



## Nest survival of the Snowy Plover *Charadrius nivosus* at Marismas Nacionales, Nayarit, Mexico

### Supervivencia de nidos del chorlo nevado *Charadrius nivosus* en Marismas Nacionales, Nayarit

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### Abstract

Breeding habitat loss and nest predation are considered the main causes of Snowy Plover (*Charadrius nivosus*) populations decline worldwide. We evaluated the effects of season, nest age, distance to nearest vegetation patch, distance to nearest body of water, habitat type, and nesting substrate on the daily survival rate of Snowy Plover nests. During 2014-2015, we located 84 nests in Las Garzas-Chahuin-Chihua lagoon in Marismas Nacionales, Nayarit, Mexico. We used MARK software to estimate daily nest survival rate, which was 0.969 (95% CI = 0.95 - 0.97) for both breeding seasons combined, with a 42% finite nesting success. A total of 44 nests (52%) were successful, while 40 (48%) failed. The main causes of nest failure were predation ( $n = 30$ ; 75% of failed nests) and flooding ( $n = 9$ ; 22.5% of failed nests); one nest was lost due to unknown causes (2.5%). Daily survival rate increased with nest age and distance from the nearest vegetation patch. By contrast, daily survival rate decreased with the progression of the breeding season; a higher probability of nest success was evident when established early in the breeding season. Our results show the importance of different positive and negative factors influencing nest survival that might be considered as part of conservation strategies.

**Key words:** daily survival rate, hatching success, nest predation, shore-bird, western Mexico, wetlands.

### Resumen

La pérdida de hábitat de reproducción y la depredación de nidos son las principales causas del declive de las poblaciones del chorlo nevado (*Charadrius nivosus*) a nivel mundial. Evaluamos el efecto de la temporada, edad del nido, distancia al parche más cercano de vegetación, distancia al cuerpo de agua más cercano, tipo de hábitat y sustrato en la tasa de supervivencia diaria de los nidos del chorlo nevado. Durante 2014 y 2015, ubicamos 84 nidos en la laguna de Las

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Garzas-Chahuin-Chihua en Marismas Nacionales, Nayarit, México. Usamos el software MARK para estimar la tasa de supervivencia diaria, el cual fue de 0.969 (95% CI = 0.95 - 0.97) para ambas temporadas reproductivas, con un éxito de anidación del 42%. Un total de 44 nidos (52%) fueron exitosos mientras que 40 (48%) fracasaron. Las principales causas de fracaso fueron depredación (n = 30; 75% de nidos fracasados) e inundaciones (n = 9; 22.5% de nidos fracasados); un nido (2.5%) se perdió por causas desconocidas. La tasa diaria de supervivencia se incrementó con la edad del nido y la distancia a un parche de vegetación. Por el contrario, la tasa de supervivencia disminuyó con el avance de la temporada, sugiriendo una alta probabilidad de éxito en nidos iniciados al principio de la temporada. Nuestros resultados muestran la importancia de diferentes factores positivos y negativos que afectan la supervivencia de los nidos, que podrían considerarse como parte de estrategias de conservación.

**Palabras clave:** ave playera, depredación de nidos, éxito de eclosión, humedales, oeste de México, tasa de supervivencia diaria.

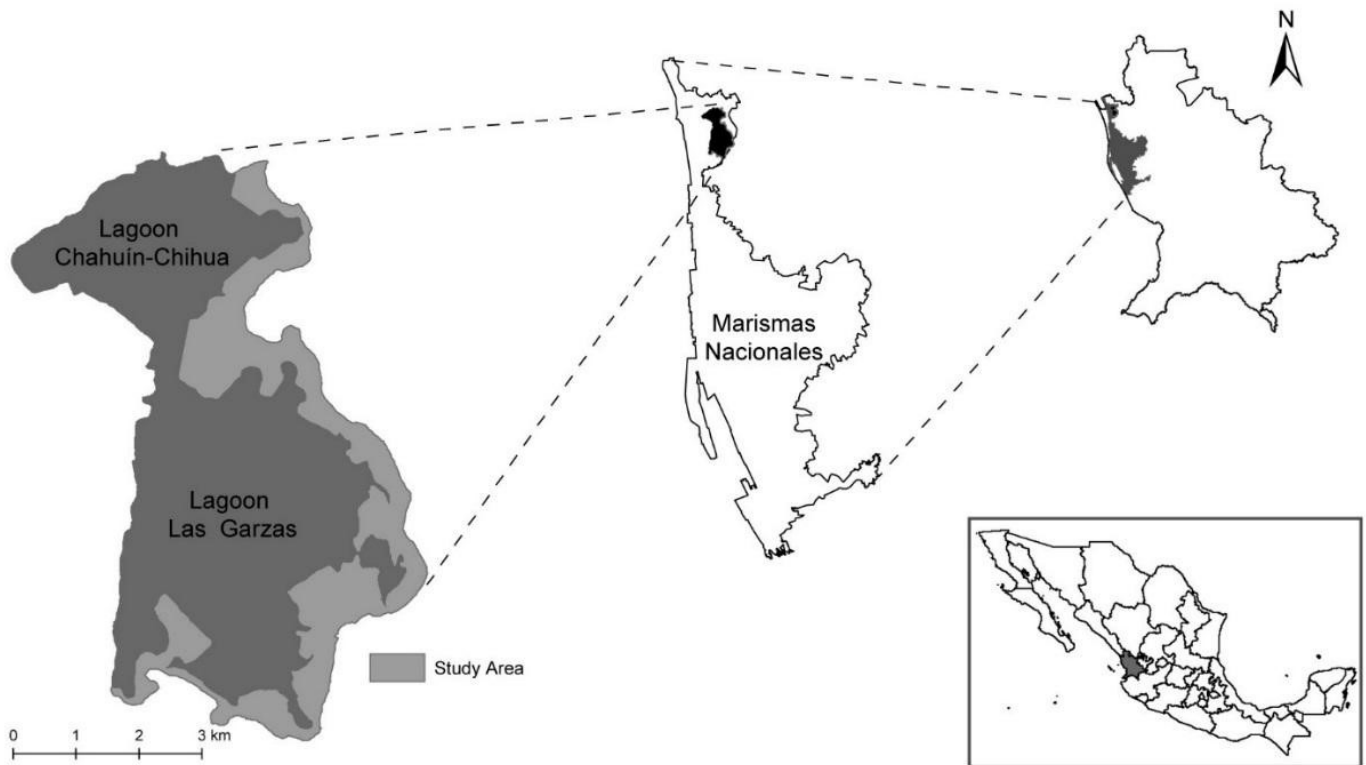
## Introduction

Information on avian life-history traits such as clutch size, incubation period, and nest-type is important to assess the vulnerability of populations to habitat degradation (Martin 1993). Nest survival in birds is considered an index of the influence of habitat on reproductive success, while the modeling of daily survival rates reflects factors that influence nesting success (Armstrong et al. 2002). One of the most important causes of the decline of Snowy Plover (*Charadrius nivosus*) populations is low nest survival (Morrison et al. 2006, USFWS 2007, Andres et al. 2012), resulting from a variety of factors, including human disturbance, high tides, inclement weather, and predation of eggs and chicks by mammals and other bird species (Hardy and Colwell 2008, Saalfeld et al. 2011, Galindo-Espinosa 2015). However, the primary threat at the present is degradation and loss of suitable nesting habitat (Page et al. 2009, Colwell 2010).

Nest survival rate is known to be variable; its variation might show patterns of changes annually, seasonally or even within a single reproductive season. In shorebirds, it has been suggested that nest survival decreases with nest initiation date (Ackerman et al. 2014), a pattern that has been found

for the Snowy Plover, in which nest survival rate is higher at the beginning of the breeding season and declines with time (Saalfeld et al. 2011). Some underlying factors that have been suggested might be involved are the selection of the best nest sites (Ellis et al. 2015), lower number of potential predators (Galindo-Espinosa 2015), and stability of surface water availability in saline lakes (Saalfeld et al. 2011). Some other events might increase variability, such as extreme weather conditions (strong winds, floods by tides and excessive rain during the reproductive season) (Colwell 2010, Saalfeld et al. 2011, Plaschke et al. 2019), as well as human disturbance (Colwell et al. 2005, Page et al. 2009, Webber et al. 2013).

Approximately 9% of the breeding population of the Snowy Plover occurs in Mexico (Thomas et al. 2012), where the species is considered threatened (SEMARNAT 2019), although there is not enough information to substantiate the status of breeding populations at a local and regional levels. Mellink and Riojas-López (2005) first registered nesting of the Snowy Plover in the Marismas Nacionales protected area on the Pacific coast of Mexico. However, it was not until 2010 that studies were conducted to characterize nesting sites and evaluate reproductive success of the Snowy Plover at this site (Martínez 2012, Vargas 2012, Bustamante 2013, Martínez et al. 2019). These studies used the traditional Mayfield method to evaluate nest success, with estimates of 42% to 58% nest success. However, the Mayfield method has fallen into disuse as it requires that a series of restrictive assumptions are met (Rotella et al. 2004, Shaffer 2004). As a result, a new approach of analyses has been suggested, and detailed studies to generate specific information related to the influence of various biological factors on the likelihood of nest success are considered timely, suitable, and necessary. In order to evaluate the influence of habitat on nest survival of the Snowy plover at Marismas Nacionales, and to provide basic information that would enable us to support management and conservation strategies for this species, we analyze changes in Daily Survival Rate (DSR) throughout the breeding season, and the influence of nest age, distance to the nearest vegetation patch and body of water, type of habitat, and nesting substrate on annual nest survival.



**Figure 1.** Study area in Las Garzas-Chahuin Chihua at Marismas Nacionales, Nayarit.

## Methods

### *Study area*

The study was conducted in Las Garzas-Chahuin Chihua wetland (22°29'26.1" N -105°35'51" W, 22°25'20.9" N -105° 35'59.1"W), a large coastal wetland complex of more than 350,000 ha located within Marismas Nacionales area in north-western Nayarit and southern Sinaloa. Marismas Nacionales is a site of international importance as it harbors a considerable number of migratory and resident birds (Ortega-Solis 2011); part of this area (133,854 ha) has been designated as Biosphere Reserve (CONANP 2005, DOF 2010). The area includes deltaic plains, marshes with coastal lagoons, and coastal beds (González et al. 2009). The general climate for the region is semi-warm subhumid Aw1(h'), with annual rainfall over 1500 millimeters and influence of humid monsoon-type winds from the sea. The average annual temperature is 26°C to 28°C, with an average annual maximum temperature of 30°C to 34°C. Total annual precipitation is 800 to 1200 mm with an annual relative humidity greater than 75% and a total annual evaporation of 1800 to 2000 mm<sup>3</sup> (SEMARNAT-CONANP 2013). Dominant vegetation is represented by halophyte species, being among the most common plants *Salicornia* sp. (glasswort), *Batis maritima* (turtleweed),

*Sesuvium portulacastrum* (shoreline sea purslane), and *Suaeda nigra* (bush seepweed). Mangroves are present on the shores of estuaries, lagoons, and other coastal water bodies with four species: *Laguncularia racemosa* (white mangrove), *Rhizophora mangle* (red mangrove), *Hilairanthus germinans* (black mangrove), and *Conocarpus erectus* (button-tree) (SEMARNAT-CONANP 2013).

The study site was selected based on earlier studies on Snowy Plover at Marismas Nacionales (Ortega-Solis 2011, Martínez 2012, Vargas 2012, Bustamante 2013). Las Garzas-Chahuin Chihua is important as a feeding, wintering, and nesting area for shorebirds (Ortega-Solis 2011); it encompasses an area of 85 ha located 12 km from the shoreline, exposed to mixed semi-diurnal tides with no apparent effect on shorebirds (Carmona et al. 2011, Bustamante 2013, Martínez et al. 2019). The lagoon is less than 20 m above sea level, with a tidal range of ±50 cm (Ortega-Solis 2011; Figure 1), and includes a mosaic of habitats such as saline waters, shell sites, muddy beaches, dry sandy plains, and shallow water-bodies. On the lagoon periphery there are 14 artificially created dredge-spoil islands (known locally as "tarquinas") that are used as nesting sites by Snowy Plovers (Bustamante 2013). These islands have shell mounds of 1.5 to 2 m high, and although they are deprived of vegetation cover,

there are a few small patches of halophytic vegetation and very scarce mangroves (Ortega-Solis 2011, Martínez 2012, Bustamante 2013).

### *Nest Surveys*

We visited nesting areas once a week during the 2014 and 2015 breeding seasons (late March-early July) to locate and monitor Snowy Plover nests (Ralph et al. 1996). We geolocated each nest using a handheld Global Positioning System (GPS) device. We gathered data on habitat type (dredge-spoil islands, saline waters, road-edge, or sandy plains) and substrate (bare soil, vegetation, shell knoll, or any other object such as cow pat, canvas, or plastic) where nests were located. We also recorded clutch initiation date, clutch size, incubation stage, and the number of hatchlings. Incubation stage was defined according to the egg flotation technique of Westerkov (1950) with six categories (A to F: A = egg on bottom approximate embryo age 0-3 days; F = egg on top of water approximate embryo age 24-27 days). Clutch initiation date was estimated retrospectively assuming a period of four laying days and a total incubation period of 27 days (Page et al. 2009, Székely et al. 2011). We defined a nest as being successful when: a) at least one of the eggs hatched, b) we observed the presence of adults with young near the nest, and c) there were small eggshell fragments <5 mm in size (Mabbe and Estelle 2000, Ellis et al. 2015). On the other hand, a nest was classified as failed if: 1) it was lost to predation, with evidence of large eggshell pieces (>8 mm), yolk stains, or animal tracks in or around the nest; 2) flooding occurred, when there was evidence of a recent heavy rain or high tide events that might have caused the eggs to disappear; and 3) lost to unknown cause, when no evidence of hatching or predation was found. In addition, we included predictors of nest age (Nage = estimated from date of clutch initiation), distance to the water (Dwater = Distance to the nearest body water to the nest), distance to the nearest patch of vegetation (Dvege = Distance to the closest vegetation patch to the nest), habitat used for the nest settlement (Habit: dredge-spoil islands, saline fields, borders of the road, sandy plains) and substrate used by the species to place the nest (Subst: on bare soil, on vegetation, on shell knoll, on any other object). Nest age was estimated from date of clutch initiation to the date of hatching or nest failure. Distance to water and the nearest vegetation patch was measured using a flexometer.

### *Data analysis*

We used the program MARK v7.2 (White and Burnham 1999) to model nest survival and estimate daily survival rate (Dinsmore et al. 2002, Rotella et al. 2004, Shafer 2004), based on the last day the nest was active, and the fate of the nest (successful vs. failed). The construction and analysis of models was carried out using the application RMark (Laake 2013) within the statistical program R (R Development Core Team 2015). We used the Akaike's Information Criterion (AIC) adjusted for small samples (AICc) to evaluate relative model support (Akaike, 1998; Burnham and Anderson 2002). We selected models with  $\Delta AICc < 2$  and the highest value of Akaike weight ( $w_i$ ), using a 95% confidence interval to evaluate support in favor of each competing model (Burnham and Anderson 2002).

Model construction was divided into two hierarchical stages based on a combination of predictors. In the first stage, we built models to evaluate the effect of a) clutch initiation date, b) habitat, c) temporary linear effect (T) to evaluate whether daily survival rate increased or decreased as the season progressed, d) a temporary quadratic effect (TT) to evaluate whether daily survival rate was higher at some point in the season, e) nest age in days, and f) daily survival rate during the breeding season, as well as all possible combinations of these factors. In the second stage, we used the best model from the first stage and added all the possible predictor combinations of a) distance to water, b) distance to vegetation, and c) type of nest substrate. We estimated annual nest success using an exponential finite daily survival rate of 27 days (Page et al. 2009). The 95% confidence intervals of the three covariates included in the best model were not overlapped with zero, with both the upper and lower confidence intervals showing a clear (+) (+) or (-) (-) trend, suggesting that these covariates were biologically relevant. We also used a chi-square test to determine whether the number of nests was associated with habitat type and nest substrate in the two reproductive seasons.

## **Results**

### *Nest Locations*

The start date of the reproductive season was 29 March in 2015 and 12 April in 2014, with a breeding season duration of 99 days. Most nests were initiated between 27 April and 28 May in 2014, while in 2015 nests were initiated earlier (from 29 March to 12 April). The last clutches for both seasons were

**Table 1.** Number of successful and failed Snowy Plover nests found at Marismas Nacionales, Nayarit (2014-2015).

	2014	2015	Total
<b>Successful</b>	14	30	44
<b>Failed</b>	13	27	40
<b>Predation</b>	10	20	30
<b>Flooded</b>	3	6	9
<b>Unknown</b>	0	1	1

recorded in early June, with the end of the breeding season estimated on 5 July in 2015, when the last active nest was located.

We located a total of 84 nests, 27 in 2014 and 57 in 2015. For both breeding seasons combined, 52% of the nests were successful ( $n = 44$  nests) and 48% failed ( $n = 40$  nests). The main cause of nest failure was predation (75% of failed nests), followed by flooding (22.5% of failed nests); we were unable to establish the cause failure in one nest (Table 1). We observed raccoon (*Procyon lotor*) and coyotes (*Canis latrans*) footprints around failed nests.

We found a significant association of Snowy Plover nests with habitat ( $X^2_3 = 13.2$ ,  $P < 0.05$ ), where most nests were located on dredge-spoil islands ( $n = 46$  nests; 55% of all nests), 19 nests on road-side edges (23%), 12 nests on sandy plains (14%), and only 7 nests in saline habitats (8%) over both breeding seasons combined. However, the number of nests on dredge-spoil islands varied significantly between the two study seasons (2014: 13 nests, 2015: 33 nests;  $X^2_1 = 8.7$ ,  $P < 0.05$ ).

The substrate of most Snowy Plover nests was bare ground ( $n = 39$  nests; 47% of all nests), followed by shell sites ( $n = 27$  nests; 32%), other objects ( $n = 12$  nests; 14%), and 6 nests were located over vegetation (7% of nests). However, we found no significant association of nests with substrate. When comparing between breeding seasons, only the substrates of shell sites (2014: 5 nests, 2015: 22 nests;  $X^2_1 = 10.7$ ,  $P < 0.05$ ) and objects (2014: 2 nests, 2015: 10 nests;  $X^2_1 = 5.33$ ,  $P < 0.05$ ) were significantly different.

#### *Factors influencing nest survival*

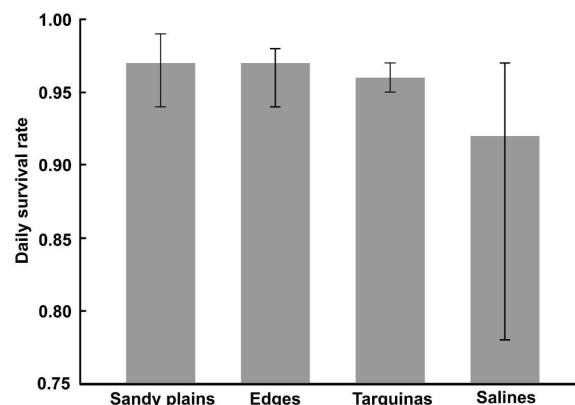
We built valid encounter histories for 83 of the 84 nests found over the two breeding seasons. The combined daily survival rate for both breeding sea-

sons was 0.969 (95% CI = 0.95 - 0.97) producing a 42% finite nesting success; nesting success was lower (36%) in 2014 compared with 2015 (45%). Nest survival rate varied among habitats (Figure 2); nests in saline habitats had the lowest 0.92 daily survival rate (95% CI = 0.78 - 0.97), while on sandy plains and road-side edges daily survival rates (0.97) were higher (95% CI: sandy plains = 0.94 - 0.99; road-side edges = 0.94 - 0.98), followed by dredge-spoil islands with 0.96 (95% CI = 0.95 - 0.97) daily survival rate.

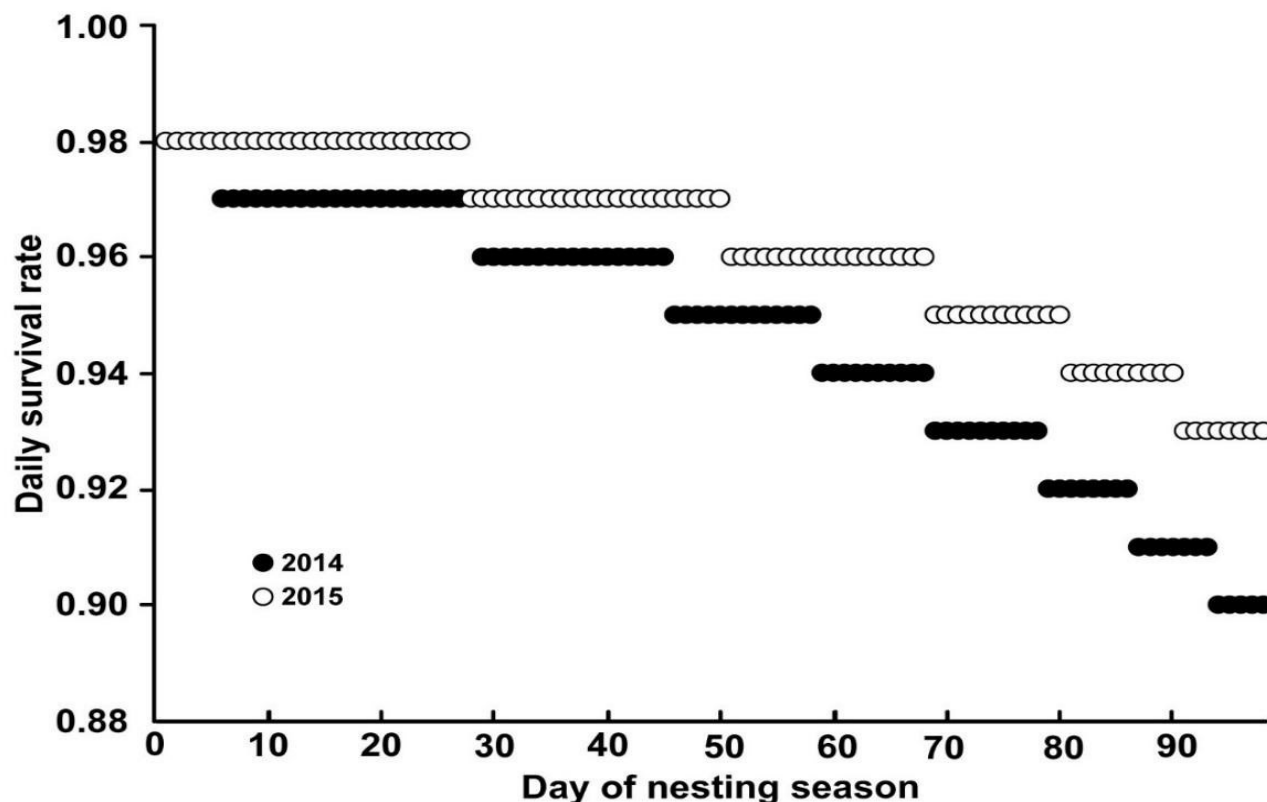
From 29 candidate models in two stages, there were 22 candidate models in the first stage and seven models in the second stage. In both breeding seasons, daily survival rate of Snowy Plover nests declined as the season progressed (Figure 3). The model with best fit to Snowy Plover nest survival had four parameters, an Akaike weight ( $w_i$ ) of 0.51, and included the variables of nest age, a temporary linear effect, and distance to the nearest vegetation patch (Table 2). There was one competing model ( $\Delta AICc = 0.87$ ,  $w_i = 0.33$ ) that included the same variables as the best model, but with the addition of distance to the nearest water-body (Table 2). Daily survival rate increased with nest age ( $\beta = 0.06$ , 95% CI = 0.02 - 0.11), and distance from the nearest vegetation patch ( $\beta = 0.23$ , 95% CI = 0.01 - 0.44), but decreased with day of nesting season ( $\beta = -0.02$ , 95% CI = -0.04 to -0.00).

## Discussion

Daily survival rate of Snowy Plover nests for both 2014 and 2015 combined was 0.97, which coincides with previous figures estimated by Vargas (2012) and Bustamante (2013) at Marismas Na-



**Figure 2.** Daily survival rate of Snowy Plover nests with 95% confidence intervals by habitat type in Marismas Nacionales, Nayarit (2014-2015 combined).



**Figure 3.** Daily survival rate of Snowy Plover nests over 99 days of the breeding season in 2014 and 2015 at Marismas Nacionales, Nayarit. Day 1 corresponds to 29 March and day 99 to 05 July.

cionales; and does not differ greatly from estimates gathered for other areas, such as San Quintin, Baja California, Mexico (0.95,  $n = 3$  years; Galindo-Espinosa 2015), and Great Salt Lake, Utah (0.96,  $n = 8$  years; Ellis et al. 2015). Our estimate of 42% finite nest success at Marismas Nacionales was similar but lower to previous reports in the same area, which were 48% (Vargas 2012) and 58% (Martinez 2012) nest success in 2010, and 50% nest success in 2011 (Bustamante 2013). Nest success for Snowy Plovers in Marismas Nacionales, Mexico, was also similar to that for breeding populations from other locations, such as the Ceuta Bay in Sinaloa, Mexico (46%; Küpper 2006), Florida (57%; Himes et al. 2006), San Diego, California (50%; Powell 2001), and northern California (48%; Colwell et al. 2011). Predation was the main cause of nest failure for Snowy Plovers at Marismas Nacionales. This was previously reported by Bustamante (2013; 70% of failed nests) for the same area, and several studies have shown that in shorebird breeding areas the primary cause of nest failure is predation (Paton 1995, Smith et al. 2007, Colwell et al. 2012). In our study, we found raccoon (*P. lotor*) and coyote (*C. latrans*)

tracks, indicating that these are predators of Snowy Plover nests at Marismas Nacionales, with raccoons being the primary predator within these wetlands (Bustamante 2013).

The second cause of nest failure in our study was flooding. Floods have been found to contribute significantly to nest failure at other sites (Warrnock et al. 2001, Sexson and Farley 2012, Vargas 2012, Bustamante 2013, Galindo-Espinosa 2015). Plaschke et al. (2019) suggested that nest flooding was more likely later in the breeding season, and is a pattern that may vary among years as a result of weather conditions and the intensity of rain at the end of spring or the beginning of summer. Furthermore, Marismas Nacionales is an important area for shorebirds that has been strongly impacted by habitat loss and degradation, producing changes in water dynamics. This makes it imperative to implement habitat restoration as part of management plans for the recovery of this large wetland.

Our results suggest that early nests are more successful than those initiated later in the breeding season. The best model showed a negative linear

**Table 2.** Models of daily nest survival (S) for Snowy Plover in Marismas Nacionales, Nayarit (2014-2015). Variables are Nage = Nest age, T = linear temporal effect, Dvege = Distance to nearest vegetation, Dwater = Distance to water, Subst = Substrate.  $\Delta AIC_c$  = the difference between each model and the best model,  $k$  = the number of parameters in each model,  $w_i$  = represents the probability that the candidate model is the best.

Stage	Model	$k$	$\Delta AIC_c$	$w_i$	Deviance
2	S(Nage + T + Dvege)	4	0.00	0.51	169.38
2	S(Nage + T + Dwater + Dvege)	5	0.87	0.33	168.24
2	S(Nage + T + Dwater)	4	4.43	0.05	173.82
2	S(Nage + T + Dvege + Subst)	7	4.74	0.04	168.06
1	S(Nage + T)	3	0.00	0.51	173.83

temporal trend, which indicates that nests initiated at the start of the breeding season had a higher probability of success than those initiated at the end, as found by Galindo-Espinosa (2015) for San Quintin, Baja California, Mexico. This pattern could be related to changes in levels of tides and the start of the rainy season (Vega-Picos 2008, Vargas 2012), as is the case with other shorebirds where climatic factors may reduce nest success during the breeding season (Smith et al. 2007).

According to the best model, nest survival increased with nest age, which is likely due to the fact that nests are more vulnerable in early developmental stages (Dinsmore et al. 2002, Hood and Dinsmore 2007, Smith and Wilson 2010, Ellis et al. 2015). Distance to the nearest vegetation patch also positively affected survival rates of Snowy Plover nests at Marismas Nacionales, as found by other studies (Prindville and Ryan 1988, Mabee and Estelle 2000, Bustamante 2013). This may be because nearby vegetation reduces visibility for shorebirds to detect approaching predators, and allows predators to make surprise attacks (Cresswell 1996, Galindo-Espinosa 2003).

In our study, we found a strong association of Snowy Plover nests with dredge-spoil island habitats that typically lack vegetation, and most nests occurred on bare soil substrate. Other studies have also found that Snowy Plovers tend to use bare substrates for nesting (Page et al. 1985, Paton 1995, Hood and Dinsmore 2007, Martínez 2012). This may be a reflection of the likelihood of decreased nest success closer to vegetation. Further research could evaluate the risks of predation for Snowy Plover nests at Marismas Nacionales in relation to characteristics of the habitat (Mabee and Estelle 2000). In terms of management, although enclosures may

be considered as a strategy to increase nest survival, they do not protect nidifugous chicks from predation (Hardy and Colwell 2008). The potential effects of enclosures on other aspects of Snowy Plover reproductive biology also needs to be seriously considered before being applied at Marismas Nacionales.

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### Literature cited

Ackerman JT, Herzog MP, Takekawa JY, Hartman AC. 2014. Comparative reproductive biology of sympatric species: nest and chick sur-

- vival of American Avocets and Black-necked Stilts. *Journal of Avian Biology* 45:609-623. <https://doi.org/10.1111/jav.00385>
- Akaike H. 1998. Information theory and an extension of the maximum likelihood principle. Pp. 199-213. En Parzen E, Tanabe K, Kitagawa G (eds). *Selected Papers of Hirotugu Akaike*. Springer, New York, USA.
- Andres BA, Smith PA, Morrison RIG, Gratto-Trevor CL, Brown SC, Friis CA. 2012. Population estimates of North American shorebirds. *Wader Study Group Bulletin* 119:178-194.
- Burnham KP, Anderson D. 2002. *Model selection and multi-model inference: a practical information-theoretic approach*. Springer-Verlag, New York, USA.
- Bustamante JM. 2013. *Ecología Reproductiva del Chorlo nevado (Charadrius nivosus) en las Lagunas Las Garzas y Chahuin Chihua, Reserva de la Biosfera Marismas Nacionales, Nayarit, México*. Tesis de Licenciatura. Instituto Tecnológico de Bahía de Banderas, Nayarit, México.
- Carmona R, Hernández-Álvarez A, Mendoza LF, Ortega L. 2011. Recent records of the Black Brant (*Branta bernicla nigricans*) in Nayarit, Mexico. *CICIMAR Océánides* 26:65-66.
- Colwell M, Millett CB, Meyer J, Hall JN, Hurley SJ, McAllister S, Transou A, LeValley R. 2005. Snowy Plover reproductive success in beach and river habitats. *Journal of Field Ornithology* 76:373-382.
- Colwell M. 2010. *Shorebird ecology, conservation, and management*. Berkeley: University of California Press.
- Colwell M, Meyer J, Hardy MA, McAllister S, Transou A, LeValley R, Dismore S. 2011. Western Snowy Plovers *Charadrius alexandrinus nivosus* select nesting substrates that enhance egg crypsis and improve nest survival. *Ibis* 153:303-311.
- Colwell M, Eberarth-Phillips LJ, Herma DM, Lawton WP, Leja SD, McAllister S, Orluck DJ, Patrick AM, Patterson JL, Peterson SA. 2012. Snowy Plover breeding in coastal northern California, recovery unit 2. Unpublished report, U. S. Department of the Interior, Fish and Wildlife Service, California.
- CONANP (Comisión Nacional de Áreas Naturales Protegidas). 2005. *Estudio previo justificativo para el establecimiento del Área Natural Protegida: Área de Protección de Flora y Fauna Marismas Nacionales, Nayarit*.
- Cresswell W. 1996. Surprise as a winter hunting strategy in Sparrowhawks *Accipiter nisus*, Peregrines *Falco peregrinus* and Merlins *F. columbarius*. *Ibis* 138:684-692. <https://doi.org/10.1111/j.1474-919X.1996.tb04770.x>
- Dinsmore S, White GC, Knopf FL. 2002. Advanced techniques for modeling avian nest survival. *Ecology* 83:3476-3488.
- DOF (Diario Oficial de la Federación). 2010. Decreto por el que se declara como Área Natural Protegida, con el carácter de Reserva de la Biosfera, la región conocida como Marismas Nacionales Nayarit. México. México (DF). 12 de mayo de 2010.
- Ellis KS, Cavitt JF, Larsen RT. 2015. Factors influencing Snowy Plover (*Charadrius nivosus*) nest survival at Great Salt Lake, Utah. *Waterbirds* 38:58-67.
- Galindo-Espinosa D. 2003. *Uso de dos humedales, dulceacuícola y costero, por Calidris mauri (Charadriiformes: Scolopacidae) al sur de la Península de Baja California, México*. Tesis de Maestría. Instituto Politécnico Nacional. La Paz, Baja California Sur, México.
- Galindo-Espinosa D. 2015. *Ecología poblacional del Chorlo nevado, Charadrius nivosus, en el Noroeste de Baja California, México*. Tesis de Doctorado. Instituto Politécnico Nacional. La Paz, Baja California Sur, México.
- González A, Bojórquez I, Nájera O, García D, Madoño A, Flores F. 2009. Regionalización ecológica de la llanura costera norte de Nayarit, México. *Investigaciones Geográficas* 69:21-32.
- Hardy M, Colwell M. 2008. The impact of predator exclosures on Snowy Plover nesting success: a seven-year study. *Wader Study Group Bulletin* 115:161-166.
- Himes JG, Douglass NJ, Pruner RA, Croft AM, Seckinger EM. 2006. Status and distribution of Snowy Plover in Florida. Unpublished re-



- port, Fish and Wildlife Conservation Commission, Tallahassee, Florida.
- Hood SL, Dismore S. 2007. The influence of habitat on nest survival of Snowy and Wilson's Plovers in the Lower Laguna Madre Region of Texas. *Studies in Avian Biology* 34:124-135.
- Küpper C. 2006. Reproductive success and breeding system of Snowy Plover at Ceuta, Mexico. Unpublished report, Pronatura Noroeste, Sinaloa.
- Laake JL. 2013. RMark: An R Interface for analysis of capture-recapture data with MARK. Point Way NE, Seattle WA: Alaska Fisheries Science Center.
- Mabbe TJ, Estelle VB. 2000. Nest fate and vegetation characteristics for Snowy Plover and Killdeer in Colorado, USA. *Wader Study Group Bulletin* 93:67-72.
- Martin TE. 1993. Nest predation among vegetation layers and habitat types: revising the dogmas. *American Naturalist* 141:163-197.
- Martínez P. 2012. Selección de sitios de anidación del Chorlo nevado (*Charadrius nivosus*) en Marismas Nacionales, Nayarit, México y el Gran Lago Salado, Utah, Estados Unidos. Tesis de Licenciatura. Universidad Autónoma de Nayarit, Nayarit, México
- Martínez P, Carmona R, Mendoza LF. 2019. Abundancia y distribución espacio temporal del playerito occidental *Calidris mauri* (Charadriiformes: Scolopacidae) invernante en Marismas Nacionales, Nayarit-Sinaloa, México. *Acta Zoológica Mexicana (nueva serie)* 35:1-7. <https://doi.org/10.21829/azm.2019.3502093>
- Mellink E, Riojas-López M. 2005. New breeding localities for the Snowy Plover in western Mexico. *Western Birds* 36:141-143.
- Morrison G, McCaffery B, Gill R, Skagen S, Jones S, Page G, Gratto-Trevor C, Andres B. 2006. Population estimates of North American shorebirds. *Wader Study Group Bulletin*, 111:67-85.
- Ortega-Solis L. 2011. Distribución espacial y temporal de aves playeras invernantes en la Reserva de la Biosfera Marismas Nacionales Nayarit. Tesis de Licenciatura. Universidad Autónoma de Nayarit. Nayarit, México.
- Page G, Stenzel LE, Ribic CA. 1985. Nest site selection and clutch predation in the Snowy Plover. *Auk* 102:347-353.
- Page G, Stenzel LE, Warriner JS, Warriner JC, Paton PW. 2009. Snowy Plover (*Charadrius nivosus*). p. 154. En Poole A (ed). *The Birds of North America*. Ithaca, New York (USA): Cornell Lab of Ornithology.
- Paton PW. 1995. Breeding biology of Snowy Plovers at Great Salt Lake, Utah. *Wilson Bulletin* 107:275-288.
- Plaschke S, Bulla M, Cruz-López M, Gómez S, Küpper C. 2019. Nest initiation and flooding in response to season and semi-lunar spring tides in a ground-nesting shorebird. *Frontiers in Zoology* 16:1-11. <https://doi.org/10.1186/s12983-019-0313-1>.
- Powell AN. 2001. Habitat characteristics and nest success of Snowy Plovers associated with California Least Tern colonies. *Condor* 103:758-792.
- Prindville GE, Ryan MR. 1988. Piping Plover habitat use and reproductive success in North Dakota. *Journal of Wildlife Management* 52:266-273.
- R Development Core Team. 2015. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from: <http://www.Rproject.org/>
- Ralph CJ, Geupel G, Pyle P, Martin TE, Desante D, Milá B. 1996. Manual de métodos de campo para el monitoreo de aves terrestres. Forest Service, US Pacific Southwest Research Station. Albany, CA.
- Rotella JJ, Dinsmore S, Shafer RL. 2004. Modelling nest survival data: a comparison of recently developed methods that can be implemented in MARK and SAS. *Animal Biodiversity and Conservation* 27:187-205.
- Saalfeld S, Conway W, Haukos D, Johnson W. 2011. Nest success of Snowy Plovers (*Charadrius nivosus*) in the southern high plains of Texas. *Waterbirds* 34:389-399.

- SEMARNAT (Secretaría de Medio Ambiente y Recursos Naturales). 2019. Modificación del Anexo Normativo III. Lista de especies en riesgo de la Norma Oficial Mexicana NOM-059-SEMARNAT-2010, Protección Ambiental – Especies nativas de México de flora y fauna silvestres – Categoría de riesgo y especificaciones para su inclusión, exclusión o cambio. Lista de especies en riesgo, publicada el 30 de diciembre de 2010–. Diario Oficial de la Federación. México (DF).
- SEMARNAT-CONANP. 2013. Programa de Manejo Reserva de la Biosfera Marismas Nacionales, Nayarit. Secretaría de Medio Ambiente y Recursos Naturales, Comisión Nacional de Áreas Naturales Protegidas. [https://www.conanp.gob.mx/que\\_hacemos/pdf/programas\\_manejo/2013/MARISMAS.pdf](https://www.conanp.gob.mx/que_hacemos/pdf/programas_manejo/2013/MARISMAS.pdf)
- Sexson MG, Farley GH. 2012. Snowy Plover nest survival in Kansas and effective management to counter negative effects of precipitation. *Journal of Wildlife Management* 76:1587-1596. <https://doi.org/10.1002/jwmg.405>
- Shaffer T. 2004. A unified approach to analyzing nest success. *Auk* 121:526-540.
- Smith PA, Gilchrist HG, Smith JNM. 2007. Effects of nest habitat, food, and parental behavior on shorebird nest success. *Condor* 109:15-31.
- Smith PA, Wilson S. 2010. Intraseasonal patterns in shorebird nest survival are related to nest age and defense behavior. *Oecologia* 163:613-624. <https://doi.org/10.1007/s00442-010-1644-y>
- Székely T, Argüelles-Tico A, Kosztolányi A, Küpper C. 2011. Practical guide for investigating breeding ecology of Kentish Plover *Charadrius alexandrinus*. Unpublished Report, University of Bath. Bath, UK. [https://www.pennuti.net/wp-content/uploads/2010/08/KP\\_Field\\_Guide\\_v3.pdf](https://www.pennuti.net/wp-content/uploads/2010/08/KP_Field_Guide_v3.pdf)
- Thomas S, Lyons J, Andres B, Elliot-Smith E, Palacios E, Cavitt J, Royle A, Fellows S, Maty K, Howe W, Mellink E, Melvin S, Zimmerman T. 2012. Population size of Snowy Plovers breeding in North America. *Waterbirds* 35:1-14.
- USFWS (United States Fish and Wildlife Service). 2001. Western Snowy Plover (*Charadrius alexandrinus nivosus*). U. S. Department of the Interior, Fish and Wildlife Service, Pacific coast population draft recovery plan. Portland, Oregon, USA.
- USFWS (United States Fish and Wildlife Service). 2007. Recovery plan for the Pacific Coast population of the Western Snowy plover (*Charadrius alexandrinus nivosus*). U. S. Fish and Wildlife Service, Endangered Species Program. Sacramento, California, USA.
- Vargas J. 2012. Comparación del éxito reproductivo de *Charadrius nivosus* en la Reserva de la Biósfera Marismas Nacionales, Nayarit, México, y el Gran Lago Salado, Utah, Estados Unidos. Tesis de Licenciatura. Universidad Autónoma de Nayarit, Nayarit, México.
- Vega-Picos X. 2008. Análisis de los problemas de conservación de las especies de aves acuáticas en ecosistemas costeros de Sinaloa, México. Tesis de Doctorado. Universidad de Extremadura, España.
- Warnock N, Elphick C, Rubega M. 2001. Shorebirds in the Marine Environment. Pp. 581-615. En Schreiber EA, Burger J (eds). *Biology of Marine Birds*. CRC Press, Boca Raton, Florida, USA.
- Webber A, Heath J, Fischer R. 2013. Human disturbance and stage-specific habitat requirements influence Snowy Plover site occupancy during the breeding season. *Ecology and Evolution* 3:853-863.
- Westerkov K. 1950. Methods for determining the age of game birds' eggs. *Journal of Wildlife Management* 14:56-67. <https://doi.org/10.2307/3795978>
- White GC, Burnham KP. 1999. Program MARK: Survival estimation from populations of marked animals. *Bird Study* 46:120-138. <https://doi.org/10.1080/00063659909477239>