* 2013). While Piping Plover fledgling counts were higher for inside surveys overall, more Least Tern fledglings and fledglings per brood 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). Although differences between monitoring techniques were observed, 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). Although adequate productivity was observed during the study period, differences in monitoring technique results would become highly important during periods, or in areas, of lower reproductive output.

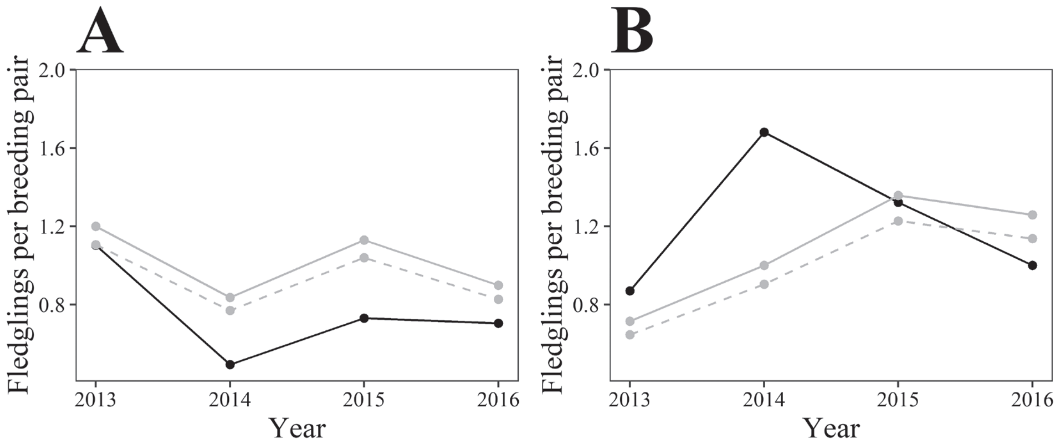

Figure 3. Annual Interior Least Tern (A) and Piping Plover (B) fledglings per breeding pair estimates using inside (black) and outside (grey) monitoring techniques on eight, central Platte River off-channel nesting sites, 2013-2016. Dashed lines represent adjusted fledgling per breeding pair estimates for outside survey crews to account for known nests, and thus breeding pairs, not detected by outside monitoring crews.

Off-channel sites have accounted for >95% of Least Tern and Piping Plover nests and broods along the central Platte River since 2001, and productivity at these sites is highly important to the local populations (Baasch *et al.* 2017). Four years of intensive monitoring at off-channel nesting sites provided sufficient data to compare monitoring techniques from inside and outside the nesting colony and their influence on central Platte River Least Tern and Piping Plover productivity estimates. 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, similar to findings of Roche *et al.* (2014) on the Missouri River.

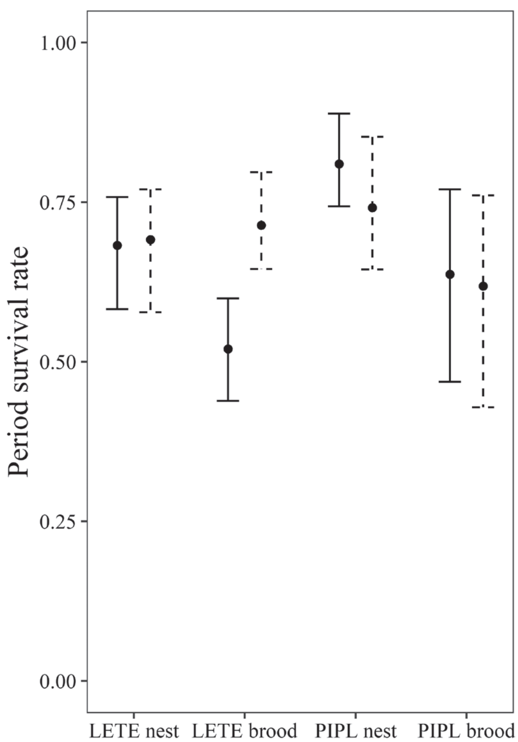

Figure 4. Estimated nesting- (nest) and brood-rearing (brood) period survival rates, with bootstrapped 95% confidence intervals, obtained by monitoring from inside (black line) and outside (dashed line) the nesting colony for Interior Least Tern (LETE) and Piping Plover (PIPL).

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 Least Tern chicks due to chick activities (e.g., hiding under objects and in depressions) and adults (e.g., 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. Inside monitoring also required re-sighting of banded chicks to determine fledglings, which is hindered by fledgling tern movements off nesting sites. Lower detectability may have led to inside surveys determining broods with chicks capable of sustained flight prior to 21 or 28 days of age as unknown or failed when outside survey crews determined these chicks as fledged.

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. Fledglings will also 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 compared to outside surveys. Our findings suggest inside monitoring during nest and early chick development and outside monitoring during chick to fledgling development would provide the most accurate observations of Least Tern productivity.

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 (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).

While it appears all monitoring efforts that employ multiple surveys, especially during the peak of the breeding season, would provide reasonable estimates for tracking long-term trends in shorebird population abundance, 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 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 when sites were viewable from multiple angles from outside the nesting colony. When detectability of nests and broods is adequate from outside areas and personnel is limited, outside surveys can be deployed in place of inside monitoring. If both monitoring techniques are deployable, inside monitoring for all Piping Plover developmental stages and Least Tern nest and early chick development, coupled with outside monitoring of Least Tern chick to fledgling development, would results in the best estimates of productivity.

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). Given the negative annual breeding pair bias observed by outside monitoring , we were able to adjust our productivity estimates to obtain more informed estimates of the number of breeding pairs, and thus fledge ratios, documented from outside the nesting colony. This provides one example of how to develop corrective factors to account for inherent differences in monitoring technique and how combining multiple monitoring strategies can provide better estimates of productivity. Future studies should directly address how to account for methodological differences when comparing productivity data from multiple sources. Appropriate comparisons of productivity would allow conservation programs to make better decisions to reach recovery goals for species with large spatial distributions.

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