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Original article

Breeding biology of Saunders's tern (*Sterna saundersi*) in the Farasan Islands, Kingdom of Saudi Arabia

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ABSTRACT

Saunders's terns (*Sternula saundersi*) are a small, ground-nesting marine bird species that have a massive rearing range, including the shores and islands of Asia and Africa adjacent to the north Indian Ocean. Despite occupying a large breeding range, little is known about the breeding ecology of this species. This research explored aspects of Saunders's terns' breeding ecology and predation rate in 2013 on the Farasan Islands of Saudi Arabia. The outcomes confirm that the mean clutch size of a Saunders's tern was 1.77 ± 0.08 (n = 31) eggs per clutch and the mean egg size was 31.05 × 23.15 mm. The results of this study show a remarkable relationship between clutch size and egg volume and length (p = .002, p = .004, respectively). Predation was the major reason for nest damage (62.5%). Evidence from cameras at nests showed that the predators of Saunders's tern nests on the Farasan Islands were white-tailed mongoose (*Ichneumia albicauda)* and Egyptian vultures (*Neophron percnopterus)*. This is the first study on the breeding ecology of Saunders's terns, and it shows that predator control is essential to the existence of the species. The results of this study suggest that fencing some breeding sites may help to minimize human disturbance and decrease the risk of nest predation from mammalian predators. Further research is needed to compare the predation rates on the mainland and islands and to develop efficient strategies to conserve this ground-nesting species.

1. Introduction

Saunders's tern (*Sterna saundersi*), also recognized as the black-shafted tern (del Hoyo et al., 1996), is in the Laridae family (BirdLife International, 2020), and it has recently been included in the genus *Sterna* (del Hoyo and Collar, 2014). It is a small seabird (weight 40–45 g) that is very similar to the little tern (*Sterna albifrons*) (Snow and Perrins, 1998; Safford and Hawkins, 2013). It has an extensive breeding range, stretching from the Red Sea coastal area and along coastal areas of the Arabian Gulf to south-west India, Sri Lanka, and the Maldives (Safford and Hawkins, 2013; del Hoyo and Collar, 2014; BirdLife International, 2020). In Saudi Arabia, it is a common and widespread nesting species along the Red Sea and the Arabian Gulf coastal areas and islands (Jennings, 2010; BirdLife International, 2020). A huge number of this species has been documented across the Arabian Gulf of Saudi Arabia during autumn, with a small number during winter. This suggests that the species most likely moves into different regions during winter (Bundy et al., 1989; Jennings, 2010; del Hoyo and Collar, 2014). Jennings (2010) reported that the population of Saunders's tern in the Red Sea of Saudi Arabia was 1000 pairs and that the total population on the Arabian Peninsula was about 4000 pairs. The population of this species in the Farasan Islands was last estimated in 1994. It showed that 20 breeding pairs and between 365 and 595 individuals were there in winter (BirdLife International, 2020).

This species occupies a variety of coastal areas: estuaries, shallow tropical and subtropical inshore waters, tidal lagoons, and harbors (del Hoyo et al., 1996; Snow and Perrins 1998; Jennings, 2010). Its diet comprises many kinds of marine animals, such as small fish, crustaceans, and mollusks, but it also eats different kind of insects (del Hoyo et al., 1996). It nests on the ground up to 2 km inland on uncovered sandy sites, shingles, or dried mud, and it nests in single pairs or small colonies of 5–30 pairs (del Hoyo

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et al., 1996; Snow and Perrins 1998). The nest is a small hollow in the ground lined with small pebbles (del Hoyo et al., 1996). The nest is usually 10 to 20 m away from other nests in the colony (Jennings, 2010).

The breeding season for the Saunders's tern is between March and June (Jennings, 2010; Shobrak and Aloufi, 2014). The female produces two pale eggs (del Hoyo et al., 1996). The species is nowadays classified as "least concern" by the IUCN Red List (BirdLife International, 2019). However, the population is decreasing (BirdLife International, 2020) because of disturbance, entertainment activities, egg collection, predation by rats, feral dogs and cats at nesting areas and habitat loss because of development (del Hoyo et al., 1996; Jennings, 2010; Gochfeld et al., 2016).

One of the most important negative factors for nesting success in seabirds is predation (Becker, 1995; Whittham and Leonard, 1999; O'Connell and Beck, 2003; Nordström et al., 2004; Scopel and Diamond, 2018; Greenwell et al., 2019). Nest predation is the primary factor of bird nest mortality, and it causes about 80% of nest failures (Ricklefs, 1969; Martin, 1993; Schlesselmann et al., 2018). Several studies have shown that predation pressure can affect the choice of nest location (Martin, 1993; Mainwaring et al., 2014; Barros et al., 2016), optimum clutch size (Martin, 1995; Dillon and Conway, 2018), and different features of breeding behavior (Martin et al., 2000; Martin and Chalambor, 2002). Predation can result in adaptive shifts in prey ecology and behavior; prey is prone to display techniques like selection of different habitat or behavioral responses to decrease the threat of predation (Caraco et al., 1980; Orians and Wittenberger, 1991; Smith and Edwards, 2018; Humphreys and Ruxton, 2020). Ground-nesting birds in particular show other behavioral tactics to avoid nest predation, for instance, nest defense (Brunton, 1999; Hernandez-Matias et al., 2003), differences in nest spacing (Larivière and Messier, 1998), lower nest accessibility (Jobin and Picman, 1997), hiding of nest sites (Clark and Nudds, 1991; Wilson-Aggarwal et al., 2016; Gómez-Serrano and López-López, 2017), and misleading behaviors, such as broken-wing displays (Gómez-Serrano and López-López, 2017; Smith and Edwards, 2018).

The Red Sea coasts in Saudi Arabia are one of the most threatened habitats in the district, and they face some robust human-induced challenges connected with population development, habitat decay, and coastal development (Sheppard et al., 2010; Sale et al., 2011; Al-Obaid et al., 2017; Khawfany et al., 2017). In addition, Raitsos et al. (2013) indicated that the Red Sea was suffering from a rapid increase in average temperature. This rise in temperature is a factor that reduces both reproduction and survival rates of seabirds (Furness, 2016), especially species nesting on uncover areas (Shobrak and Aloufi, 2014). Moreover, AlRashidi et al. (2012) indicated that the potential impacts of rising sea levels because of climate change will cause a decrease in suitable nesting habitats of ground-nesting species in Farasan Islands. Furthermore, the war at the southern border of the Kingdom of Saudi Arabia might have potential negative impacts on biodiversity and the ecosystem in the Farasan Islands (Lawrence et al., 2015). These include habitat modification, pollution, declining populations, and reduced biodiversity (Lawrence et al., 2015; Hanson, 2018).

Saunder's terns are studied not only for their value in their ecosystems and the decline in their population, but also because only a modest amount of research on them has been carried out. We believe that the knowledge gained through this research can affect management decisions about conservation strategies for the Saunders's tern.

The goals of this study are 1) gathering basic demographic and behavioral data of the Saunders's tern and 2) identifying the predation rate and main predators of Saunders's tern eggs in the Farasan Islands.

2. Methods

2.1. Study area

This study was carried out between 21 March and 4 June 2013 on the eastern section of Farasan Island, the largest island in the archipelago. It is in the Red Sea, roughly 50 km southwest of Jizan, Saudi Arabia, at 16°36′46.9″ N, 42°8′45.6″ E (Fig. 1) For more information about the study area see AlRashidi et al. (2011a).

2.2. Breeding parameters and observations

The area was explored for nests from the coastline to 1000 m inland, using binoculars (10 × 50). Two strategies were utilized to detect nests: 1) driving a vehicle at slow speed and looking for incubating birds and 2) following parents when they turned back from the coastline to their nest sites. For each discovered nest, the time, date, clutch size, measurements of the eggs, and geographic coordinates utilizing a GPS device were recorded. In addition to that, each discovered nest was photographed. Mean clutch sizes were estimated from nests known to be completed or if the clutch size was unaltered for at least five days before a loss occurred. The nest and egg number were marked on the obtuse end of each egg, utilizing black permanent marker (see Székely et al., 2008). When an egg was detected, a digital caliper (±0.01 mm) was used to measure the length (L) and breadth (B). Egg volume (V) was estimated only for complete clutches according to the formula used by Catry et al. (2004), $V = K_v \times L \times B^2$, where the constant $K_v = 0.4866$. Egg flotation was utilized to approximate the date the egg was laid (see Székely et al., 2008). To recognize nesting sites, nest markers (plastic straws) were erected about 10 m from each discovered nest. All the straws were collected after the breeding season.

Parents of Saunders's terns were caught with funnel traps on the nest or funnel traps suited to the chicks (see Székely et al., 2008). The chicks were coated with an appropriately sized sieve which harbored whole chicks, and the funnel trap was placed around the sieve. Captured adults were ringed using one metal ring from the Saudi Wildlife Authority and two colored rings in a unique mixture. Chicks were ringed with one metal ring and one colored ring. Biometric data were gathered from adults and chicks: weight, length of right tarsi, length of the right wing, and length of the bill.

The weight of Saunders's terns was measured with a spring balance (100 g), the right tarsi and the length of the bill were measured with sliding calipers, and the length of the right wing was measured with a ruler.

Data on nest attendance routines were recorded either from direct observation of ringed birds or by using Reconyx (SC950HyperFireSecurityIR) cameras. The cameras were placed about 1.5 m from nests to determine predators and give further details on nest attendance behavior. Because Saunders's terns are easily disturbed by foreign materials around the nesting area, the cameras were colored with clay-colored paint to appear like the environment around the nests (Fig. 2). The cameras were set to take one photo every 5 s for 24 h. The installation of each camera required less than 5 min, a small inconvenience that allowed the parents to come back to the nest only a few minutes later.

2.3. Predation and reproductive success

To record the status of discovered nests and to seek chicks, the nests were checked every 2–5 days during the laying period until the entire clutch failed or at least one nestling successfully fledged. For each nest with eggs, the number of hatched eggs and number

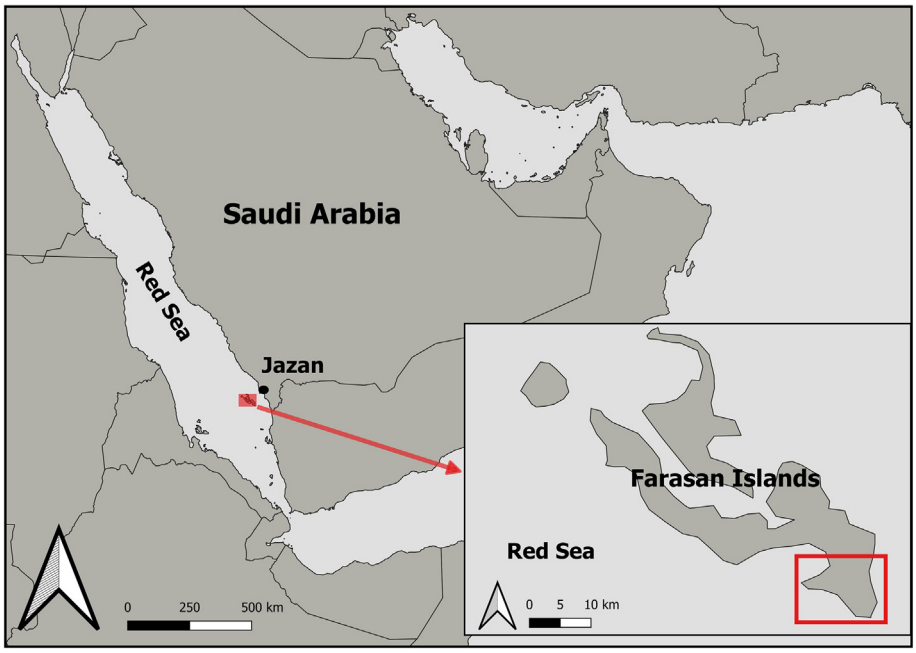

Fig. 1. Map of the Farasan Islands, Red rectangle displaying the Saunders's tern study site.

Fig. 2. Showing the cameras coloured with clay-coloured paint to become invisible in the environment surrounding the nests.

of fledged chicks were documented. In addition, the fates of nests were documented utilizing the following criteria: (1) "hatched" when one or more eggs hatched, (2) "predated" when the eggs disappeared from the nest with no indication of chicks, (3) "abandoned" when parents were absent from the nest all day, or there were no Saunders's tern footprints on any side of the nest, or (4) "unknown" when the fate of the nest was not followed up on or the eggs vanished and neither hatching nor predation was proven. Nest hatching success was estimated as the percentage of nests with at least one hatched egg.

To evaluate egg predation, we determined the ratio of nests that suffered any form of egg predation in relation to the entire number of nests marked. In addition, we determined the likelihood of predation as the number of nests that suffered egg predation out of the overall number of nests, eliminating those nests that had been deserted for unknown causes.

2.4. Statistical analyses

Statistical examinations were implemented utilizing R (version 3.2.2, "Fire Safety," R Core Team, 2015). The normal distribution of data was examined utilizing a Shapiro-Wilk test (Shapiro and Wilk, 1965). This test showed that the morphometric data had variances that did not differ from a normal distribution ($p > .05$). Correlations among egg measurements and clutch sizes were calculated utilizing Pearson's correlation test. The statistical standard of importance was set at $p < .05$ for the whole statistical analysis. Means are presented as ±; standard error as SE.

3. Results

3.1. Breeding ecology

3.1.1. Nest site

In total, 40 Saunders's tern nests were discovered. The nests were shallow scrapes in exposed sand on an open site without vegetation (Fig. 3). Some birds placed their nests on flat sandy areas whereas others placed their nests on small mounds and surrounded them with several shells. The material inside the nests was tiny pebbles and marine shells. The nests were between approximately 50 m and 500 m from the shoreline. Most nests were recorded singly. The other nests were recorded in small loose colonies. Moreover, the nests were generally located between 10 and 100 m from each other. We recognized that when the distances between nests were less than 10 m, there would be fighting between neighbors. The oldest neighbors, who had two eggs, attempted to disclose the nest of their neighbor (which had a single egg) by standing or hovering over their neighbor's nest.

3.1.2. Laying date, clutch size, and egg dimensions

Egg laying occurred between the end of February 2013 and the beginning of June 2013. The eggs began to hatch by the end of March 2013. Each female laid one or two eggs. The eggs were generally a pale cream with brown and gray markings. Nine out of 40 nests were uncompleted clutches. Regarding clutch size, most nests (24 of 31 or 77.4%) contained two eggs, and 10 (22.6%) con-

Fig. 3. The nest site selection and nest materials of Saunders's terns.

tained one egg. The mean clutch size of the studied Saunders's terns nests was 1.77 ± 0.08 eggs per clutch (median = 2).

The mean length and breadth of whole eggs were 31.05 ± 0.16 mm (range 29–35 mm; n = 64, median = 31 mm) and 23.15 ± 0.07 mm (range 22–24.5 mm; n = 64, median = 23 m m), respectively. In addition, mean egg volume was 8.15 ± 0.07 cm^3 (n = 31). Egg volume and egg length were negatively and remarkably correlated with clutch size (Pearson's correlation coefficient r = -0.523, p = .002, n = 31 and r = -0.497, p = .004, n = 31, respectively), whereas egg breadth was negatively and not remarkably correlated with clutch size (Pearson's correlation coefficient r = -0.318, p = .081, n = 31).

3.1.3. Capture and measurements

Thirty-three Saunders's terns were caught on the Farasan Islands (28 adults and 5 chicks). The mean weight, wing length, tarsus length, and bill length of caught adults were 45.58 ± 0.97 g (range = 38–59.5 g; n = 27, median = 45 g), 167.95 ± 0.5 mm (range = 162–175 mm; n = 27, median = 168 mm), 17.5 ± 0.29 m m (range = 12–22 mm; n = 27, median = 18 mm) and 28.6 ± 0.26 mm (range = 25.25–31 mm; n = 27, median = 28.75 mm), respectively.

3.1.4. Parental behavior

Although there was a high number of nest predators on Farasan Island, some information on the incubation routine was recorded. For example, incubation usually started once the first egg was produced. The nest cameras recognized that the two parents shared the incubation routine almost equally. Furthermore, they seemed to support each other. One parent would fetch food for its mate, who was incubating the eggs (Fig. 4). In addition, nest cameras recorded parents bringing food (small fish) for their mate during incubation and to chicks after hatching, grasping the food in its bill until the mate or chick caught the food. When the chicks hatched, they generally remained around the nest and their parents cared for them near the nest. In three families, the researcher caught both parents with their chicks. Several active behavioral characteristics of Saunders's tern parents and chicks were noticed. These included parents' defense of the nest by directly attacking predators and the chicks' evasive tactics by moving to a hiding place, making them quite difficult for an Egyptian vulture to catch.

Fig. 4. One parent would brought prey (small fish) for its mate, who was incubating the eggs.

3.2. Nest predation

The main consequences for Saunders's tern nests (n = 40) were eight hatched (20%), 25 predated (62.5%), three deserted (7.5%), and four unknown (10%). Predation was the largest cause of nest mortality for the Saunders's terns. The predators included white-tailed mongoose (*Ichneumia albicauda*) and Egyptian vultures (*Neophron percnopterus*). Mongoose preyed upon 13 nests and Egyptian vultures on eight nests (Fig. 5). The potential predators of Saunders's tern nests also included sooty gulls (*Larus hemprichii*) and Egyptian saw-scaled viper (*Echis pyramidum*). After the peak of the Saunders's tern breeding season, the numbers of sooty gulls started to rise. Consequently, they appeared as potential predators of the Saunders's tern eggs and chicks. Even though there was no evidence that they predated any eggs or chicks, some sooty gulls were observed hovering over the Saunders's tern nesting sites and standing on the shoreline in groups. No cases of nest flooding were observed at any time during the breeding season, and there were no attempts to re-nest around the nesting area after predation.

4. Discussion

This first study of Saunders's tern breeding biology in the Farasan Islands has yielded basic information on the breeding parameters of this poorly known species in one part of the tern breeding range in Saudi Arabia. This allows wide comparisons with similar research at other locations. The current study found that the Saunders's tern selected sandy open sites without vegetation for nesting. This result is consistent with that of Jennings (2010), who reported that this species selected open areas with no distinctive features, likely because such a site would thereafter become less attractive and visible to ground predators. In addition, this study confirmed that this species generally nests singly but sometimes nests in small, loose colonies. Tern species usually breed in colonies, but a few them nest in small or sparse groups (Gochfeld and Burger, 1996). Burger and Gochfeld (2001) indicated that large

Fig. 5. Showing mongooses and Egyptian vultures prey on nests of Saunders's terns.

tern species are inclined towards breeding in wide, high-density colonies. In contrast, smaller tern species tend to nest in small, sparse, low-density colonies (Gochfeld and Burger, 1996). A possible explanation for nesting singly on the Farasan Islands might be to avoid being discovered by mammalian predators. Öst and Steele (2010) showed that expert breeders can nest at concealed locations to decrease being detected by predators.

This study showed that the breeding season of this species occurs from the end of February to the beginning of June. This is considerably longer than results from other studies conducted in Saudi Arabia. For instance, Newton (2006) showed that the breeding season of Saunders's terns took place between February and late April in the Red Sea of Arabia, and Jennings (2010) reported that breeding in the southern part of the Red Sea occurred between late March and June. Moreover, Shobrak and Aloufi (2014) assumed that the breeding season of this species happened between late March and late June.

Another important finding was that more clutches had two eggs (>77%), and > 23% were finished with only one egg. This result is consistent with other research which stated that most nests (>60%) contained two eggs and minorities contained one egg or three eggs (Jennings, 2010). In addition, the results showed that the mean length and breadth of the eggs were 31.05 mm and 23.15 mm (n = 64), respectively. This finding corroborates the ideas of Shobrak and Aloufi (2014), who stated that the mean length and breadth of the eggs were 31.21 mm and 22.68 mm (n = 3), respectively. Moreover, this study found that the weight of a Saunders's tern adult was 45.58 g. This outcome is somewhat higher than the findings by del Hoyo et al. (1996) who indicated that the weight of this species was between 40 and 45 g.

Incubation is a fundamental element of avian parental behavior, and it requires an essential investment in caring for offspring by the incubators (Camfield and Martin, 2009; Bulla et al., 2015). This care requires a great deal of time and energy from both parents, increasing the fatality rate of parents or reducing the size of future generations (Clutton-Brock, 1991; Székely et al., 2006; McGraw et al., 2010; Nord and Williams 2015; Williams, 2018). Cockburn (2006) recorded that among avian species, 81% of brood care is supplied by both sexes. This study indicated that the Saunders's tern was analogous to other species of tern, in that incubation efforts were shared by both parents (Gochfeld and Burger, 1996).

This study reported that Saunders's tern parents brought small fish to feed their chicks. This finding is consistent with Nisbet et al., 2002; Catry et al., 2006; Alfaro et al., 2011 and Gaglio et al., 2018 who reported that, generally, tern species' diets depend predominantly on small fish, crustaceans, and insects, but they can feed on a wider variety of foods, depending on what is available.

This study showed that Saunders's terns suffered high predation rates from both the white-tailed mongoose and Egyptian vultures. This outcome is highly consistent with that of AlRashidi et al. (2011b), who reported that the predation of Kentish plover on the Farasan Islands was very high. Furthermore, Shobrak and Aloufi (2014) reported that the eggs of Saunders's terns were eaten by Sooty gulls in small colonies on the Al Wajh archipelago. In addition, AlRashidi and Shobrak (2015) reported that Saunders's tern parents generally left their nest to defend against predators, especially in periods when predator activity was rising. Many elements influence seabird breeding success, for instance, the quality of breeding habitat, the availability of food, competition, predation, and disease (Becker et al., 2007, Brooke et al., 2018; Edna et al., 2018). It has been contended that predation is the most selective pressure driving nest failure for the vast majority of birds (e.g. Johnson et al., 1989; Martin, 1995; Thompson, 2007). Eggs and chicks of seabird species, particularly tern species, are occasionally exposed to great rates of predation (Lack, 1968; Hulsman, 1977; Greenwell et al., 2019), while predation risk is minimal for adults (Lack, 1968).

4.1. Future management

Controlling predators is a vital issue to guarantee the survival of Saunders's terns and other ground-nesting birds on the Farasan Islands. Based on this research, we strongly agree with the ideas of AlRashidi et al. (2011a) idea about fencing off some locations—at least 1 km inland from the shoreline—to afford secure and sufficient nesting areas and brood rearing sites in isolation from mammalian predators. Such a resolution would be a vital element of conservation plans for ground-nesting populations, which are suffering from the risk of mammalian predators.

5. Conclusions

This study yielded essential data on the breeding ecology and predation rates of a Saunders's tern population on the Farasan Islands. For example, the results of this study show a significant correlation between clutch size and egg volume and egg length, respectively. Furthermore, this study exposed the high predation rates by white-tailed mongoose and Egyptian vultures on Saunders's tern nests. While this study has contributed beneficial information about the breeding ecology of Saunders's tern species, several issues remain. In particular, future research should focus on (1) exploring mate and site fidelity in the Saunders's tern by ringing both parents and collecting blood samples to determine males and females, (2) recording the incubation routine of the males and females to discover parental cooperation throughout the incubation period, (3) exploring and comparing the predation rates on the nests of Saunders's terns on the other, remote islands of the Farasan Archipelago, and (4) investigating the potential impacts of warfare at the southern border of the kingdom on the biodiversity in the Farasan Islands. Such research would help to understand the drivers of biodiversity tendencies after warfare.

All such information would help to establish suitable conservation strategies and habitat restoration efforts in the affected areas.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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