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Source: *Waterbirds*, 37(4):371-380. 2014.

Published By: The Waterbird Society

DOI: <http://dx.doi.org/10.1675/063.037.0404>

URL: <http://www.bioone.org/doi/full/10.1675/063.037.0404>

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# Reproductive Success of the American Oystercatcher (*Haematopus palliatus*) in Texas

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**Abstract.**—The American Oystercatcher (*Haematopus palliatus*) is listed as a Species of High Concern in the United States Shorebird Conservation Plan due to a small population size and threats during its annual cycle. Previous studies of the American Oystercatcher have focused on Atlantic Coast populations; however, little is known about the reproductive success of the western Gulf Coast population. The objective of this study was to determine nest and brood survival of American Oystercatchers in Texas. A total of 337 nests and 121 broods were monitored on the Texas Gulf Coast during 2011-2013. The top model for nest survival in Program MARK included a linear decline in survival across the nesting season and as nests aged. Survival also declined as island size and foraging habitat near the nest site increased. The probability of a nest surviving from mean initiation date to hatching was 0.384 (95% CI = 0.317, 0.451). The top model for brood survival included a linear decline in survival across the season and an increase in survival as broods aged. Brood survival also varied among years and coastal region. The probability of a brood surviving from mean hatch date to 35 days after hatch ranged from 0.397 (95% CI = 0.204, 0.578) in 2013 to 0.887 (95% CI = 0.673, 0.964) in 2011 across all regions. Known causes of nest and brood loss included beach overwash, depredation, and starvation. This study provides the first estimates of nest and brood survival of the American Oystercatcher along the western Gulf Coast. The additional insight into patterns of nest and brood survival in this species will be useful for future conservation planning efforts that target breeding American Oystercatchers. Received 21 March 2014, accepted 25 April 2014.

**Key words.**—American Oystercatcher, brood survival, *Haematopus palliatus*, nest survival, reproductive success, Texas.

Waterbirds 37(4): 371-380, 2014

The American Oystercatcher (*Haematopus palliatus*; hereafter, oystercatcher) is a conspicuous shorebird that relies on coastal habitats throughout its annual cycle. In a 2002-2003 range-wide survey, the United States population of the oystercatcher was estimated at 11,000 individuals with ~500 individuals in Texas (Brown *et al.* 2005). Oystercatchers are a long-lived species and do not begin breeding until 3-4 years of age. Nesting occurs on barrier island beaches, saltmarshes, dredge spoil islands, and shell rakes (American Oystercatcher Working Group *et al.* 2012). Once paired, adults are monogamous and exhibit biparental care throughout the nesting and brood-rearing stages. Reproductive success has been shown to vary among years and geographic loca-

tion, yet oystercatchers generally exhibit relatively low productivity (Davis *et al.* 2001; McGowan 2004; Murphy 2010). Causes of nest and brood loss have been found to include overwash from tides and storms, depredation of nests and young, starvation of young, and disturbance by humans (Sabine *et al.* 2006; Schulte 2012). Like many beach nesting birds, oystercatchers also are subject to habitat loss from increasing urban development, pollution, and sea-level rise (Brown *et al.* 2001).

The small population size, low productivity, and threats during all portions of the annual cycle led to the listing of the oystercatcher as a Species of High Concern in the United States Shorebird Conservation Plan (Brown *et al.* 2001). The oystercatcher also is

a species of concern according to the Texas Parks and Wildlife Department (Bender *et al.* 2005). After its listing, many studies were conducted to assess the reproductive success and population dynamics of the oystercatcher along the Atlantic Coast, yet no such research has been conducted along the western Gulf Coast.

This study is the first extensive monitoring of oystercatchers on the western Gulf Coast, and provides baseline data on the reproductive success of oystercatchers in Texas. The roles of environmental variables, including the amount of available foraging habitat and nesting-island characteristics, were examined in an effort to explain the variation in nest and brood survival. The results of this study will be useful in conducting range-wide conservation for this species and will assist management decisions for other coastal nesting species and habitat along the Texas Coast.

#### METHODS

##### Study Area

The Texas Gulf Coast consists of a network of barrier islands and coastal bays, with bay shoreline covering over 5,300 km. Our study area included six major bay systems along the Texas Gulf Coast (Fig. 1). Bays from East Matagorda Bay north were considered upper coast and those from Matagorda Bay to Corpus Christi Bay were central coast (Fig. 1). Oyster (*Crassostrea virginica*) reefs are common within these shallow bays and provide foraging habitat for oystercatchers. Potential nesting habitat included shell rakes, spoil islands, barrier islands, and the mainland. Tides are mainly wind-driven and are generally lower in the winter when winds are out of the north and higher in the spring when winds are from the south.

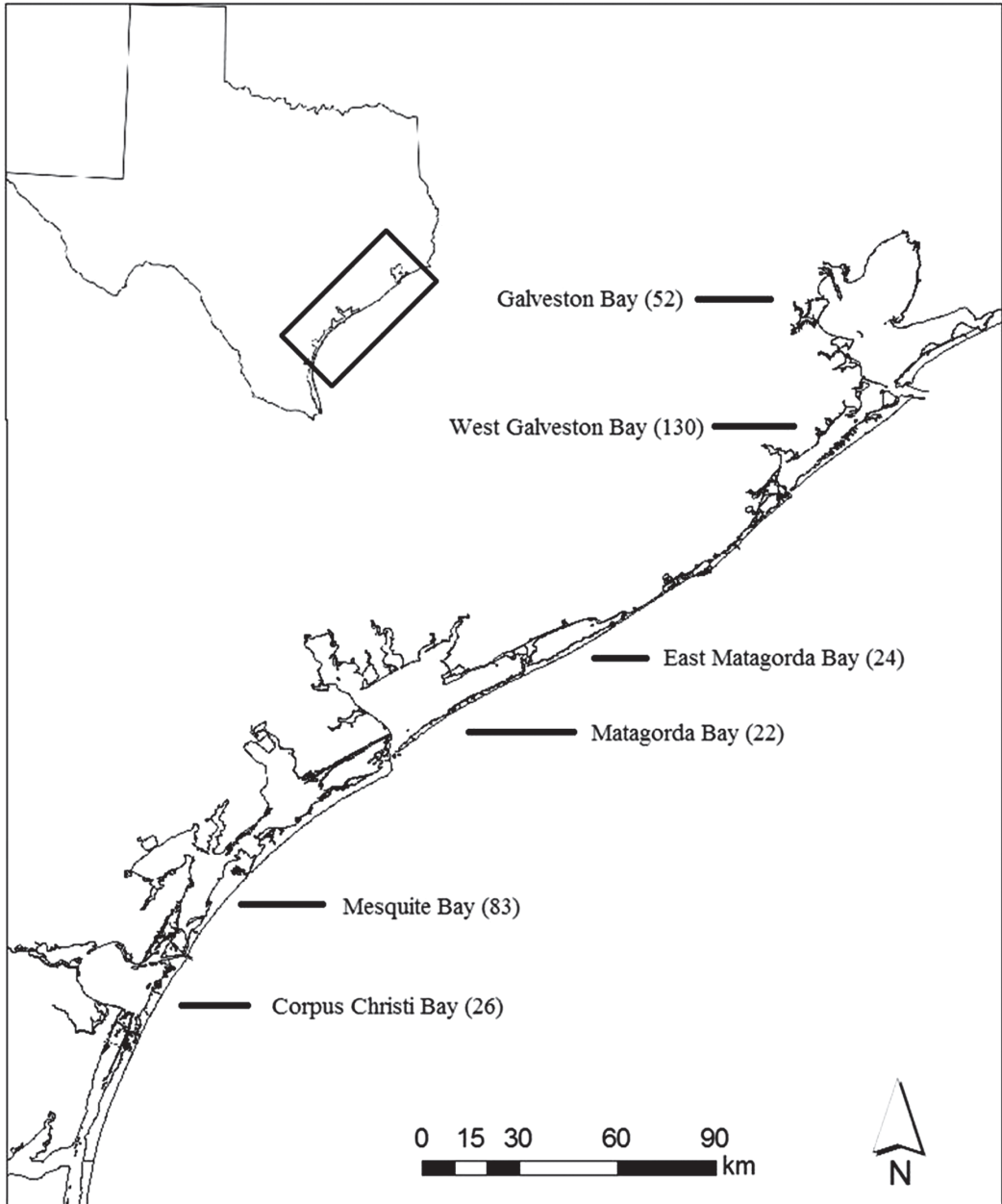
Colonial nesting waterbird species occur within the study area. Colonies are highly variable, both in abundance of breeding pairs and number of species present (Turner 2011). For example, some small islands may contain only a few nesting terns, whereas large islands may support thousands of nesting birds composed of several species. Larger colonies generally have a high density of nesting Laughing Gulls (*Leucophaeus atricilla*). Oystercatchers that nest on large colonial islands may have to expend more energy defending nests and broods from other nesting birds. These islands also are loud and active, which can attract predators. Based on known predators from previous studies on the Atlantic Coast, potential predators in our study area included Laughing Gull, coyote (*Canis latrans*), opossum (*Didel-*

*phis virginiana*), and raccoon (*Procyon lotor*) (Davis *et al.* 2001; Sabine *et al.* 2006; American Oystercatcher Working Group *et al.* 2012).

##### Nest and Brood Monitoring

Breeding pairs were monitored during February–July 2011–2013. We trapped territorial adults when possible using a noose carpet or whoosh net (Sutherland *et al.* 2004; McGowan and Simons 2005). An oystercatcher decoy was placed near the trap or net along with a recording of an oystercatcher call. Captured adults were banded with a stainless steel leg band and two duplicate, colored leg bands with unique alpha codes (one on each leg). Once a pair was observed incubating, we searched the area by foot to locate the nest and recorded the location with a hand-held Garmin GPS60, limiting the time spent at the nest site to < 5 min. If the nest contained  $\leq$  three eggs, we checked it the following week to determine clutch size. Initiation date was estimated by considering the clutch size when a nest was first discovered given oystercatchers lay eggs 24–36 hr apart (American Oystercatcher Working Group *et al.* 2012). We corroborated this approach by back dating from date of hatch and assumed a 27-day incubation period (American Oystercatcher Working Group *et al.* 2012). For nests that were first detected with a complete clutch, we estimated the initiation date as the midpoint between the last check and the date found and then corroborated by back-dating from date of hatch for those nests that were successful. Nests that were on colonial waterbird islands were checked by foot only once or not at all to reduce disturbance to the colony and to reduce the chances of nest depredation. If we did not check a nest by foot, we considered it to be active if the adult was incubating in the same spot  $\geq$  2 consecutive weeks. These nests were not used in our calculation of mean clutch size. We conducted subsequent nest checks once weekly (Range = 5–12 days) by observation through 10×50 binoculars from a boat anchored ~100 m from the nest to minimize disturbance, and considered nests active if an adult was incubating (Schulte 2012).

We used an incubation period of 27 days to estimate hatch date (American Oystercatcher Working Group *et al.* 2012) and considered nests successful when  $\geq$  one egg hatched. Evidence of a successful nest included direct observation of chicks, or adults behaving defensively or carrying whole food to the territory following hatch (Traut *et al.* 2006; Murphy 2010; Schulte 2012). In the event of nest failure, we made an effort to determine the cause of failure. Evidence of failure included partial or complete flooding of the nest or shell fragments in the nest; this was usually corroborated by the absence of an incubating adult or lack of any defensive behavior by the pair (Murphy 2010). We continued to monitor the pair following nest failure to determine if renesting attempts were made. For successful nests, we continued weekly monitoring following hatch and considered chicks successfully fledged at 35 days after hatch (American Oystercatcher Working Group *et al.* 2012). Chicks and broods were considered unsuccessful if chicks were found dead, if the adults did not dis-



**Figure 1.** Major bay systems included in the study area along the Texas Coast where breeding American Oystercatchers were monitored during 2011-2013, with number of nests in each bay system in parentheses.

play aggressive behavior or give alarm calls when approached, or if chicks were not seen in  $\geq 3$  consecutive weeks (Schulte 2012).

#### Environmental Variables

For every nest location, we measured the size of the island and distance to the mainland using ArcGIS and LandSat imagery (Environmental Systems Research Institute 2012). We measured distance as the shortest

straight-line distance from the island to the mainland or barrier island. For mainland nests, island size was recorded as 1,000 ha and distance to the mainland was recorded as 0 m.

We quantified the amount of foraging habitat within 50-m, 100-m, 150-m and 200-m buffers around each nest location. We used the Texas Benthic Habitat Dataset (National Oceanic and Atmospheric Administration 2004, 2007) and extracted the reef habitat class as this

type of benthic habitat is known to be a primary foraging habitat of oystercatchers (American Oystercatcher Working Group *et al.* 2012). We then used digitized bathymetry (National Oceanic and Atmospheric Administration 2012) and tide gauge data (National Oceanic and Atmospheric Administration 2013) to estimate the amount of reef within the foraging depth for oystercatchers during the tidal cycle (-0.28-0.10 m). Benthic habitat data were unavailable in the proximity of 14% of nests; therefore, the mean of known values for each buffer was used for nests with no data in all subsequent analyses.

#### Statistical Analysis

We estimated nest and brood survival of oystercatchers using the nest survival model (Dinsmore *et al.* 2002) in Program MARK (White and Burnham 1999). This model allows date of loss to be assigned to an interval and does not require an assumption about the precise time when an individual is lost or result in a loss of information caused by censoring an individual following the last live sighting. Our modeling approach follows the general advice of Burnham and Anderson (2002), and we used Akaike's information criterion corrected for bias due to small sample size ( $AIC_c$ ; Hurvich and Tsai 1995) to select among competing models. We compared survival estimates only among top models with  $\Delta AIC_c \leq 4$ , as models with  $\Delta AIC_c \leq 4$  are considered to have strong to moderate support over candidate models with  $\Delta AIC_c > 4$  (Burnham and Anderson 2002). We used survival estimates from the top model to calculate period survival of nests and broods. We also calculated pseudo  $r^2$  values (Nagelkerke 1991) to determine how well each model explained variation in nest and brood survival.

We tested the effects of seven variables (Table 1) on their ability to explain variation in nest and brood survival of oystercatchers. In 2011, data were collected only on the upper coast, and the sample size is smaller for

this year; therefore, a model to test for a coastal region effect was run as a preliminary analysis to determine if nests and broods would be best grouped by year or by year and region of coast. We used a hierarchical approach to model building (Dinsmore *et al.* 2002) and first tested for effects of individual covariates on constant survival. We then ran models that allowed survival to vary temporally. As the final step, we added covariates to the top temporal model to see if they improved the model. We used the top model with mean values of covariates to calculate period survival for nests and broods.

We used two-sample *t*-tests and considered differences significant if  $P = 0.05$  (SAS Institute, Inc. 2009) to determine if there were differences in clutch size and initiation date between first nest attempts and renests. If our assumption of equal variance was not met, we used the Satterthwaite approximation (SAS Institute, Inc. 2009). We report means  $\pm$  SD for environmental variables.

## RESULTS

### Environmental Variables

Nests were located on bay islands ( $n = 301$ ), barrier islands ( $n = 8$ ), and the mainland ( $n = 28$ ). Islands were variable in size, ranging from 0.008 to 351 ha ( $\bar{x} = 6.05 \pm 37.24$ ). We separated bay islands and barrier islands because barrier islands are more typical of mainland sites in terms of area and ability to support mammalian predators. The distance a nest site was from the mainland or barrier island ranged from 0 to 3,374 m ( $\bar{x} = 747.03 \pm 709.87$ ).

**Table 1. Variables used in Program MARK to assess variation in nest and brood survival of American Oystercatchers breeding in Texas from 2011-2013.**

Variable	Justification
Year	Survival has been shown to vary between years (Sabine <i>et al.</i> 2006).
Linear Time Trend (T) and Quadratic Time Trend (TT)	Survival has been shown to vary over the course of the breeding season (Schulte 2012).
Nest / Brood Age	Mortality has been observed to be higher in younger shorebird chicks (Colwell <i>et al.</i> 2007).
Island Size (IS)	Large islands, such as barrier islands, can support mammalian predators, whereas small islands may be susceptible to tidal overwash.
Distance to Mainland (DM)	An island close to the mainland may be more accessible to mammals and people.
% Foraging Habitat (FH)	The amount of nearby foraging habitat may allow adults to remain nearby to defend the brood (Nol 1989).

## Nest Survival

We monitored 337 nests across the 3 years of the study (Table 2). Thirty-four percent of nests ( $n = 114$ ) were located in West Galveston Bay. Two thirds ( $n = 227$ ) of nests were first nest attempts, and one third ( $n = 110$ ) were re-nest attempts. Clutch size ranged from one to three eggs, and mean clutch size was 2.4 eggs ( $n = 254$  clutches of known size). Mean clutch size for first nest attempts was 2.5 eggs ( $n = 168$ ) and was lower for re-nests at 2.2 eggs ( $n = 86$ ;  $t_{252} = 2.8$ ,  $P = 0.005$ ). The nesting season, from first nest initiation to last nest hatched or failed, was 156 days. The earliest nest was initiated on 15 February 2013, and the latest nest initiation was 18 June 2013. Overall mean nest initiation date was 13 April. Seventy-four percent of first nest attempts were initiated between 1 March and 30 April, and mean initiation date for first nest attempts was 2 April. Mean nest initiation for first nest attempts was earlier in 2011 (26 March;  $n = 50$ ) than 2012 (15 April;  $n = 148$ ;  $t_{71,544} = -4.3$ ,  $P < 0.001$ ) and earlier in 2013 (24 March;  $n = 139$ ) than 2012 ( $t_{266,52} = 4.8$ ,  $P < 0.001$ ). Nest initiation date did not differ between 2011 and 2013 ( $t_{187} = -1.0$ ,  $P = 0.306$ ).

Most re-nest attempts were initiated in April ( $n = 32$ ) and May ( $n = 67$ ), and mean initiation date for all re-nests was 7 May. There was little variation in mean initiation date among years; 8 May in 2011, 7 May in 2012, and 6 May in 2013.

Preliminary models used in Program MARK included 2012 and 2013 nests grouped by coastal region (upper coast and central coast), as sampling in 2011 was restricted to the upper coast. This model did not support a coastal region effect ( $\beta_{\text{Coast}} =$

$0.025$ ,  $SE = 0.149$ ,  $95\% \text{ CI} = -0.267, 0.318$ ); therefore, nests were pooled across coastal regions in subsequent analyses. Preliminary analysis also showed that of the four foraging habitat buffers, the 50-m buffer best explained variation in nest survival ( $> 3.84 \text{ AIC}_c$  units better than other buffers); therefore, the other three buffers were excluded from further analyses.

Final modeling results showed that a linear time trend, nest age, island size, and percent foraging habitat within 50 m were all important predictors of nest survival (Table 3). A linear time trend and nest age occurred in the top four models, which accounted for  $> 99\%$  of the cumulative  $\text{AIC}_c$  weights. In the top model, nest survival declined across the nesting season ( $\beta_T = -0.009$ ,  $SE = 0.003$ ,  $95\% \text{ CI} = -0.013, -0.004$ ), declined with increasing amount of foraging habitat within 50 m ( $\beta_{\text{FH}} = -0.012$ ,  $SE = 0.005$ ,  $95\% \text{ CI} = -0.022, -0.002$ ), and declined as nests aged ( $\beta_{\text{Age}} = -0.072$ ,  $SE = 0.01$ ,  $95\% \text{ CI} = -0.909, -0.054$ ). The effect of island size was weak ( $95\% \text{ CI}$  for this effect included zero). There was poor support that nest survival differed between years ( $\Delta\text{AIC}_c = 61.47$  for best year effect model), and we found no evidence that nest survival was affected by distance to mainland ( $\beta_{\text{DM}} = 0.00002$ ,  $SE = 0.0001$ ,  $95\% \text{ CI} = -0.0002, 0.0002$ ).

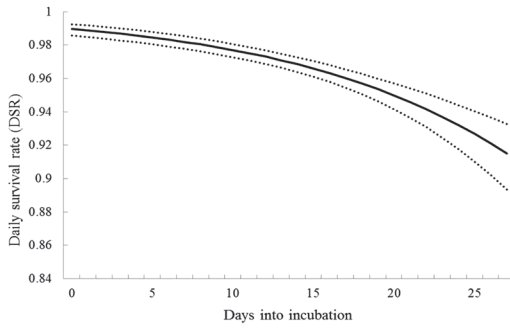
The pseudo  $r^2$  of the top model indicated the model explained 26% of the variation in nest survival (Table 3). The top model was used to estimate period survival from the mean nest initiation date (13 April) to hatching. Based on this model, the probability of a nest surviving the 27-day incubation period was 0.384 ( $95\% \text{ CI} = 0.317, 0.451$ ; Fig. 2). The causes of nest failure included overwash ( $n = 25$ ), depredation ( $n = 5$ ), and unknown causes ( $n = 181$ ).

**Table 2.** Measures of productivity recorded for American Oystercatchers nesting in Texas during 2011-2013.

Year	Pairs	Nests	Broods	Chicks	Fledglings	Productivity
2011	40	50	28	45	32	0.80
2012	95	148	44	62*	28	0.29
2013	92	139	54	80*	35	0.38
Total		337	126	187	95	

\*Two nests in 2012 and two nests in 2013 had an unknown number of chicks and were counted as one chick per nest.





**Figure 2.** Daily nest survival rates and 95% confidence intervals, from mean initiation date to hatching, of American Oystercatcher nests monitored in Texas from February-July 2011-2013. These results are from the top model that included additive effects of a linear seasonal pattern within years, nest age, and covariates for island size and the amount of foraging habitat within 50 m of the nest. Survival was predicted using mean covariate values from this top model.

### Brood Survival

We monitored 121 broods until 35 days after hatch or until failure was observed. Overall productivity was 0.42 fledglings/pair (Table 2). Seventy-six of the broods were successful, and about half (50.8%) of the chicks that hatched survived to 35 days.

Our modeling results indicated that there was a year effect, with survival in 2011 greater than that in 2013 ( $\beta_{2011} = 2.045$ , SE = 0.620, 95% CI = 0.829, 3.260). Survival in 2012 was similar to 2013. There also was a moderate effect of coastal region on survival, with lower survival on the upper coast than the central coast ( $\beta_{\text{UpperCoast}} = -0.656$ , SE = 0.336, 95% CI = -1.315, 0.002). Daily survival rate ranged from 0.975-0.997 among years and coastal regions. Our results indicated that year, coastal region, a linear time trend, and brood age were important predictors of brood survival (Table 4). Year, coastal region, and linear time trend occurred in the

top four models, which accounted for > 99% of the cumulative AIC<sub>c</sub> weights. In the top model, brood survival was higher in 2011 than 2013 ( $\beta_{2011} = 2.052$ , SE = 0.622, 95% CI = 0.834, 3.271), was lower on the upper coast ( $\beta_{\text{Coast}} = -0.640$ , SE = 0.346, 95% CI = -1.319, 0.038), declined across the season ( $\beta_{\text{T}} = -0.021$ , SE = 0.006, 95% CI = -0.033, -0.009), and increased as broods aged ( $\beta_{\text{Age}} = 0.020$ , SE = 0.009, 95% CI = 0.003, 0.037).

The 150-m and 200-m foraging habitat buffers were negatively related to brood survival, although both were weak effects as the confidence intervals included zero ( $\beta_{\text{FH}_{150\text{m}}} = -0.03$ , SE = 0.02, 95% CI = -0.06, 0.01;  $\beta_{\text{FH}_{200\text{m}}} = -0.03$ , SE = 0.02, 95% CI = -0.07, 0.01). Island size and distance to mainland were not correlated with brood survival ( $\beta_{\text{IS}} = -0.0003$ , SE = 0.001, 95% CI = -0.002, 0.001;  $\beta_{\text{DM}} = -0.0001$ , SE = 0.0002, 95% CI = -0.001, 0.0003).

The pseudo  $r^2$  value indicated the top model explained 25% of the variation in brood survival (Table 4). Additionally, the top model indicated that the probability of a brood surviving from the mean hatch date (4 May) to 35 days after hatch ranged from 0.397 (95% CI = 0.204, 0.578) in 2013 to 0.887 (95% CI = 0.673, 0.964) in 2011 (Fig. 3). Causes of brood loss included unknown causes ( $n = 38$ ), starvation ( $n = 5$ ), depredation ( $n = 1$ ), and overwash ( $n = 1$ ).

### DISCUSSION

This study demonstrates that nest survival of oystercatchers is influenced by a combination of environmental and temporal factors. The top model showed evidence for a negative linear time trend. A decrease in nest survival as the season progresses is common in birds and has been documented in

**Table 3.** Summary of model results for American Oystercatcher nest survival in Texas during 2011-2013 (T = linear time trend, IS = island size, FH = foraging habitat).

Model	$\Delta\text{AIC}_c$	$w_i$	$K$	Dev	Pseudo $r^2$
T + Nest Age + IS + FH <sub>(50m)</sub>	0.00	0.61	5	1,022.28	0.26
T + Nest Age + FH <sub>(50m)</sub>	2.13	0.21	4	1,026.41	0.25
T + Nest Age + IS	2.83	0.15	4	1,027.11	0.25
T + Nest Age	6.18	0.03	3	1,032.46	0.24

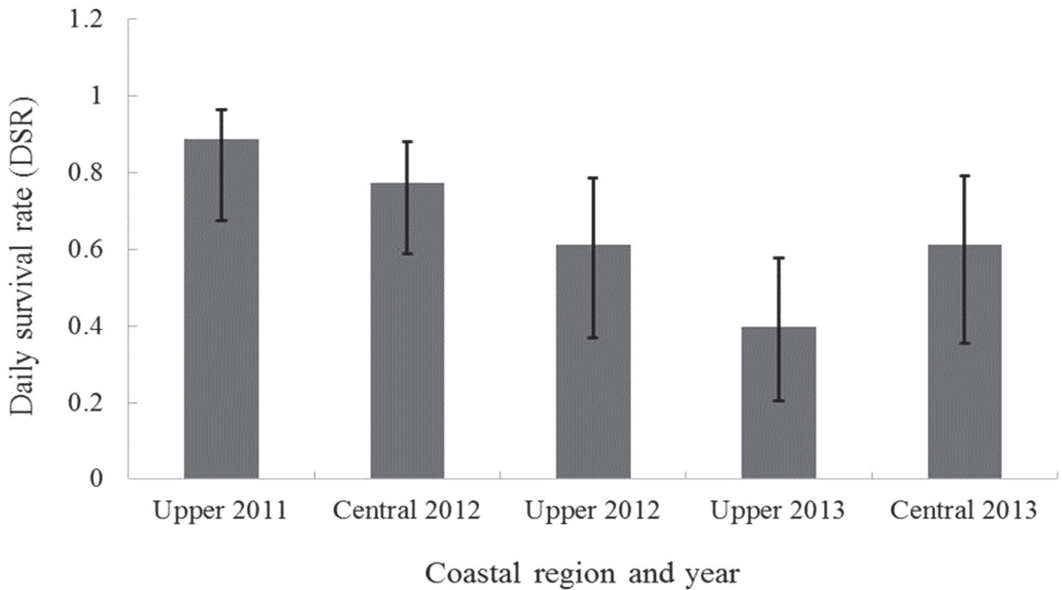
**Table 4. Summary of model results for American Oystercatcher brood survival in Texas during 2011-2013 (Coast = coastal region, T = linear time trend, FH = foraging habitat).**

Model	$\Delta AIC_c$	$w_i$	$K$	Dev	Pseudo $r^2$
Year + Coast + T + Brood Age	0.00	0.32	6	284.78	0.25
Year + Coast + T + Brood Age + FH <sub>(150m)</sub>	0.29	0.27	7	283.06	0.26
Year + Coast + T + Brood Age + FH <sub>(200m)</sub>	0.55	0.24	7	283.32	0.26
Year + Coast + T	1.27	0.17	5	288.06	0.22

oystercatchers nesting along the Atlantic Coast (Murphy 2010; Schulte 2012). There are multiple factors, such as increased nesting activity of other species leading to more interspecific interactions and increased recreational activity by humans leading to more disturbance to nesting birds, that cause nest survival to decrease later in the season; Rusticali *et al.* (1999) found that Eurasian Oystercatchers (*H. ostralegus*) nesting later in the season were affected more by Yellow-legged Gull (*L. michahellis*) nest depredation than early nesters. Tjørve and Underhill (2008) also found nest survival to be lower for later nesting African Black Oystercatchers (*H. moquini*).

We also found that nest survival declined as nest age increased. This was unexpected

as several studies have found the converse; Klett and Johnson (1982) found that Mallard (*Anas platyrhynchos*) and Blue-winged Teal (*A. discors*) nests had higher daily survival during incubation than laying. Dinsmore *et al.* (2002) also found that Mountain Plover (*Charadrius montanus*) nest survival increased with nest age. As nest age increases, adults have invested more in the nest and typically increase defensive behavior as a result (Smith and Wilson 2010). Similar to our findings, Johnson and Walters (2008) found a negative relationship between nest survival and nest age in Western Sandpipers (*Calidris mauri*) and suggested that this effect was more important for pairs nesting in the area for the first time. They suggested that pairs with more experience may be better able to



**Figure 3. Daily brood survival rates and 95% confidence intervals, from mean hatch date to 35 days after hatch, of American Oystercatcher broods monitored in Texas during March-July 2011-2013. These results are from the top model that included additive effects of year, coastal region, a linear seasonal pattern within years, and brood age. Survival was predicted using mean covariate values from this top model.**



balance energy requirements and incubation duties than pairs with little to no experience. Such comparisons were not possible in this study.

The negative effect of foraging habitat within a 50-m buffer is not well understood, and the relationship between nest survival and foraging habitat should be examined more closely. More foraging habitat around the nest site may lead to more foraging activity by waterbirds and consequently more time defending territories by adult oystercatchers. We also found a weak negative relationship with island size in our top model, indicating nest survival decreased with increasing island size. Nests on the mainland or large islands may be more susceptible to depredation.

The proportion of nests that successfully hatched (37%) was relatively high compared to several studies on the Atlantic Coast. Davis *et al.* (2001) reported hatching success of 13% on barrier islands in North Carolina, with depredation accounting for 76% of nest failures. McGowan (2004) found that 24% of nests survived to hatch for combined sites of barrier islands and river islands; however, the probability of a nest hatching on the barrier islands was 76% lower than on river islands. Similarly, Virzi (2008) reported a lower hatching success on barrier islands (6%) than isolated islands (37%). Murphy (2010) found a high hatching success (67%) of oystercatcher nests on Nantucket Island, Massachusetts, as a result of an absence of predators on the island. The relatively high success rates in Texas may be due to oystercatchers primarily nesting on relatively isolated islands free of mammalian predators.

Many studies of American Oystercatcher reproductive success have reported nest survival, whereas relatively few have documented brood survival. Mortality of chicks has been documented as a cause of reproductive failure in shorebirds, and nest survival alone is not adequate when estimating reproductive output for populations. For example, Murphy (2010) found nest survival of oystercatchers to be relatively high, but subsequent chick survival to be low, causing low overall productivity. This illustrates the importance

of estimating nest and brood survival when striving for a holistic understanding of reproductive success in oystercatchers.

Our top model indicated that brood survival varied among years. A yearly variation in survival is common; there may be more severe weather events in a particular year that could lead to low survival. We also found that coastal region weakly influenced brood survival of oystercatchers, indicating the daily survival rate was 1% higher on the central coast compared to the upper coast; however, this was a weak influence and appears not to be biologically meaningful.

The negative linear time trend indicated that brood survival decreased as the season progressed, and the reasons for this negative relationship may be similar to those discussed for nest survival. The positive influence of brood age on survival indicates that as chicks become older survival increases. This is not surprising, as young chicks are likely more vulnerable to extreme temperatures and depredation than older, larger chicks (Loefering and Fraser 1995; Colwell *et al.* 2007). Schulte (2012) monitored 121 American Oystercatcher chicks using radio telemetry and found that mortality was highest within the first week after hatching and during the early fledging period. Chick mortality is most common at an early age in other oystercatcher species as well. In a study of Eurasian Oystercatchers, Kersten and Brenninkmeijer (1995) found that only 44% of chicks survived to 12 days old. Hazlitt and Butler (2001) also found mortality to be highest within the first week after hatching in Black Oystercatchers (*H. bachmani*).

In our study, fledging success (percent of successful nests that produced successful broods) ranged from 48 to 89%. This is at the high end of the range of fledging success documented in Atlantic Coast studies (38-75%; Davis *et al.* 2001; Sabine *et al.* 2006; Murphy 2010). Productivity estimates (fledglings/pair) were also relatively high in our study compared to Atlantic Coast studies. Davis *et al.* (2001) found productivity to range from 0.04 to 0.15, Schulte (2012) recorded productivity of 0.31, and Sabine *et al.* (2006) estimated overall productivity at 0.71.

The most common causes of nest and brood failure, depredation and overwash, also have been recorded for the Atlantic Coast population (Davis *et al.* 2001). Many of the causes of failure in this study were unknown. Identifying depredation as a cause of failure is difficult, particularly on shell substrates where predator tracks are not noticeable. Also, with nest checks occurring only once weekly, signs of overwash and depredation could have easily been diminished between checks.

Our study provides the first estimates of nest and brood survival of American Oystercatchers for Texas. In the United States, most American Oystercatchers occur on the Atlantic Coast, although an estimated 500 individuals occur in Texas (Brown *et al.* 2005). Texas oystercatchers appear to have above-average reproductive success because both nest and brood survival estimates were generally greater than those from other studies on the Atlantic Coast. Using population viability models, Davis (1999) suggested that oystercatcher populations can remain stable and possibly increase even with low productivity. Our estimates of nest and brood survival in Texas suggest that the population should remain stable or exhibit positive growth; however, more insight into subadult and adult survival of oystercatchers in Texas is needed.

#### ACKNOWLEDGMENTS

Funding for this project was provided by the Walter Fondren III Fellowship in Shorebird and Wading Bird Research at the Caesar Kleberg Wildlife Research Institute, National Fish and Wildlife Foundation, ConocoPhillips, U.S. Fish and Wildlife Service Coastal Program, The Hershey Foundation, George and Mary Josephine Hamman Foundation, The Trull Foundation, and Coastal Bend Audubon Society Bird Conservation Research Award. Banding was conducted under U.S. Geological Survey banding permits 21314, 23546, and 23712. We would like to thank Dr. David Wester for his input on statistical analyses and the many volunteers that assisted with field work. We would also like to thank two anonymous reviewers for their constructive comments. This is manuscript #14-108 of the Caesar Kleberg Wildlife Research Institute.

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