Interior Least Tern and Piping Plover Reproductive Monitoring During the Cooperative Agreement (2001-2006), Central Platte River, Nebraska

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INTRODUCTION

Reproductive data was obtained through the implementation of the interior least tern (*Sternula antillarum*) and piping plover (*Charadrius melodus*) reproductive success and reproductive habitat parameters monitoring protocol (PRESP, 2002) during the Cooperative Agreement period. The protocol was implemented during six breeding seasons, from 2001 to 2006. This report presents an analysis that was completed for the Platte River Recovery Implementation Program (Program).

There were three objectives stated in the protocol:

1. Gather information on least tern and piping plover reproductive success and reproductive habitat parameters in the study area.
2. Evaluate the biological response of terns and plovers and habitat to the land and water management activities of the Program.
3. Document long term trends in reproductive parameters.

We addressed the first and last objectives with analyses of trends in reproductive parameters and linear statistical models of the associations between reproductive and habitat parameters. The second objective was not specifically addressed as Program management activities were limited during the Monitoring period. The objectives were intended to apply both before and after initiation of the Program and this report covers the period before Program initiation.

METHODS

The CA study area consists of the Platte River beginning at the junction of U.S. Highway 283 and Interstate 80 near Lexington, Nebraska, and extending eastward to Chapman, Nebraska. This includes approximately 90 miles of the Platte River and sandpits within 3.5 miles of the main channel or 2 miles of a side channel if the side channel extends beyond 3.5 miles of the main channel (PRESP, 2002). The protocol defines two survey components to document reproduction by terns and plovers in the study area. In Component One of the protocol, surveys were conducted on the river. In Component Two of the protocol, surveys were conducted of sandpits and constructed riverine islands. This report analyzes the habitat characteristics associated with the reproductive outcomes for nesting least terns and/or piping plovers.

There were 41 sites surveyed during the Cooperative Agreement period. A site is defined as a sandpit or constructed riverine island that was monitored according to the survey protocol. The protocol specifies that sandpits with areas of bare sand (<20% vegetative cover) greater than one acre, and for which access can be gained, were to be surveyed three times for active tern and plover colonies. Also, any nesting area constructed and maintained by the Program was to be visited weekly between May 15 and July 15 for active tern and plover colonies. Nests located during these surveys were to be monitored every three days until chicks were no longer observed at the natal area.

Reproductive Parameters
Reproductive parameters were calculated for each species and survey year and for each site. The nest was the sample unit for the calculation of reproductive parameters at each site. The following parameters were calculated:

Total Nests Initiated – The total number of nests initiated whether successful or not. This total includes first nesting attempts as well as re-nesting attempts.
Nest-based Hatching success – The total number of hatched eggs (chicks) divided by the total number of nests initiated (i.e., if there were 60 chicks and 75 nests, the hatching rate would be 0.80 or 80%). Using the number of nests in the denominator of this statistic recognizes the greater independence of fate between nests than between eggs.
Nesting success – The total number of successful nests divided by the total number of nests initiated (i.e., if there were 125 nests initiated and 100 nests were successful, nest success would be 0.80 or 80%).
Nest-based Fledging success – The number of fledged birds per initiated nest (i.e., if 60 chicks were fledged from 50 nests, the fledging success would be 1.2 fledged birds per nest).
Pair-based Fledgling success – The number of fledged birds per bird pair (i.e., if 60 chicks were fledged from 50 pairs, the fledging success would be 1.2 fledged birds per pair). The number of pairs was estimated two ways; 1) the maximum number of nests and number of broods at any one survey, or 2) half of the maximum number of adults counted during any one survey. Pair-based estimates of fledgling success were calculated using both estimates of the number of pairs.
Mayfield Daily Survival Rate **–** One minus the daily mortality rate, where the daily mortality rate was calculated as the ratio of total number of unsuccessful nests to the total number of exposure days (Johnson, 1979).
Mayfield Incubation Period Survival Rate – The daily survival rate raised to the power of the length of the incubation period (Johnson, 1979).

Trends in Reproductive Parameters
The slope of the least squares regression line for each reproductive parameter against time was estimated for each colony with nests (Rawlings et al., 1998). The average and standard error of the slope statistic across colonies provides an estimate and confidence interval for average trend (Urquhart et al., 1998).

Habitat Parameters
Nest-level habitat parameters were recorded on the ground at each nest after the birds left the area. Ocular estimates of nest elevation, vegetation composition, vegetation density and vegetation height were made in $1m^2$ and $5m^2$ areas around the nest. Means and confidence intervals were estimated across nests for each species and survey year.

Colony-level habitat parameters were recorded on the ground and extracted from data layers of a GIS. Management activities and the adjacent land use were recorded for each site for each year. Indicator variables were constructed for herbicide spraying, fencing, and predator trapping, where the value was 1 if the management action had occurred in a given year and 0 if not.

Bare sand area and size of adjacent pond were measured for each site in a GIS on the 1998, 2003, and 2005 color infrared digital aerial photographs. Bare sand area was delineated as the area of contiguous sand around the centroid of the colony, including any islands and peninsulas devoid of vegetation. If there was no nesting activity, the centroid of the colony was inferred as the center of the largest expanse of bare sand on the site. Pond size was delineated as the area of water immediately adjacent to the bare sand area. The distance from the colony to river was measured from the centroid of the colony to the nearest edge of the closest active river channel on the 1998 color-infra red photographs (taken during a flow of approximately 1,200 cfs).

Using the BOR land use/cover GIS layer based on 1998 photographs (USBOR, 2000), we calculated the distance to the nearest wooded area from each colony. We also extracted the proportion of sand and gravel, the proportion of wooded area, and the proportion of open water within a circle with a two mile radius which was centered on the colony. Means and confidence intervals for each variable were estimated across colonies for each species and survey year.

Associations between Reproductive Outcomes and Habitat Parameters

Nest-level habitat parameters were used in linear statistical models to predict reproductive parameters (nesting success and fledgling success) to investigate the relationship between reproductive outcomes and habitat. A regression model with binomial errors was fit to nesting success where the response variable was a 1 if the nest succeeded and a 0 if not. A regression model with Poisson errors was fit to fledging success where the response variable was the number of birds that fledged from the nest.

Colony-level habitat parameters were used in linear statistical models to predict reproductive parameters (hatching success, nesting success, fledgling success) to investigate the relationship between reproductive outcomes and habitat. Pond size and bare sand area from the most recent photograph were attributed to the reproductive response for a given year. A mixed model with normal errors was used to accommodate the lack of independence among colonies in successive years. The covariance structure was modeled with a auotoregressive order one (AR(1)) covariance structure. AR(1) has larger covariance for observations close together in time and the covariance decreases as the time between observations increases. We also fit the model with compound symmetric (CS) and unstructured (UN) covariance structures and determined the one with the best fit using the Akaike's information criterion (AIC) (Littell et al., 1996). During model selection, the estimation method was maximum likelihood but to calculate estimates for final model parameterization, the estimation method was residual maximum likelihood, as recommended by Little et al. 1996. Models were assessed with residual plots to compare the data with the fitted model. The parameter estimates and type III tests of significance were used to determine if a habitat variable had a positive or negative relationship with the response. The inference area for these analyses was the sandpits and/or constructed islands monitored within the study area.

Model selection for the nest- and colony-level models involved a forward selection routine. There were 14 covariates in the candidate variable list for the nest-level models and 12 covariates in the candidate variable list for the colony-level models, including the quadratic effects of distance to channel and distance to wooded areas. The AIC was used to determine the entry of a variable at each step of the selection procedure. For example, each variable in the candidate variable list was fit in a model. The model with the lowest AIC score was selected for the first step. The variable added to this model was then removed from the candidate variable list, along with any variables with a high correlation (greater than 0.75 or less than -0.75) with this variable. Next, each variable in the candidate variable list was fit in a model with the variable selected during the previous step. The model with the lowest AIC score from this set of models was selected for the next step. The procedure was continued until there were no variables in the candidate variable list for which their addition into the model produced a model with a lower AIC. Since the latter steps in this model selection procedure generally continue to add variables to the model, though no significant reduction of the AIC is occurring, a graph of AIC through the model selection procedure was used to select a model at the point where additional variables entering the model do not contribute substantially.

RESULTS

There were and no least tern or piping plover nests found on the river or constructed riverine islands during the Cooperative Agreement period. There were six colonies with least tern nests and five colonies with piping plover nests located on sandpits.

Trends in Reproductive Parameters

Reproductive parameters were estimated across colonies for each year for least terns (Table 1) and piping plovers (Table 2) nesting at sandpits.

There were 4 significant trends in reproductive parameters for least terns during the Cooperative Agreement period (Table 3). Total nests initiated increased by 1.44 nests per year (95% CI: 0.33, 2.56; Figure 1) and nest-based hatching success declined by 0.20 eggs per nest per year (95%CI: -0.22, -0.17; Figure 2). Nest-based fledgling success declined by 0.20 fledglings per nest per year (95%CI: -0.27, -0.11; Figure 3) and pair-based fledgling success declined by 0.21 fledglings per pair per year (95% CI: -0.34, -0.08; Figure 4) where pairs was defined as half the maximum number of adults counted during any one survey.

There were no significantly non-zero trends in reproductive parameters for piping plovers during the Cooperative Agreement period (Table 4).

Associations between Reproductive Outcomes and Habitat Parameters

Nest-level Models

Habitat parameters were summarized across nests for least terns (Table 5) and piping plovers (Table 6). Forb cover within $5m^2$ was selected for the model for least tern nesting success, though the parameter estimate for this variable was not significantly different from 0 (p=0.2552). There were no variables that reduced the AIC statistic from the null model for least tern fledging success. This result was due to the fact that the habitat variables lacked variation, being entirely zeros.

There were no variables that reduced the AIC statistic for piping plover nesting success or piping plover fledging success. This result was due to the fact that the habitat variables lacked variation, being entirely composed of zeros.

Colony-level Statistical Models

Habitat parameters were summarized across nests for least terns (Table 7) and piping plovers (Table 8).

Least Terns

The model for total nests initiated was based on 23 observations and contained the effect of distance to nearest channel. A larger mean number of nests initiated was associated with sandpits with shorter distances to the nearest channel ($p=0.0359$).

The models for nest-based hatching success was based on 21 observations and contained the effects of herbicide application and distance to channel, though neither parameter estimate was significantly different from zero.

The model for nest-based fledging success and pair-based fledging success (with pair defined as half of the maximum number of adults) were based on 19 observations, and contained the effect of pond size. Smaller areas of water were associated with sandpits with greater mean nest-based fledging success ($p=0.0305$) and greater mean pair-based fledging success ($p=0.0085$).

The model for Mayfield daily survival rate was based on 23 observations and contained the effects of pond size, distance to woods, and distance to channel. Higher mean survival rate was associated with sandpits with larger areas of water ($p<0.0001$), longer distances to the nearest forest ($p=0.0464$), and longer distances to channel ($p=0.0780$).

The model for pair-based fledging success was not significantly improved over the null model with the addition of any habitat parameter, when pair was defined as the maximum number of nests and broods. The models for nest success and Mayfield incubation period survival rate were not significantly improved over the null model with the addition of any habitat parameter.

Piping Plovers

The model for total nests initiated was based on 21 observations and contained the effects of acres of bare sand and percentage of open water within 2 miles. A larger mean number of nests initiated were associated with sandpits with larger areas of bare sand ($p=0.0042$) and larger areas of open water within 2 miles ($p=0.0525$).

The model for nest-based hatching success was based on 19 observations and contained the effect of percentage of sand and gravel and pond size. Greater mean hatching success was associated with sandpits with a smaller percentage area of sand and gravel within 2 miles ($p=0.1280$) and smaller areas of water ($p=0.0406$).

The model for nesting success was based on 21 observations and contained the effect of percentage of open water within 2 miles. Greater mean nesting success was associated with sandpits with larger areas of open water within 2 miles ($p=0.0525$).

The model for Mayfield incubation period survival rate was based on 21 observations and contained the effects of bare sand area and distance to channel. Higher mean survival rate was associated with sandpits with larger areas of bare sand (p=0.0083) and longer distances to channel (p=0.0997).

The models for nest-based fledging success, Mayfield daily survival rate, and pair-based fledging success were not significantly improved over the null model with the addition of any habitat parameter, regardless of the pair definition.

DISSCUSSION

This protocol was designed to monitor terns and plovers nesting on the river and on both constructed islands and sandpit locations. The monitoring surveys found nesting birds only at sandpit areas and the following discussion is focused on the analyses of habitat and reproductive outcomes at sandpits.

Trends in Reproductive Parameters

Significant trends in hatching and fledging success for least terns indicate a decline in reproductive success during the Cooperative Agreement period. The increase in nests initiated was probably due to re-nesting attempts associated with the decreased hatching success. Changes in the Mayfield survival rates and the pair-based fledging success (using nests in the definition of pair) do not reflect the same trend, as they were not significantly different from zero. There were no significant trends in reproductive parameters detected during the Cooperative Agreement period for piping plovers.

Nest-level Statistical Models

Models constructed to quantify the associations between reproductive outcomes and habitat parameters at the nest level were not very informative. Monitoring of nests was hampered by access at three day intervals at some sandpits, which precluded the calculation of reproductive parameters. On the sandpits for which reproductive parameters could be calculated, there was intensive vegetation management resulting in “0” values for all vegetative habitat parameters. The combination of these events resulted in a dataset with very little information for statistical associations.

Colony-level Statistical Models

Models constructed to quantify the associations between reproductive outcomes and habitat parameters at the colony level provide an indication of the association. These models were based on 19 to 23 observations and incorporated covariance structures suitable for repeated measures on the same sample of sandpits over the six-year time frame.

For least terns, colonies closer to the river had lower daily survival rates. Colonies closer to the river also had more nests initiated, possibly because of re-nesting attempts associated with failed nests. Colonies also had higher mean survival rates when they were further from wooded areas, which may be attributed to the use of wooded areas by predators. It is likely that there is an interaction between the distance to the river and the distance to wooded areas.

Pond size at sandpits was associated with fledging success and survival rate for least terns, though there was a negative association with fledging success and a positive association with survival rate. In other words there was a higher mean fledging success on smaller ponds, and higher daily survival on larger ponds.

The management indicator variables were rarely selected for inclusion in the models for least tern. This result indicates there was no significant association between reproductive outcome and herbicide, trapping, or fencing and was likely due to a lack of variation in the dataset, as the majority of sandpits received management during the Cooperative Agreement period.

For piping plovers, colonies closer to the river had lower daily survival rates. Colonies with large areas of bare sand had higher daily survival rates and more nests initiated on average. There were also more nests initiated in areas with large areas of open water and these areas had higher nesting success on average.

Hatching success for piping plovers was better in areas with smaller areas of sand and gravel within 2 miles and smaller areas of water adjacent to the nesting substrate.

The management indicator variables were not selected for inclusion in the models for piping plover. This result indicates there was no significant association between reproductive outcome and herbicide, trapping, or fencing and was likely due to a lack of variation in the dataset, as the majority of sandpits received management during the Cooperative Agreement period.

REFERENCES

Johnson, D.H. 1979. Estimating nest success: The Mayfield method and an alternative. The Auk 94:651-661.

Littell, R.C., G.A. Milliken, W.W. Stroup, R.D. Wolfinger. 1996. SAS System for mixed models. SAS Institute Inc. Cary, NC, USA.

Platte River Endangered Species Partnership (PRESP). 2002. Protocol for monitoring reproductive success and reproductive habitat parameters of least terns and piping plovers in the central Platte River valley, unpublished material, May 1, 2002.

Rawlings, J. O., S. G. Pantula, and D. A. Dickey. 1998. Applied regression analysis: a research tool, 2nd edition. Springer-Verlag, New York.

USBOR (U.S. Bureau of Reclamation). 2000. Central Platte River 1998 Land Cover/Land Use Mapping Project, Nebraska. Remote Sensing and Geographic Information Group (RSGIG) of the Bureau of Reclamation's Technical Service Center. Technical Memorandum No. 8260-00-08.

Urquhart, N.S., S.G.Paulsen, and D.P. Larsen. 1998. Monitoring for policy-relevant regional trends over time. Ecological Applications. 8(2) 246-257.

TABLES

Table 1. Reproductive parameter estimates for least terns on sandpits and constructed islands in the Cooperative Agreement study area. The first estimate of pair-based fledgling success used the maximum number of nests and number of broods at any one survey to estimate the number of pairs, the second estimate used half the maximum number of adults counted during any one survey to estimate the number of pairs.

Year	n	Total nests initiated	Nest-based Hatching Success	Nesting Success	Nest-based Fledging Success	Pair-based Fledging Success	Pair-based Fledging Success 2	Mayfield Daily Survival Rate	Mayfield Incubation Period Survival Rate
2001	4	27	1.70	0.74	1.63	.	2.15	0.98	0.70
2002	4	39	1.67	0.69	1.51	1.79	1.48	0.98	0.70
2003	4	49	1.27	0.63	1.16	1.84	1.81	0.98	0.62
2004	4	48	1.50	0.69	1.25	1.58	1.71	0.98	0.70
2005	4	56	1.30	0.68	1.11	1.51	1.20	0.98	0.70
2006	3	49	0.78	0.39	0.51	0.74	0.68	0.96	0.46

Table 2. Reproductive parameter estimates for piping plovers on sandpits and constructed islands in the Cooperative Agreement study area. The first estimate of pair-based fledgling success used the maximum number of nests and number of broods at any one survey to estimate the number of pairs, the second estimate used half the maximum number of adults counted during any one survey to estimate the number of pairs.

Year	n	Total nests initiated	Nest-based Hatching Success	Nesting Success	Nest-based Fledging Success	Pair-based Fledging Success	Pair-based Fledging Success 2	Mayfield Daily Survival Rate	Mayfield Incubation Period Survival Rate
2001	4	10	2.80	0.80	2.00	.	2.22	0.98	0.53
2002	3	15	2.67	0.87	1.87	2.33	2.55	0.99	0.75
2003	3	15	2.87	0.87	1.47	1.83	2.00	0.99	0.85
2004	4	13	2.62	0.69	1.77	1.92	1.70	0.98	0.63
2005	4	20	2.30	0.75	1.40	2.00	2.33	0.98	0.64
2006	3	15	2.47	0.73	1.93	2.64	2.90	0.98	0.65

Table 3. Trends (per year) in reproductive parameters for least terns, 2001-2006. Asterisks indicate significant non-zero trend.

Parameter	n	Trend	95% Confidence Interval
Total Nests Initiated	5	1.443	(0.33, 2.56)*
Nest-based Hatching Success	4	-0.192	(-0.22, -0.17)*
Nesting success	5	0.007	(-0.11, 0.12)
Nest-based Fledging Success	4	-0.192	(-0.27, -0.11)*
Pair-based Fledgling Success	4	-0.124	(-0.39, 0.14)
Pair-based Fledgling Success 2	4	-0.211	(-0.34, -0.08)*
Mayfield Daily Survival Rate	5	0.001	(-0.01, 0.01)
Mayfield Incubation Period Survival Rate	5	0.005	(-0.09, 0.10)

Table 4. Trends (per year) in reproductive parameters for piping plovers, 2001-2006. There were no significant non-zero trends estimated.

Parameter	n	Trend	95% Confidence Interval
Total Nests Initiated	6	0.157	(-0.05, 0.36)
Nest-based Hatching Success	4	-0.096	(-0.26, 0.07)
Nesting success	6	-0.017	(-0.05, 0.01)
Nest-based Fledging Success	4	-0.153	(-0.34, 0.03)
Pair-based Fledgling Success	4	-0.008	(-0.16, 0.14)
Pair-based Fledgling Success 2	4	-0.027	(-0.22, 0.17)
Mayfield Daily Survival Rate	6	0	(0.00, 0.00)
Mayfield Incubation Period Survival Rate	6	-0.015	(-0.05, 0.02)

Table 5. Habitat parameters estimated at least tern nests on sandpits during the Cooperative Agreement period.

Habitat parameters	n	Mean	Minimum	Maximum
Cover of forbs within $1m^2$	84	2.14	0	20
Cover of forbs within $5m^2$	84	3.27	0	30
Cover of grass within $1m^2$	84	0.12	0	5
Cover of grass within $5m^2$	84	0.26	0	5
Cover of woody vegetation within $1m^2$	84	0.00	0	0
Cover of woody vegetation within $5m^2$	84	0.00	0	0
Nest elevation (meters)	84	1.58	0	4.6
Nest Management	144	0.01	0	1
Number of stems of forbs within $1m^2$	84	2.48	0	20
Number of stems of forbs within $5m^2$	84	12.58	0	100
Number of stems of grass within $1m^2$	84	0.21	0	10
Number of stems of grass within $5m^2$	84	2.04	0	50
Number of stems of woody vegetation within $1m^2$	84	0.00	0	0
Number of stems of woody vegetation within $5m^2$	84	0.00	0	0
Height of vegetation within $1m^2$ (meters)	61	0.07	0	0.3
Height of vegetation within $5m^2$ (meters)	68	0.10	0	0.5

Table 6. Habitat parameters estimated at piping plover nests on sandpits during the Cooperative Agreement period.

Habitat parameter	n	Mean	Minimum	Maximum
Cover of forbs within 1m^2	35	1.00	0	5
Cover of forbs within 5m^2	35	1.20	0	10
Cover of grass within 1m^2	35	0.23	0	5
Cover of grass within 5m^2	35	0.20	0	2
Cover of woody vegetation within 1m^2	35	0.71	0	20
Cover of woody vegetation within 5m^2	35	0.60	0	20
Nest elevation (meters)	30	1.72	0.2	3.05
Nest Management	57	0.04	0	1
Number of stems of forbs within 1m^2	35	2.14	0	20
Number of stems of forbs within 5m^2	35	7.51	0	100
Number of stems of grass within 1m^2	35	0.23	0	5
Number of stems of grass within 5m^2	35	0.71	0	6
Number of stems of woody vegetation within 1m^2	35	0.17	0	5
Number of stems of woody vegetation within 5m^2	35	0.89	0	30
Height of vegetation within 1m^2 (meters)	26	0.11	0	0.5
Height of vegetation within 5m^2 (meters)	28	0.10	0	0.5

Table 7. Habitat parameters estimated at colonies with least tern nests during the Cooperative Agreement period.

Habitat parameter	n	Mean	Minimum	Maximum
Distance to nearest channel	5	957.60	220.00	2190.00
Distance to nearest wooded area	5	91.00	0.00	200.00
Percent sand and gravel within 2 mile area	5	1.65	0.80	2.71
Percent open water within 2 mile area	5	2.81	1.47	3.88
Percent wooden areas within 2 mile area	5	13.23	7.04	17.39
Acres of sand on 1998 photographs	5	28.94	16.69	50.93
Acres of sand on 2003 photographs	5	26.83	15.10	34.68
Acres of sand on 2005 photographs	5	30.81	16.47	44.11
Acres of water on 1998 photographs	5	38.18	14.23	53.12
Acres of water on 2003 photographs	5	38.94	19.81	49.15
Acres of water on 2005 photographs	5	41.44	21.05	49.59

Table 8. Habitat parameters estimated at colonies with piping plover nests during the Cooperative Agreement period.

Habitat parameter	n	Mean	Minimum	Maximum
Distance to nearest channel	6	955.67	190.00	2190.00
Distance to nearest wooded area	6	108.00	20.00	200.00
Percent sand and gravel within 2 mile area	6	1.61	0.80	2.71
Percent open water within 2 mile area	6	2.77	1.59	3.88
Percent wooden areas within 2 mile area	6	16.42	7.04	27.68
Acres of sand on 1998 photographs	6	24.20	0.48	50.93
Acres of sand on 2003 photographs	6	25.86	0.03	42.55
Acres of sand on 2005 photographs	6	28.83	0.03	44.11
Acres of water on 1998 photographs	6	36.30	2.44	53.12
Acres of water on 2003 photographs	6	38.56	2.32	54.16
Acres of water on 2005 photographs	6	40.79	2.37	56.18

FIGURES

Figure 1. Trend in number of nests initiated by least terns during the Cooperative Agreement Period. Each colony is represented by a linear regression line.

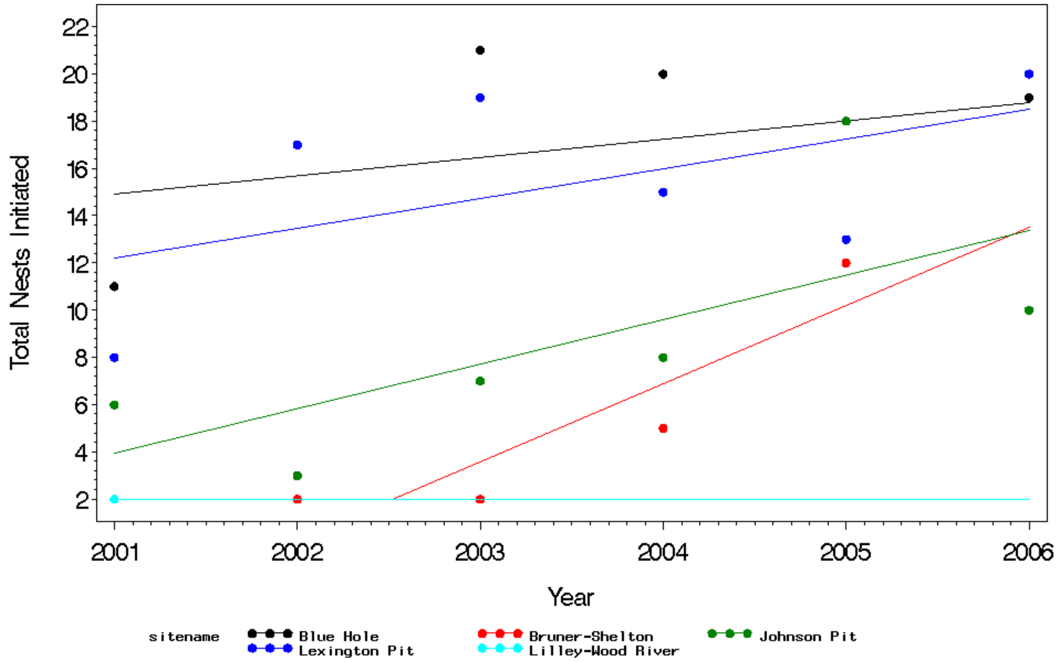

Figure 2. Trend in nest-based hatching success by least terns during the Cooperative Agreement Period. Each colony is represented by a linear regression line.

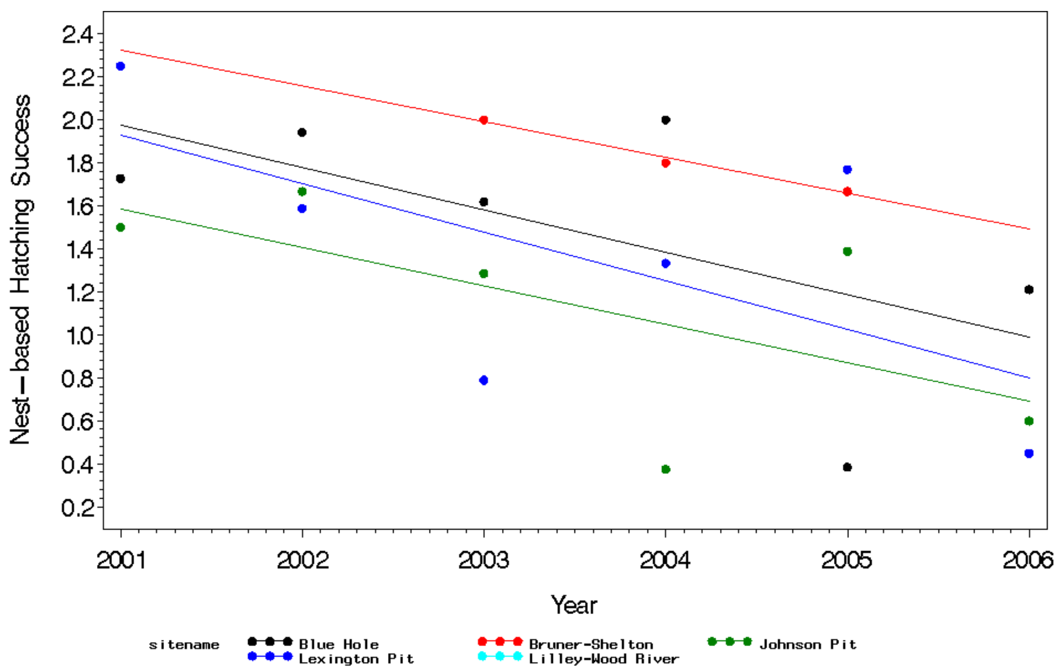

Figure 3. Trend in nest-based fledging success by least terns during the Cooperative Agreement Period. Each colony is represented by a linear regression line.

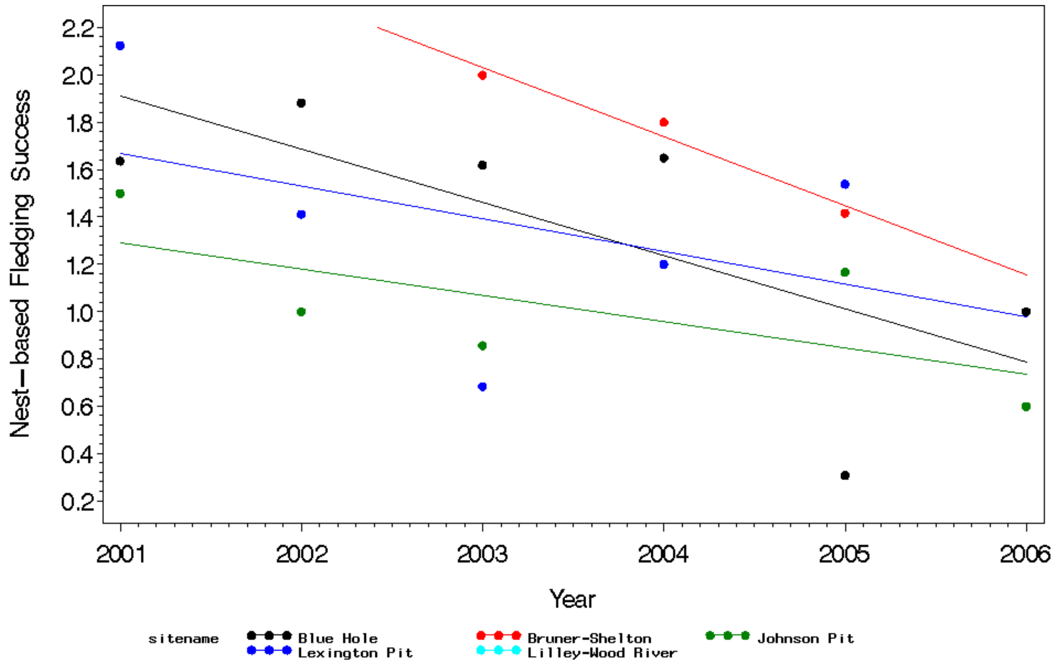

Figure 4. Trend in pair-based fledging success by least terns during the Cooperative Agreement Period. Each colony is represented by a linear regression line.