STATUS OF SEABIRD NESTING POPULATIONS ON ARRECIFE ALACRANES, GULF OF MEXICO

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† This work is dedicated to Edward O. Keith, a good friend and colleague, who died on 14 September 2012 at the age of 60, and whose contribution was key to accomplishing these surveys and gathering the information reported here.

ABSTRACT

MORALES-VERA, T.E., RUZ-ROSADO, F.D., VELARDE, E., & KEITH, E.O. 2017. Status of seabird nesting populations on Arrecife Alacranes, Gulf of Mexico. *Marine Ornithology* 45: 175–185.

Arrecife Alacranes is the largest coral atoll of the Campeche Bank, situated in the southern end of the Gulf of Mexico and encompassing 60 ha. It has five coral islands: Isla Chica, Isla Blanca (or Isla Pájaros), Isla Pérez, Isla Desertora (or Isla Muertos), and Isla Desterrada, some with significant seabird nesting colonies. Trans-Gulf migrating birds use Arrecife Alacranes for resting. Fisheries, tourism, and oil-drilling activities have been a threat to the reef's biodiversity. However, the protection recently granted by the Mexican Government, on 6 June 1994, designating the area a National Park, has reduced human disturbance. Before this survey, the impact of this designation on seabird colonies was unknown. The last seabird survey, in 1986, had determined that the archipelago is home to the largest colony of Masked Boobies *Sula dactylatra* in the Atlantic region and the only known nesting site of Red-footed Boobies *Sula sula* in the Gulf of Mexico. Herein, we report on totals of abundance, which ranged from 140 000 to 13 nests, and on the nesting phenology of nine seabird species: Sooty Tern *Onychoprion fuscatus*, Brown Noddy *Anous stolidus*, Masked Booby, Laughing Gull *Leucophaeus atricilla*, Cabot's Tern *Thalasseus acuflavidus*, Magnificent Frigatebird *Fregata magnificens*, Royal Tern *Thalasseus maximus*, Brown Booby *Sula leucogaster*, and Red-footed Booby. We observed a significant increase in nesting populations of most species, except Magnificent Frigatebirds and Masked Boobies. However, some aspects of the breeding biology of these seabirds may have been influenced by introduced species. Among the population of Red-footed Boobies, which had only 13 nests, we observed three color morphs, thus leading to uncertainty about their geographic affinities. Despite the increased protection, which includes the presence of park rangers, human activity and related factors, such as increased fisheries pressure, damages to the atoll, risk posed by rising sea levels, and oil drilling, continue to threaten this important seabird nesting area.

Key words: *Anous stolidus,* Arrecife Alacranes, atolls, Gulf of Mexico, *Onychoprion fuscatus,* seabird populations, *Sula dactylatra, Sula sula.*

RESUMEN

Arrecife Alacranes es el mayor arrecife coralino en la Sonda de Campeche, al sur del Golfo de México, con 60 hectáreas. Presenta cinco islas coralinas: Chica, Blanca (o Pájaros), Pérez, Desertora (o Muertos) y Desterrada, algunas con colonias importantes de anidación de aves marinas. Aves migratorias que cruzan el golfo usan Arrecife Alacranes para descanso. Las actividades de pesca, turismo y explotación petrolera son una amenaza para la biodiversidad del arrecife, pero la protección reciente otorgada el 6 de junio de 1994 por el gobierno mexicano, con la designación de Parque Nacional, ha reducido la perturbación humana. Hasta este trabajo, no se conocía el efecto de esta protección en las colonias de aves marinas. La última prospección, en 1986, encontró que el archipiélago contiene la colonia de anidación más grande de bobo enmascarado *Sula dactylatra* del Atlántico, y la única localidad conocida de anidación de bobo patas rojas *Sula sula* en el Golfo de México. Determinamos la abundancia, desde 140 000 hasta 13 nidos, y fenología de anidación de las nueve especies de aves marinas, en orden descendente de abundancia: charrán sombrío *Onychoprion fuscatus,* charrán-bobo café *Anous stolidus,* bobo enmascarado*,* gaviota reidora *Leucophaeus atricilla,* charrán de Cabot *Thalasseus acuflavidus*, tijereta *Fregata magnificens,* charrán real *Thalasseus maximus,* bobo café *S. leucogaster* y bobo patas rojas. Observamos incrementos notables en las poblaciones reproductivas de la mayoría de las especies, con excepción de *F. manificens* y *S. dactylatra.* Algunos aspectos de la biología reproductiva de algunas especies pudieron estar influidas por la presencia de especies exóticas. Es interesante que la pequeña población reproductiva de bobos patas rojas, con sólo 13 nidos, presenta tres morfos de coloración del plumaje, generando incertidumbre sobre sus afinidades geográficas. A pesar de la protección, incluyendo la presencia de guarda parques, actividades humanas o factores relacionados, tales como el incremento en la actividad y presión pesquera, daños al arrecife, el potencial incremento del nivel del mar y extracción petrolera, aún representan riesgos para esta importante zona de anidación de aves marinas.

Palabras clave: *Anous stolidus,* Arrecife Alacranes, arrecifes coralinos, Golfo de México, *Onychoprion fuscatus,* poblaciones de aves marinas, *Sula dactylatra, Sula sula.*

INTRODUCTION

Information about seabird nesting colonies in the Mexican section of the Gulf of Mexico is scarce due to scant research efforts. Tunnell & Chapman (2000) provided a comprehensive review of the major seabird nesting colonies located on reef islands of the Campeche Bank, most importantly of Arrecife Alacranes (Scorpion Reef; Fig. 1). Species found include, in order of descending population size: Sooty Tern, Brown Noddy, Masked Booby, Laughing Gull, Magnificent Frigatebird, Cabot's Tern, Brown Booby, Royal Tern, and Red-footed Booby. Also important, but to a lesser degree, are the seabird colonies in Cayo Arcas, Cayo Arenas, and Arrecife Triángulos (Tunnell & Chapman 2000). Much smaller colonies of some species occur on islands located in coastal reefs and lagoons, such as Tamiahua Lagoon (approximate central location: 24.83°N and 97.67°W). However, colonies in these locations usually consist of less than 100 nests (Mellink *et al.* 2007, García Domínguez 2009).

In 1994, the Mexican federal government designated Arrecife Alacranes a protected area (DOF 1994), but there have been no systematic long-term survey data providing breeding numbers and population fluctuations. The islands are at a low elevation (1 to 4 m at high tide) and may be threatened by rising sea levels. Given that Arrecife Alacranes is the only available seabird nesting site in the entire region, information on temporal status and nesting numbers is needed to inform conservation activities. Recent research shows that fluctuations in the sizes of seabird nesting populations are excellent early indicators of variation in oceanographic and climatic conditions (Ainley *et al.* 1995, Lyver *et al.* 1999, Sydeman *et al.* 2006, Humphries *et al.* 2015, Velarde *et al.* 2015) as well as of the management actions required to mitigate impacts (e.g., Crawford *et al*. 2017). This connectivity provides a useful basis for examining and modeling ecological parameters (e.g., forage fish dynamics, Ainley *et al*. 2015) toward predicting or understanding future conditions (Devney *et al.* 2009).

In this article, we compare recent changes in the numbers of nine species of nesting seabirds breeding in Arrecife Alacranes, mostly comparing the results of our survey in 2009 to those of Tunnell & Chapman's, conducted in 1986 and published in 2000—a total of 15 years after these islands became protected (DOF 1994). We also discuss other field observations, whenever information is available and these observations are relevant. We do not discuss island topography and vegetation because we observed no evident changes to the descriptions provided by Tunnel & Chapmen (2000) other than the vegetative cover, which changes with the seasons, dry or wet. In other words, sea-level rise has yet to have an effect on seabird breeding habitat.

METHODS

Study site

Approximately 130 km north of the Yucatan Peninsula, there is a wide area of coral reefs and islands known as Arrecife Alacranes (Howell 1989; Fig. 1). This oval-shaped atoll encompasses almost 1 500 000 ha (from 22.15°N to 22.80°N and from 89.40°W to 90.00°W). The long northwest–southeast axis of the atoll is 26.79 km long, and its widest section is 14.61 km wide. The Alacranes-atoll platform is about 300 km^2 (CONANP 2006). This extensive atoll has five emerging areas, or islands; they are, from north to south, Isla Desterrada, Isla Desertora (also known as Isla Muertos), Isla Pérez, Isla Chica, and Isla Blanca (also known as Isla Pájaros) (Fig. 1). These islands are an important breeding sites for several seabird species, as well as a refuge to many migratory bird species, because there are few other sites where landbirds of eastern North America can find food and rest (although no fresh water in this case) in their migratory route. For some of the seabirds, these islands are their only nesting site in the Gulf of Mexico (Tunnell & Chapman 1988, 2000, Gallardo del Ángel *et al.* 2004, Gallardo *et al.* 2009).

Although for hundreds of years it has been known that seabirds nest on these islands (Dampier 1699, and compilation in Tunnell & Chapman 2000), current ornithological data need to be expanded and updated. For example, 60 years ago there were no reports of Brown Boobies in the region (Lowery & Newman 1954); this is no longer the case, as reported herein. Also, the last published article (Tunnell & Chapman 2000) is based on counts made in 1986; however, the counts were conducted during a period that for several species was off peak nesting season. Based on this literature, containing colony size estimates (both qualitative and quantitative) since 1675, we infer that some of the nesting populations were larger in the past. For example, Paynter (1955), referring to the Sooty Tern, states that Isla Pérez was "carpeted with eggs." However, several factors lead us to suspect that some populations have undergone major changes. For instance, it is known that local fishermen used to collect eggs of some of these seabirds for food. Undoubtedly, this practice led to a severe reduction in the number of some of the breeding populations as well as to a decrease in breeding success due to both human disturbance and the introduction of exotic species, such as rodents (Latofski-Robles *et al.* 2014). Since 1994, the harvesting of eggs has decreased considerably after Arrecife Alacranes became a National Park, now called "Parque Nacional Arrecife Alacranes" (PNAA; DOF 1994). As well, rats and mice introduced to the Arrecife Alacranes islands were eradicated in 2011 (Samaniego-Herrera *et al.* 2017).

Most of the seabirds nesting in the region are of a tropical affinity (Lowery & Newman 1954, Gallardo del Ángel *et al*. 2004, Gallardo *et al*. 2009). These nesting colonies harbor populations in the

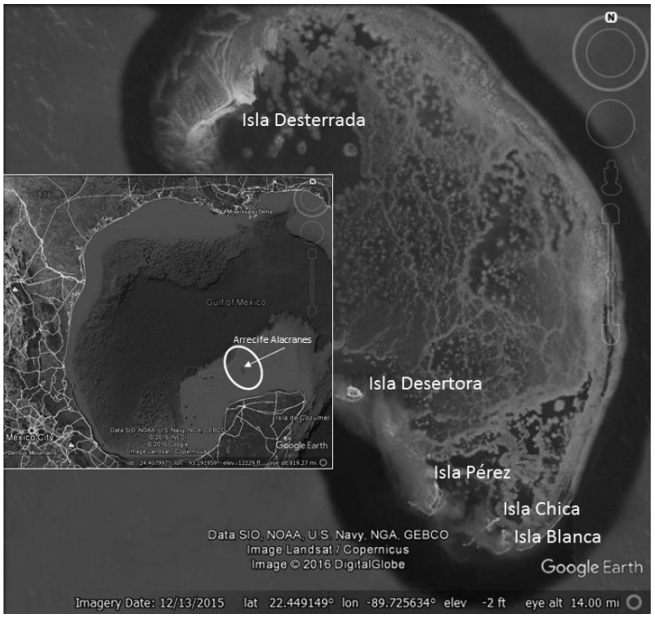

Fig. 1. Location of Arrecife Alacranes in the Gulf of Mexico.

northernmost portion of their distribution, except for Laughing Gulls and the two *Thalasseus* terns (AOU 1998).

Nest numbers and individual estimates

We visited the five islands in Arrecife Alacranes National Park (Pérez, Blanca, Chica, Desertora, and Desterrada) on two occasions: from 12 to 16 March and from 1 to 9 July 2009, in accordance with Mexican environmental regulations (Secretaría de Medio Ambiente y Recursos Naturales [SEMARNAT] and Comisión Nacional de Áreas Naturales Protegidas [CONANP]). Permits to conduct the surveys were granted by the CONANP regional office (Permit number PNAA/27/10).

To minimize disturbance, census methods were adjusted to the conditions of each island, species, and colony conformation. Seabirds are technically monogamous (except for frigatebirds). Therefore, to estimate the size of the breeding population, we counted or estimated the number of active nests and multiplied their numbers by two. When no nests were found, our census was based on the count of fledglings and adults. That was the case for Royal and Cabot's terns, which had not established nests in March, but whose chicks had already fledged in July. The number of breeding pairs of these terns was estimated at half the maximum number of adults observed. Given that the clutch size of the Royal Tern is most commonly one egg, for this species we used the number of fledglings as an estimate of the minimum number of nests (Buckley & Buckley 1972, 2002; Shealer 1999). Given that we are working with estimates, we rounded these amounts to the nearest five nests, except for estimates under 20 nests.

Direct counts. These were carried out at all islands for most species. We used slightly different methods to accommodate for the different conditions found for each species, as explained below. Direct counts were used in March for Brown and Masked boobies, both ground nesters, and Red-footed Booby, a shrub nester. When conditions allowed, we recorded the content of the nests. To avoid disturbance, we did not record the clutch size of Brown Noddies (shrub nesters). The direct counting of Sooty Terns (ground nesters) was done in a small area of the colony. Due to the high probability that we would create disturbance if we entered the colony, nesting density and clutch sizes were estimated based on nests sampled along a 4 m-wide transect along the border of a section of the colony. To estimate the total nesting population, we extrapolated the numbers to the total nesting area.

Counts based on photographs. To avoid disturbance, portions of the censuses were based on panoramic photographs taken 1) in July from the lighthouse on Isla Pérez, to estimate Brown Noddy numbers; 2) in March at ground level on Isla Desertora, and 3) in July, also on Isla Desertora for Red-footed and Masked boobies, and 4) in July, on Isla Desterrada for frigatebird and Brown Booby nests and juveniles.

Estimates based on nest densities. Estimates were performed on Isla Pérez for the Sooty Tern, which nests on the ground among shrubs, making it impossible to count nests without causing disturbance. The total number of nests was estimated based on the nest density at the periphery, using the sample area 4 m-wide described above. The total number of nests was estimated based on the total nesting area, which was in turn calculated using Google Earth 5.

TABLE 1
Number of nests of seabirds breeding at Arrecife Alacranes in 1986, numbers by Tunnell & Chapman (2000), and the number of this study (2009)

Islands	Red-footed Booby	Masked Booby	Brown Booby	Magnificent Frigatebird	Laughing Gull	Sooty Tern	Brown Noddy	Royal Tern	Cabot's Tern
Isla Chica									
Tunnell & Chapman	-	-	-	-	3	-	-	28	151
This study	-	20	-	-	18	15	-	40	-
Isla Blanca									
Tunnell & Chapman	-	3	-	-	-	-	-	-	-
This study	-	65	-	-	30	-	-	-	-
Isla Pérez									
Tunnell & Chapman	-	-	-	-	-	13 080	1 357	-	-
This study	-	-	-	-	110	139 115	5 565	35	260
Isla Desertora									
Tunnell & Chapman	3	2 533	-	206	10	10	-	-	-
This study	13	1 530	-	50	18	170	-	-	8
Isla Desterrada									
Tunnell & Chapman	-	-	10	52	50	-	-	-	-
This study	-	-	80	155	300	220	-	13	100
Totals									
Tunnell & Chapman	3	2 536	10	258	63	13 090	1 357	28	151
This study	13	1 615	80	205	476	139 520	5 565	88	368

RESULTS

See Table 1 and Figures 2 and 3 for summaries of the following results.

Isla Pérez

Brown Noddy: the nests were built on casuarina shrubs *Casuarina equisetifolia* and on native shrubs of *Tournefortia gnaphalodes*. In March, we estimated that there were 981 active nests (or 1962 individuals) and, in July 5565 active nests (or 11130 individuals).

Sooty Tern: in March, we direct counted 4262 nests, based on a density of 38 nests per 16 m^2. Based on this information, we estimated that the total number of nests was 139115 (or 278230 individuals). In July, we estimated that the total number of adults on nests or caring for chicks or fledglings was only 5600. Therefore, it appeared that the remaining Sooty Terns had already left the island.

Royal Terns, Cabot's Terns, and Laughing Gulls (Laridae): in July, we recorded 70 adult Royal Terns, 514 adult Cabot's Terns with 256 fledglings, and 212 adult Laughing Gulls with 50 associated chicks, most at the fledgling stage.

According to local staff at Isla Pérez, at the time there were at least two cats *Felis catus* and numerous black rats *Rattus rattus* inhabiting the island. Later, house mice *Mus musculus* were also found on Isla Blanca (Pájaros) and Isla Desertora (or Isla Muertos) (Latofski-Robles *et al.* 2014, Samaniego-Herrera *et al.* 2017). Introduced rodents were not found either on Isla Chica or Isla Desterrada. These exotic species very likely affected the breeding success of the seabirds.

Isla Chica

Masked Booby: in March, we found 26 breeding adults on 22 nests (thus 44 nesting adults) with 18 eggs and 17 chicks. In July, no Masked Boobies were seen nesting.

Sooty Tern, Laughing Gull, and Royal Tern (Laridae): we recorded 15 active Sooty Tern nests (30 adults), 18 Laughing Gulls with nine chicks, and 80 Royal Terns with 30 chicks.

Isla Blanca

Masked Booby: in March, 76 adults were recorded, occupying 64 nests (thus, 128 nesting adults) with 32 eggs, 27 chicks, and three juveniles. In July, three active nests with fledglings were observed.

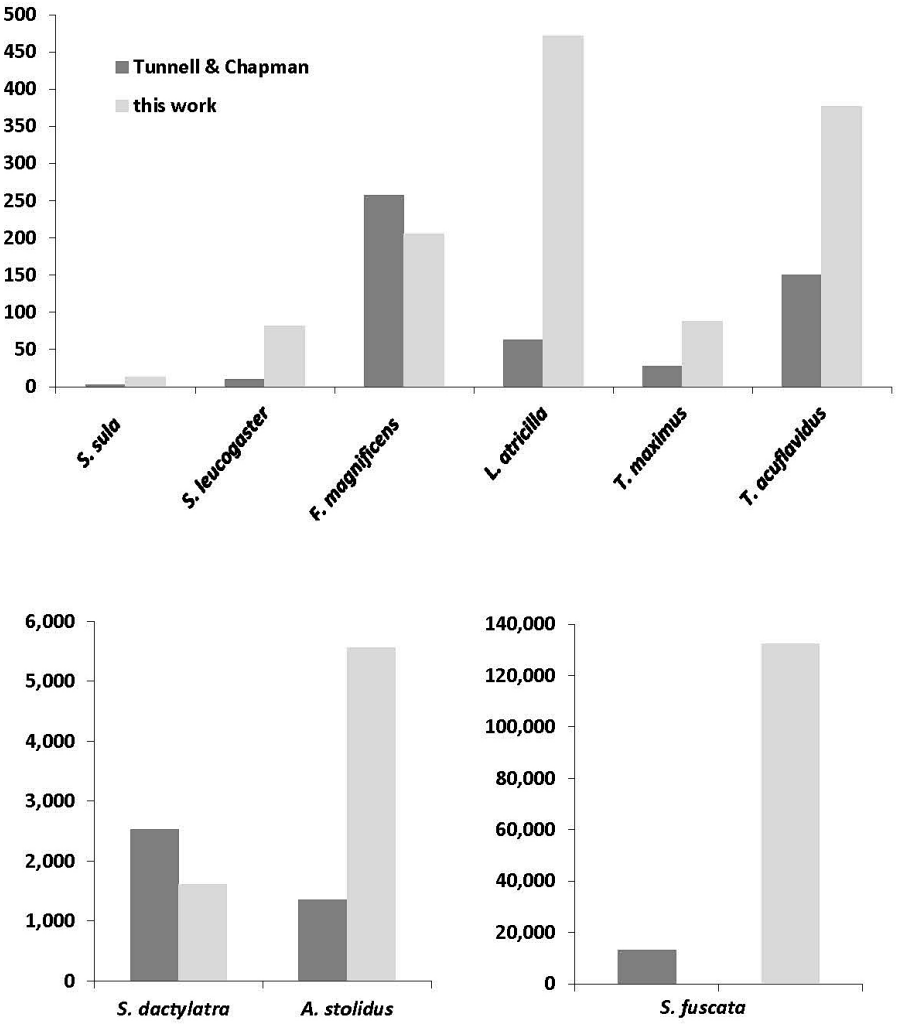

Fig. 2. Nest numbers of all seabird species breeding on islands of the Arrecife Alacranes in 2009.

Laughing Gull: in March, we estimated that there were at the most 56 nesting adults, based on counts that totaled four single chicks and 24 two-chick broods (thus, 28 pairs). In July, 17 pairs were observed.

Isla Desertora

Masked Booby: in March, a total of 844 adults were recorded through direct counts, occupying 827 nests (estimating 1 654 breeding adults) with 622 eggs, 456 chicks, and three juveniles. The photographic censuses revealed 702 additional adults at nests, indicating ~1 400 additional breeding adults, or a total of 3 054 breeding adults. In July, the photographic census revealed 3 028 adults; however, these were no longer on nests, and the vast majority of chicks had fledged. It seems highly unlikely that most adults were on the island when the photographic census was made. The figure of 3 028 adults is probably a low estimate of the total adult population in this area; therefore, we believe that this figure represents the lowest possible number of adult Masked Boobies on this island.

Red-footed Booby: in March, we found 12 active nests: four of them had chicks and eight had an attending adult. In July, we found 13 active nests: five with incubating adults and eight with chicks, two of which still in down, and six fledglings. Three color morphs were observed: "white" (white with black primary and secondary feathers), of which we observed at most 12 individuals in a single day; "brown" (completely dark brown plumage), of which we observed only one individual; and "white-tailed brown" (brown body with white tail and vent feathers), of which we observed two individuals. These were all in contiguous nests. Based on photographs and direct counts, the approximate ratio of color morphs was approximately 73:6:21.

Magnificent Frigatebird: in March, of the 50 nests recorded, 21 had large fledglings and 42 had an adult sitting on the nest. To avoid disturbance, we were unable to determine whether these adults were incubating or brooding a very small chick. In July, the frigatebirds had abandoned their nests.

Laughing Gulls, Sooty Terns, and Cabot's Terns (Laridae): in July, 30 adult Laughing Gulls were associated with 18 fledglings; 340 adult Sooty Terns, and 16 adult Cabot's Terns were also observed.

Isla Desterrada

Brown Booby: in March, 82 nests were recorded through direct counts (thus, 164 breeding adults), of which 56 had an adult, 17 had eggs, 57 had chicks, and 10 had fledglings. In July, there were no nests of this species, but we recorded 45 adults and 192 fledglings.

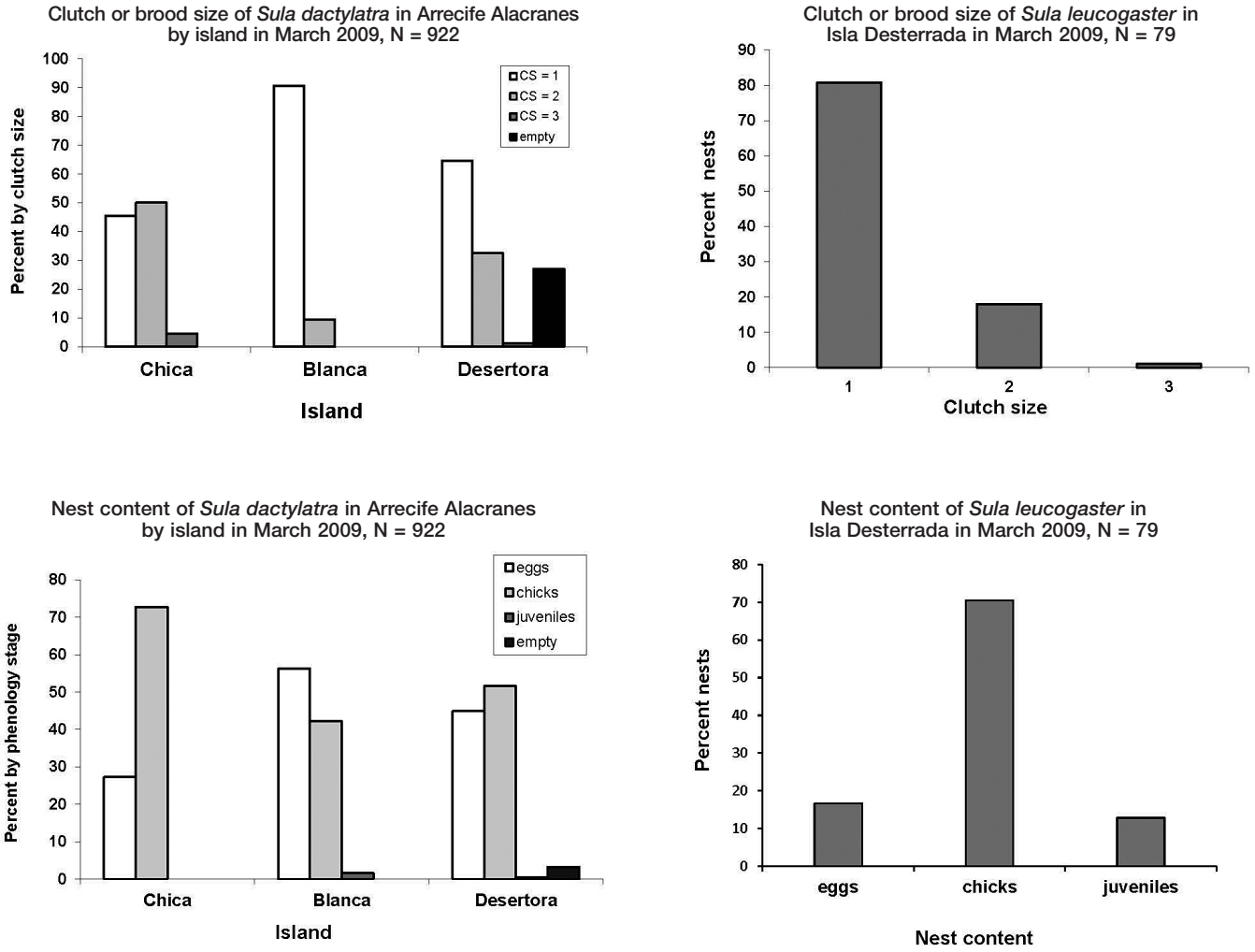

Fig. 3. Nest content and clutch/brood size of Masked and Brown Boobies on islands of Arrecife Alacranes in 2009.

Magnificent Frigatebird: The photos detected 156 adults on nests, at a male-to-female ratio of 50:50. In July, direct counts revealed 200 females, 20 males, and 60 juveniles perching on shrubs of *T. gnaphalodes*—none nesting. On a different occasion, 703 females, 15 males, and 57 juveniles were recorded flying over the island. We are unsure whether these adults were nesters, or whether they had just gathered in this region as they moved from other areas after breeding.

Royal Terns, Laughing Gulls, Cabot's Terns, and Sooty Terns (Laridae): in March, we recorded 25 adult Royal Terns. In July, we recorded 604 adult Laughing Gulls with 31 associated fledglings; 14 adult Royal Terns and seven fledglings; 125 adult Cabot's Terns with 109 fledglings (an estimated of 100 nests at the most, given that this species normally lays one egg); and 436 adult Sooty Terns, providing an approximate total of 218 pairs.

DISCUSSION

Species

Masked Booby

The Masked Booby is a member of the Sulidae family. It has a pantropical distribution and is the most abundant and widely distributed species of its family (Nelson 1978). It has pelagic foraging habit, consuming mainly flying fish and squid (Anderson 1993, AOU 1998, BirdLife International 2012); therefore, it is not surprising that it breeds in large numbers in this area—an atoll near the continental shelf edge. Peaks of breeding activity occur between January and March, when Tunnell & Chapmann (2000) and we observed the highest numbers of nests. However, it seems that this species has individuals that nest at different times almost year-round. The peak of the nesting season may vary from year to year, depending on oceanographic conditions and food availability, which is common among tropical nesting seabirds (Anderson 1993, Ramos 2001).

Brown Booby

The Brown Booby, whose distribution is pantropical, feeds inshore (Nelson 1978, BirdLife International 2012). It nests sympatrically with other sulids in our study area because this atoll is within reach of both the continental shelf edge and inshore coastal waters. However, the Brown Booby was not reported as a nester in this area until about 60 years ago (Lowery & Newman 1954). Also, the breeding chronology of this species is quite variable. In their January 1986 visit, Tunnell & Chapman (2000) found a small number of nests (a total of 10, with either eggs or chicks), but they also observed about 70 newly fledged young, suggesting that in that year there were about 80 nests. In March 2009, we counted 62 nests containing eggs and chicks (Fig. 3); therefore, according to our estimates of recent nesting numbers, little has changed since 1986 (Table 1). Our observations suggest also that the breeding season of the Brown Boobies is temporally extended, although we concur with Tunnell & Chapman (2000) that peak egg laying occurs mostly from October to March.

Red-footed Booby

The Red-footed Booby, which also has pantropical distribution and is abundant worldwide (Nelson 1978, Schreiber *et al*. 1996, Birdlife International 2012), is rare in the Gulf of Mexico (Lowery & Newman 1954, Clapp *et al.* 1982). The first reports of Red-footed Boobies nesting in this area were in 1986, by Tunnell & Chapman (1988) and in 1988 by Lockwood (1989), who found three and one active nests, respectively. The closest Red-footed Booby nesting area is in the Caribbean, some 600 km south, in Half Moon Cay, Belize (Verner 1961).

The Red-footed Booby is one of the few seabirds to exhibit color morphs (Nelson 1978, del Hoyo *et al.* 1992). We found three color morphs in a very small nesting population, while in other, much larger, nesting colonies, only one or two-color morphs have been found (Le Corre 1999). However, at the Galápagos Islands, which has the largest nesting colonies of the species (with ~140 000 pairs on Genovesa Island), and at Johnston Atoll, three color morphs are also present (Nelson 1978, Baiao *et al.* 2007). Also, the mixed color morphs of the Galápagos Islands and Johnston Atoll differ from each other (with a few light feathers in different areas of the predominantly brown body; Baiao *et al.* 2007) and from the one found in Arrecife Alacranes, which is brown with clearly defined white vent and tail feathers (Fig. 4). Nelson (1978) did not report the species nesting in the Gulf of Mexico, and stated that the white-tailed brown morph does not nest in the Caribbean. It will be interesting to try to determine the origin of the Red-footed Boobies that have started breeding at Isla Desertora, given that the closest nesting colony of this species, situated in Half Moon Cay, apparently includes only white phase individuals (Verner 1961). The brown morph is found nesting on the Cayman Islands and other Caribbean sites, and the white-tailed brown morph is found nesting on islands of the Atlantic Ocean, such as the Fernando de Noronha Archipelago, in Brazil (Schulenberg 2010).

As indicated by Tunnell & Chapman (2000), the species nests on shrubs or small trees. Consequently, the absence of vegetation tall enough to support nests of a relatively large seabird is a limiting factor. On Isla Desertora, the presence of *T. gnaphalodes* bushes is relatively recent, as reported by Bonet & Rzedowski (1962); as a result, the establishment of a nesting colony of Red-footed Boobies on this archipelago may be related to the arrival of this plant. Therefore, this is quite recent as well. Although Tunnell & Chapman (2000) suggest that the nesting season of the species on

Fig. 4. Red-footed Booby color morphs observed among individuals nesting on Isla Desertora, Arrecife Alacranes, in 2009. "White" and "brown with white tail" morphs on the left and "brown" morph on the right.

Isla Desertora is from November to April, they report having found nests with eggs both in February and July, and we also observed several nests with eggs in March and July. Therefore, the egg laying season of this species in this area seems to include an even longer time span than that for the other two booby species.

Magnificent Frigatebird

This pantropical member of the family Fregatidae commonly nests along the Pacific coast of Mexico and the Mexican and US coasts of the Gulf of Mexico (Lowery & Newman 1954, AOU 1998). It prefers to build nests on low trees and tall shrubs, but may also be found nesting on the ground, as reported by Tunnell & Chapman (2000) in Cayo del Este, part of the Cayo Arcas reef system, in Mexico. The egg laying season extends from September to January both in Barbuda (Diamond 1973) and on islands of the Campeche Bank (Tunnell & Chapman 2000). In March, we observed 50 attended nests on Isla Desertora and 156 adults flying over Isla Desterrada, while in July we recorded 718 non-nesting adults. This number is smaller than the 1 162 frigatebirds reported by Tunnell & Chapman (2000) and much smaller than the 3 000 reported by Howell (1989) as well as the 2 500 nests reported by Paynter (1955), both on Isla Desterrada. Given that these two surveys were carried out in October, the nesting population was most likely at its peak, and this may be why neither Tunnell & Chapman (2000) nor we found similarly high nesting numbers. This supports the need for more continuous and long-term monitoring of these important seabird nesting areas.

Laughing Gull

This species nests in very diverse habitats in North, Central, and South America, along the Pacific and Atlantic coasts, the Gulf of Mexico, and the Caribbean, mostly on islands (Clapp *et al*. 1983, Burger 1996, AOU 1998). There are 100-year-old reports indicating that it nested on Arrecife Alacranes (Kennedy 1917, Tunnell & Chapman 2000). In late July, we saw mostly fledglings (except for two incubating adults: one on Isla Blanca and one on Isla Desterrada). Therefore, the peak laying period must be in May, and that is why our March visit revealed no incubating adults. Our findings are consistent with dates reported by Tunnell & Chapman (2000) and by Schreiber *et al.* (1979), who collected data in Florida.

Tunnell & Chapman (2000) observed this species nesting on only some of the islands but predicted that the nesting area could expand in future years, and warned that such expansion could harm other species, particularly terns (Ansingh *et al*. 1960, Nisbet & Welton 1984). However, the numbers of Royal and Cabot's terns that we observed are almost twice as many as those reported by Tunnell & Chapman (Table 1). The presence of gulls and terns nesting in the same area is not necessarily cause for concern, since many such combinations appear to be common (Velarde & Anderson 1994, Gochfeld & Burger 1996, Shealer 1999, Rebón 2000, Velarde *et al.* 2005). This is particularly true when smaller terns nest together with larger, more aggressive terns, which could be the case in this archipelago. Larger terns may confer the smaller terns some protection against gull attacks, particularly when forming mixed colonies and mixed chick crèches, as observed here. Comparing Tunnell & Chapman's (2000) estimates of Royal and Cabot's terns with ours, in 1986 the size of these populations was half or less than in 2009 (Table 1). Therefore, in our view, the population of these terns has increased, and the status of these birds is not cause for concern.

Royal Tern

Nesting colonies of Royal Terns have been documented in North America (in the Atlantic, Gulf of Mexico, Caribbean, and Mexican Pacific) (Rebón 2000, Velarde *et al.* 2005, Angulo-Gastelum *et al.* 2011) as well as the east coast of South America (AOU 1998). Although Royal Terns are not considered threatened or of special concern, the species is not particularly abundant in any major area (del Hoyo *et al.* 1996). Royal Terns nest on flat open areas, usually with sandy bottoms and little or no vegetation, often along with other species of terns and gulls, feeding on small pelagic and demersal fish (Clapp *et al.* 1983, Buckley & Buckley 1972, 2002). The species was not found nesting during our visit in March; however, it was found with fledglings in late July. Therefore, we assume that egg laying occurred in late April or early May. This supports Tunnell & Chapman's (2000) recommendation to survey the Alacranes nesting colonies for this species from late April to late May.

Cabot's Tern

Cabot's Tern, until recently classified as the subspecies *Thalasseus sandvicensis acuflavidus,* is now considered a distinct species (Efe *et al*. 2009, Gill & Donsker 2016). It breeds along the Atlantic coast of North America and of the Caribbean, wandering as far north as eastern Canada and inland to Minnesota, Michigan, and Illinois (AOU 1998, Clapp *et al.* 1983). It usually nests in dense colonies with Royal Terns and Laughing Gulls (Shealer 1999). It winters in coastal waters of the Atlantic Ocean and of the Gulf of Mexico, from Florida to the West Indies, and is occasionally observed as far south as southern Brazil and Uruguay; it also winters along the Pacific coast, mainly from Oaxaca, Mexico, south to Panama (Howell & Webb 1995). It occurs sporadically in Colombia, Ecuador, and Peru (AOU 1998), as well as California and the Hawaiian Islands (Hamilton *et al*. 2007). The latter individuals are considered vagrants from Atlantic and Caribbean colonies (Collins 1997, Hiltry & Brown 1986, Ridgely 1981, Ridgely & Greenfield 2001). On occasion, Cabot's terns have been observed forming mixed-species pairs mainly with Elegant Terns *T. elegans* (Collins 1997, Velarde & Tordesillas 2009); there are reports of some hybrids and presumed hybrid offspring (Collins 1997, Velarde & Rojo 2012). The species usually nests on flat, scantily vegetated coastal areas, normally with a sandy or coral debris substrate (Shealer 1999). Howell (1989, cited in Tunnell & Chapman 2000) reported the presence of 250 individuals on Isla Pérez, but did not mention whether they were nesting; Kennedy (1917, in Tunnell & Chapman 2000) found 50 nests on Isla Blanca; and Tunnell & Chapman (2000) saw 151 nests on Isla Chica. In July, our observation of a total of 374 fledglings on three islands, Pérez, Desertora, and Desterrada, indicate that at least 748 adults could be breeding on these three islands, an increase from previous censuses.

Sooty Tern

The Sooty Tern is highly pelagic, abundant, and widely distributed in tropical and subtropical waters of the Atlantic and Pacific (Ashmole 1963, Clapp *et al*. 1983, AOU 1998, BirdLife International 2012). There are several reports of large numbers of Sooty Terns at Arrecife Alacranes, as summarized by Tunnell & Chapman (2000). In their 1986 visit, they reported having found 13 570 adults on Isla Pérez and 10 nests on Isla Desertora (approximately 20 breeding adults). This is significantly different from the 139 115 nests

estimated in our censuses on Isla Pérez in March 2009. It seems that the nesting population peaks after January, most likely in March. In July fledglings had dispersed from the area, given that only a few nests were found at that time.

Brown Noddy

This is a pantropical species that is quite eclectic in selecting their nesting sites, covering a large variety of habitats. Large colonies occur in the Gulf of Mexico and in the Caribbean, where it is one of the most abundant seabird species (see review by Tunnell & Chapman 2000). Our estimate of 11 130 nesting individuals is the highest recorded in this archipelago. This population increase may be explained in part by the fact that the Brown Noddy nests in trees, and the density of native shrubs and introduced trees—such as *Surina maritime* and *Casuarina equisetifolia*—has increased.

For all tern species in this archipelago, direct and indirect human disturbance in the form of egg collection and introduced species that may prey on eggs and adults have undoubtedly limited the number of nests and breeding success. Measures to protect the archipelago and eradicate exotic species will most likely help to increase nesting success and nesting populations (Latofski-Robles *et al*. 2014, Samaniego-Herrera *et al.* 2017). That has been the case in other islands where, for example, introduced rodents have been eradicated (Velarde *et al*. 2015).

Island

Our perspective is based on a comparison with the most recent survey of the islands, done by Tunnell & Chapman (2000). The information we were able to collect was determined by the dates of our visits. Ideally, we would have gathered data on nesting numbers more often, and we would have also gathered data on the outcome of breeding attempts. This type of data is particularly important in tropical areas, where the breeding habits of seabirds tend to be asynchronous and for extended periods (Anderson 1993, Ramos 2001). Variation in ocean and climate properties may also lead to important changes to the breeding ecology of seabirds because of changes in food availability (e.g., Anderson *et al.* 1980, Anderson & Gress 1984, Furness & Nettleship 1991, Crawford 1998, Velarde *et al.* 1994, 2004).

Another important factor that likely affects breeding patterns in general is the presence of introduced species that may prey on eggs and chicks. We observed that Isla Chica—where the Masked Booby had a greater proportion of clutches and broods with two eggs or chicks—had a greater proportion of nests with chicks than Isla Blanca and Isla Desertora (Fig. 3). Isla Chica had no rodents. Consequently, we suspect that the larger proportion of empty nests and of one-egg clutches on Isla Blanca and Isla Desertora was likely due to predation by rodents. Also, at these two islands, breeding occurred at a later time and fewer nests hatched chicks than on Isla Chica. Given that these islands are very close to each other, one would assume that they all share similar climatic conditions. Therefore, it is hard to use climatic differences to explain the differences above. The fact that Isla Blanca and Isla Desertora had juveniles suggests that the timing of nesting was overall similar. Therefore, introduced predators would appear to be the only difference. The total count of Royal and Cabot's terns in the entire archipelago is about three- and two-fold higher, respectively, than that reported by Tunnell & Chapman (2000). This increase may well be the result of the new protected status of the islands.

Isla Pérez

We found the nesting population of Sooty Terns to be an order of magnitude higher than that reported by Tunnell & Chapman (2000). The censuses were conducted in different seasons of the year, which may account for the different numbers. Our Brown Noddy count, conducted in the same month of the year as Tunnell & Chapman (2000), was significantly higher than in 1986. Tunnel & Chapman (2000) did not report on the presence of Cabot's and Royal terns on Isla Pérez.

Isla Chica

The population of Masked Boobies nesting on this island dropped compared to numbers by Kennedy (1917 in Tunnell & Chapman 2000), who reported 100 individuals. We recorded only 44. This difference could be explained by the fact that this species is known for changing where it nests. This is the first time Sooty Terns were seen nesting on Isla Chica. As for Cabot's Tern chicks, we observed only three, while Tunnell & Chapman (2000) reported on 151 nests of this species. Terns are well known for changing their nesting sites between or even within seasons either due to disturbances in the nesting areas or for no apparent reason.

Isla Blanca

The number of Masked Booby nests increased since the report by Tunnell & Chapmann (2000), from three to 64, according to our counts. However, between 1952 and 1962, at least 100 nests were reported by Paynter (1955) and Fosberg (1962), respectively (in Tunnell & Chapman 2000). However, oceanic factors may drive these yearly differences in the number of nesting individuals; unfortunately, this is hard to prove in retrospect.

Isla Desertora

In our March census, we estimated that 3 058 Masked Boobies were nesting on this island, while the census conducted by Tunnell & Chapman (2000) in January reported 5 066. Our July census revealed 3 028 individuals, while Tunnell & Chapman (2000) found 2 050 (based on 1 025 nests). We have no explanation to offer for these differences, except for yearly seasonal variations. As Tunnell & Chapman (2000) pointed out, according to information published globally and their own data on this species, the colony on Isla Desertora is the largest nesting concentration of Masked Boobies in the eastern Caribbean and Gulf of Mexico regions and is among the largest in the world. The difference between our count and Tunnell & Chapman's (2000) emphasizes the need for more permanent and long-term monitoring of these important seabird populations.

The number of Red-footed Boobies increased significantly. In 1986, Tunnell & Chapman (2000) observed three pairs, whereas we counted 13. Although this species has a pantropical distribution (Nelson 1978), it had not been reported nesting in the Gulf of Mexico until Tunnell & Chapman (2000) published their research, conducted in 1986; the closest known nesting site of Red-footed Boobies is in Belize (Vermer 1961). This small colony, with growth rate of approximately 0.44 individuals per year, represents a westward expansion. This information is important for Mexico, given that the species is included in standard NOM-

059-SEMARNAT-2010, the official standard that describes species under some kind of official protection status. Previously, Red-footed Boobies had been reported nesting only on a few islands of the Pacific coast of Mexico.

The number of Magnificent Frigatebirds dropped to almost half the number reported by Tunnell & Chapman (2000) for this island. The nesting periods of the year that we observed matched those observed by these authors, where January had the largest number of active nests. The count of Sooty Terns increased from 20 to 340 for the same period (Tunnell & Chapman 2000). We cannot explain this increase, except to suggest that it is a result of the current protected status given to these islands.

Isla Desterrada

This is the first time we observed the presence of Sooty and Cabot's terns nesting on this island. For Laughing Gulls, according to our records the nesting population increased from 400 to 604 individuals at the most, compared with Tunnell & Chapman's numbers (2000).

CONCLUSION

The coral reef islands of the Campeche Bank are an important nesting site for several seabird species. It is on these islands that we find the northernmost nesting populations of several species with mainly tropical affinity. In addition, the information provided by local staff and visiting researchers suggests that during the autumn many landbirds can be found on the islands, including raptors. Together, the presence of seabirds and landbirds notably increase the biotic importance of these islands. Therefore, we strongly recommend that monitoring be carried out regularly, especially to keep track of the main nesting seabird species in the area. Monitoring should include records of nesting population size, phenology, and breeding success.

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REFERENCES

AINLEY, D., SYDEMAN, W. & NORTON, J. 1995. Upper trophic level predators indicate interannual negative and positive anomalies in the California Current food web. *Marine Ecology Progress Series* 118: 69-79.

AINLEY, D.G., ADAMS, P.B. & JAHNCKE, J. 2015. California Current System – Predators and the Preyscape. *Journal of Marine Systems,* Special Issue 146: 1-130. doi.org/10.1016/j.jmarsys.2014.10.011

AOU (American Ornithologists' Union). 1998. *Check-list of North American Birds*. 7th ed. Washington, DC: American Ornithologists' Union.

ANDERSON, D.J. 1993. Masked Booby (*Sula dactylatra*) In: POOLE, A. & GILL, F. (Eds.) *The Birds of North America*, No 73. Washington, DC: American Ornithologists' Union, and Philadelphia: Academy of Natural Sciences.

ANDERSON, D.W., GRESS, F., MAIS, K.F. & KELLY, P.R. 1980. Brown pelicans as anchovy stock indicators and their relationship to commercial fishing. *California Cooperative Oceanic Fisheries Investigations, Reports* 21: 54-61.

ANDERSON, D.W. & GRESS, F. 1984. Brown Pelicans and the anchovy fishery off southern California. In: NETTLESHIP, D.N., SANGER, G.A. & SPRINGER, P.F. (Eds.) *Marine birds: their Feeding Ecology and Commercial Fisheries Relationships*. Canadian Wildlife Service, Canada: Pacific Seabird Group.

ANGULO-GASTÉLUM, U.T., CASTILLO-GUERRERO, J.A. & MELLINK, E. 2011. Breeding ecology of the royal tern (*Thalasseus maximus*) at Isla El Rancho, México: colony size and nest location affect predation. *Ornitología Neotropical* 22: 131-142.

ANSINGH. F.H., KOELERS, H.J., VAN DER WERF, P.A. & VOONUS, K.H. 1960. The breeding of the Cayenne or Yellow-billed Sandwich Tern in Curacao in 1958. *Ardea* 48: 51-65.

ASHMOLE, N.P. 1963. The biology of the Wideawake or Sooty Tern *Sterna fuscata* on Ascención Island. *Ibis* 103: 297-364.

BAIAO, P.C., SCHREIBER, E.A. & PARKER P.G. 2007. The genetic basis of the plumage polymorphism in Red-footed Boobies (*Sula sula*): a Melanocortin-1 receptor (MC1R) analysis. *Journal of Heredity* 98: 287-292.

BIRDLIFE INTERNATIONAL. 2012. BirdLife International Species Factsheet [Available online at: www.birdlife.org/datazone/species/. Accessed 13 June 2012].

BONET, F. & RZEDOWSKI, J. 1962. La vegetación de las islas del Arrecife Alacranes, Yucatán (México). *Anales Escuela Nacional de Ciencias Biológicas* 11: 15-59.

BUCKLYE, P.A. & BUCKLEY, F.G. 1972. The breeding ecology of Royal Terns (*Sterna* (*Thalasseus*) *maxima maxima*). *Ibis* 114: 344-359.

BUCKLEY, P.A. & BUCKLEY F.G. 2002. Royal Tern (*Sterna maxima*). In: POOLE, A. & GILL, F. (Eds.). *The Birds of North America*, No. 700. Washington, DC: American Ornithologists' Union, and Philadelphia, PA: Academy of Natural Sciences.

BURGER, J. 1996. Laughing gull (*Larus atricilla*). In: POOLE, A. & GILL, F. (Eds.) *The Birds of North America*, No. 225. Washington, DC: American Ornithologists' Union, and Philadelphia: Academy of Natural Sciences.

CLAPP, R.B., BANKS, R.C., MORGAN-JACOBS, D. & HOFFMAN, W.A. 1982. *Marine Birds of the Southeastern United States and Gulf of Mexico. Part I. Gaviiformes through Pelecaniformes*. Washington, DC: US Fish and Wildlife Service Office of Biological Services, FWS/OBS-82/01.

CLAPP, R.B., MORGAN-JACOBS, D. & BANKS, R.C. 1983. *Marine Birds of the Southeastern United States and Gulf of Mexico. Part III: Charadriiformes*. Report FWS/OBS-83/30. Washington, DC: US Fish and Wildlife Service, Division of Biological Services.

COLLINS, C.T. 1997. Hybridization of a Sandwich and Elegant Tern in California. *Western Birds* 28: 169-173.

COMISIÓN NACIONAL DE ÁREAS NATURALES PROTEGIDAS (CONANP). 2006. *Programa de Conservacion y Manejo Parque Nacional Arrecife Alacranes*. Mexico, DF: Comisión Nacional de Áreas Naturales Protegidas.

CRAWFORD, R.J.M. 1998. Responses of African Penguins to regime changes of sardine and anchovy in the Benguela System. *South African Journal of Marine Sciences* 19: 355-364.

CRAWFORD, R.M.J., MAKHADO, A.B. & OOSTHUIZEN, W.H. 2017. Bottom-up and top-down control of the Benguela ecosystem's seabirds. *Journal of Marine Systems*. doi:10.1016/j.jmarsys.2017.04.004.

DEL HOYO, J., ELLIOTT, A. & SARGATAL, J. 1992. *Handbook of the Birds of the World*. Vol. 1. Barcelona, Spain: Lynx Edicions.

DAMPIER, W. 1699. *Voyages and Descriptions, Volume 2, Part 2: Two Voyages to Campeachy*. 2nd Edition (Microfiche). London, UK: James Knapton.

DEVNEY, C.A., SHORT, M. & CONGDON, B.C. 2009. Sensitivity of tropical seabirds to El Niño precursors. *Ecology* 90: 1175-1183.

DIAMOND, A.W. 1973. Notes on the breeding biology and behavior of the Magnificent Frigatebird. *Condor* 75: 200-209.

DIARIO OFICIAL DE LA FEDERACIÓN (DOF). 1994. Decreto por el que se declara como área natural protegida, con carácter de parque marino nacional, la zona conocida como Arrecife Alacranes, ubicada frente a la costa del municipio de Progreso, del estado de Yucatán (06 July 1994). *Diario Oficial de la Federación*, México, DF, México.

EFE, M.A., TAVARES, E.S., BAKER, A.J. & BONATTO, S.L. 2009. Multigene phylogeny and DNA barcoding indicate that the Sandwich tern complex (*Thalasseus sandvicensis*, Laridae, Sternini) comprises two species. *Molecular Phylogenetics and Evolution* 52: 263-267.

FOSBERG, F.R. 1962. A brief survey of the cays of Arrecife Alacrán, a Mexican atoll. *Atoll Research Bulletin* 93: 1-25.

FURNESS, R.W. & NETTLESHIP, D.N. 1991. Seabirds as monitors of changing marine environments. *Acta XX Congresus Internationalis Ornithologici* 4: 2239-2240.

GALLARDO DEL ÁNGEL, J.C., VELARDE G., E. & ARREOLA A., R. 2004. Las aves del Golfo de México y las áreas prioritarias para su conservación. In: CASO, M., PISANTY, I. & EZCURRA, E. (Comps.). *Diagnóstico Ambiental del Golfo de México*, Vol. I. México, DF: Secretaría de Medio Ambiente y Recursos Naturales/ Instituto Nacional de Ecología/ Instituto de Ecología/ Harte Research Institute for Gulf of Mexico Studies.

GALLARDO, J.C., VELARDE, E. & MACÍAS, V. 2009. Aves: Birds of the Gulf of Mexico. In: FELDER, D., CAMP, D. & TUNNELL, J.W. (Eds.). *The Gulf of Mexico, its Origin, Waters and Marine Life*, Vol. I. College Station, TX: Texas A& M University Press.

GARCÍA DOMÍNGUEZ, J.A. 2009. *Avifauna Marina y Acuática de la Laguna de Tamiahua, Veracruz: Aspectos Ecológicos y Perspectivas de Conservación*. B.Sc. thesis. Xalapa, Mexico: Universidad Veracruzana.

GILL, F. & DONSKER, D. (Eds). 2016. IOC World Bird List (v 5.4). [Available online at: http://www.worldbirdnames.org/. Accessed 19 August 2017] doi:10.14344/IOC.ML.5.4.

GOCHFELD, M. & BURGER, J. 1996. Family Sternidae (Terns). In: DEL HOYO, J., ELLIOTT A. & SARGATAL, J. (Eds.) *Handbook of the Birds of the World*, Vol. 3. Barcelona, Spain: Lynx Edicions.

HAMILTON, R.A., PATTEN, M.A. & ERICKSON, R.A. (Eds.). 2007. *Rare Birds of California*. Camarillo, CA: Western Field Ornithologist.

HILTRY, S.L. & BROWN, W.L. 1986. *A Guide to the Birds of Colombia*. Princeton, NJ: Princeton University Press.

HOWELL, S.N.G. 1989. Additional information on the birds of the Campeche Bank, México. *Journal of Field Ornithology* 60: 504-509.

HOWELL, S.N.G. & WEBB, S. 1995. *A Guide to the Birds of Mexico and Northern Central America*. New York, NY: Oxford University Press.

HUMPHRIES, G.R.W., VELARDE, E., ANDERSON, D.W., HAASE, B. & SYDEMAN, W.J. 2015. Seabirds as early warning indicators of climate events in the North Pacific. *Pices Press* 23: 18-20.

KENNEDY, J.N. 1917. A little-known bird colony in the Gulf of México. *Ibis* 10: 41-43.

LATOFSKI-ROBLES, M., AGUIRRE-MUÑOZ, A., MÉNDEZ-SÁNCHEZ, F., REYES-HERNÁNDEZ, H. & SCHLÜTER, S. 2014. Prioritizing restoration actions for the islands of Mexico. *Monographs of the Western North American Naturalist* 7: 435-441.

LE CORRE, M. 1999. Plumage polymorphism of red-footed boobies (*Sula sula*) in the western Indian Ocean: an indicator of biogeographic isolation. *Journal of Zoology* 249: 411-415.

LOCKWOOD, C.C. 1989. *The Yucatán Peninsula*. Baton Rouge: Louisiana State University Press.

LOWERY, G.H., JR. & NEWMAN, R.J. 1954. The birds of the Gulf of México. *Fishery Bulletin of the Fish and Wildlife Service* 55: 519-540.

LYVER, P., MOLLER, H. & THOMPSON, C. 1999. Changes in sooty shearwater *Puffinus griseus* chick production and harvest precede ENSO events. *Marine Ecology Progress Series* 188: 237-248.

NELSON, J.B. 1978. *The Sulidae: Gannets and Boobies*. London, UK: Oxford University Press.

MELLINK, E., PEREZBARBOSA, E., RODRÍGUEZ, R. & MÁRQUEZ, H. (2007). Breeding waterbirds in Lagunas Tamiahua and Pueblo Viejo, northern Veracruz, Mexico. *Bulletin of the Texas Ornithological Society* 40: 84-87.

NISBET, I.C.T. & WELTON, M.J. 1984. Seasonal variations in breeding success of Common Terns: consequences of predation. *Condor* 86: 53-60.

PAYNTER, R.A., Jr. 1955. The ornithogeography of the Yucatan Peninsula. *Bulletin of the Peabody Museum of Natural History* 9: 1-329.

RAMOS, J.A. 2001. Seasonal variation in reproductive measures of tropical Roseate Terns *Sterna dougallii* previously undescribed breeding pattern in a seabird. *Ibis* 143: 83-91.

REBÓN G., F. 2000. Distribución, abundancia y conservación de la avifauna de las Islas Marietas, Nayarit, México. *Anales del Instituto de Biología*, *Universidad Nacional Autónoma de México, Serie Zoología* 71: 59-88.

RIDGELY, R.S. 1981. *A Guide to the Birds of Panama*. Princeton, NJ: Princeton University Press.

RIDGELY, R.S. & GREENFIELD, P.J. 2001. *The Birds of Ecuador. Volume 1: Status, Distribution and Taxonomy.* Ithaca, NY: Cornell University Press.

SAMANIEGO-HERRERA, A., AGUIRRE-MUÑOZ, A., BEDOLLA-GUZMÁN, Y., ET AL. 2017. Eradicating invasive rodents from wet and dry tropical islands in Mexico. *Oryx* 1-12. doi:10.1017/S0030605316001150.

SCHREIBER, E.A., SCHREIBER, R.W. & DINSMORE, J.J. 1979. Breeding biology of Laughing Gulls in Florida, Part I: nesting, egg, and incubation parameters. *Bird Banding* 50: 304-321.

SCHREIBER, E.A., SCHREIBER, R.W. & SCHENK, G.A. 1996. Red-footed Booby (*Sula sula*). In: POOLE, A. & GILL, F. (Eds.) *The Birds of North America*, No. 241. Washington, DC: American Ornithologists' Union, and Philadelphia, PA: Academy of Natural Sciences.

SCHULENBERG, T.S. (Ed.). 2010. Red-footed Booby (*Sula sula*). *Neotropical Birds Online*. Ithaca, NY: Cornell Laboratory of Ornithology. [Available online at: http://neotropical.birds.cornell.edu/portal/species/overview?p_p_spp=107836. Accessed 19 August 2017].

SHEALER, D. 1999. Sandwich Tern (*Sterna sandvicensis*). In: POOLE, A. & GILL, F. (Eds.) *The Birds of North America*, No. 404. Washington, DC: American Ornithologists' Union, and Philadelphia, PA: Academy of Natural Sciences.

SYDEMAN, W., BRADLEY, R., WARZYBOK, P., ET AL. 2006. Planktivorous auklet *Ptychoramphus aleuticus* responses to ocean climate, 2005: Unusual atmospheric blocking? *Geophysical Research Letters* 33: L22S09.

TUNNELL, J.W., JR. & CHAPMAN, B.R. 1988. First record of Red-footed Boobies nesting in the Gulf of México. *American Birds* 42: 380-381.

TUNNELL, J.W., JR. & CHAPMAN, B.R. 2000. Seabirds of the Campeche Bank Islands, Southeastern Gulf of México. *Atoll Research Bulletin* No. 482: 1-50.

VELARDE, E. & ANDERSON, D.W. 1994. Conservation and management of seabird islands in the Gulf of California: setbacks and successes. In: BURGER, J., GOCHFELD, M. & NETTLESHIP, D. (Eds.) *Seabirds on Islands: Threats, Case Studies and Action Plan*s, Cambridge, UK: ICBP Technical Publications.

VELARDE, E., CARTRON, J.L.E., DRUMMOND, H., ET AL. 2005. Nesting seabirds of the Gulf of California's offshore islands : diversity, ecology and conservation. In: CARTRON, J.L.E., CEBALLOS, G. & FELGER, R.S. (Eds.) *Biodiversity, Ecosystems, and Conservation in Northern Mexico*. New York, NY: Oxford University Press.

VELARDE, E., EZCURRA, E., CISNEROS-MATA, M.A. & LAVIN, M.F. 2004. Seabird ecology, El Niño anomalies, and prediction of sardine fisheries in the Gulf of California. *Ecological Applications* 14: 607-615.

VELARDE, E., EZCURRA, E., HORN, M.H. & PATTON R.T. 2015. Warm oceanographic anomalies and fishing pressure drive seabirds nesting north. *Science Advances*. doi: 10.1126/sciadv.1400210.

VELARDE, E. & ROJO, P. 2012. Presumed hybrid Elegant × Cabot's Terns in Isla Rasa, Gulf of California, Mexico. *Marine Ornithology* 40: 25-29.

VELARDE, E. & TORDESILLAS, M. 2009. Sandwich Terns on Isla Rasa, Gulf of California, Mexico. *Western Birds* 40: 230-233.

VELARDE, E., TORDESILLAS, M.S., VIEYRA, L. & ESQUIVEL, R. 1994. Seabirds as indicators of important fish populations in the Gulf of California. *California Cooperative Oceanic Fisheries Investigations, Reports* 35: 137-143.

VERNER, J. 1961. Nesting activities of the Red-footed Booby in British Honduras. *Auk* 78: 573-594.