BREEDING ECOLOGY AND INCUBATION BEHAVIOURS OF LITTLE TERN *STERNULA ALBIFRONS* IN THE SABKHAT AL-FASL LAGOONS, SAUDI ARABIA

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ABSTRACT

AlRashidi, M. (2025). Breeding ecology and incubation behaviours of Little Tern *Sternula albifrons* in the Sabkhat Al-Fasl Lagoons, Saudi Arabia. *Marine Ornithology*, *53*(2), 235–241. http://doi.org/

Aspects of the breeding ecology and behaviour of the Little Tern *Sternula albifrons* were studied in the Sabkhat Al-Fasl Lagoons, Saudi Arabia, a region characterized by extreme temperature fluctuations. Ground temperatures in the area can range from 50 °C during the day to 25 °C at night. Observations of 147 nests revealed that Little Terns prefer to nest in exposed sites with no vegetation cover. The distance from nests to the nearest bushes ranged from 11–17 m (median = 13 m), while the distance to water ranged from 2–10 m (median = 4 m). Using a small trail camera, adult incubation behaviours were recorded at eight randomly selected nests over a 24-hour period. Results indicated that ground temperature influenced Little Tern nest attendance. During the hottest part of the day, when temperatures exceeded 45 °C, and at night, when temperatures dropped below 30 °C, nest attendance increased to over 95%, likely to prevent the eggs from experiencing lethal conditions. In addition, sunlight direction—especially during the hottest hours of the day—affected the orientation of the incubating adults. Adults frequently oriented themselves toward the east or north, using their bodies to shade the eggs. These two behaviours of incubating adults may reflect the species' remarkable ability to adapt to extreme environmental conditions.

Key words: harsh environments, incubation behaviour, nest attendance, seabirds, *Sternula albifrons*

INTRODUCTION

The Little Tern *Sternula albifrons* is a nearly cosmopolitan species, breeding across much of Europe, along the coasts and inland areas of parts of Africa, throughout much of western, central, and the extreme east and south of Asia, as well as in northern Australasia and at Midway Island, Hawai'i (BirdLife International, 2019; Pyle et al., 2001). Migratory individuals expand their distribution to cover most of the African coast, the Arabian Peninsula, the western coast of India, and the waters of Southeast Asia and Australasia, including New Zealand (BirdLife International, 2019). Despite being classified as Least Concern by the International Union for Conservation of Nature (IUCN), the species' overall population is in decline (BirdLife International, 2019). However, trends for some populations remain unknown or are increasing (Wetlands International, 2024). Several factors may contribute to population declines, including habitat loss and degradation, rising sea levels, human disturbance, and depredation (BirdLife International, 2019; Gochfeld & Burger, 1996; Gochfeld et al., 2020; Holloway, 1993; Jennings, 2010).

On the Arabian Peninsula, the Little Tern is primarily recognized as a rare breeding migrant. It arrives from Africa mainly in April and May and returns in September (Boland & Alsuhaibany, 2020; Jennings, 2010). Although precise data on its breeding numbers are lacking, the population in the Arabian Peninsula—estimated at approximately 200 pairs—appears to fluctuate annually, depending on conditions at available breeding sites (Jennings, 2010). Little Terns have been observed in a variety of habitats, including freshwater marshes, irrigation canals, inland pools, inundated areas, and lagoons formed by treated effluent, reaching distances of up to 70 km from the coast (Jennings, 2010). The species is socially monogamous and typically nests in small colonies, usually with fewer than 25 widely scattered nests (Boland & Alsuhaibany, 2020). Both parents share responsibilities for incubation and caring for the young. Nests are generally shallow scrapes or natural depressions in open ground and are often unlined or sparsely lined with materials such as plant debris, mud flakes, or shell fragments (Castro et al., 2024; Cheah & Ng, 2008; Jennings, 2010). The typical clutch size is two to three eggs, which are incubated for 21–24 d. Chicks are semi-precocial, leaving the nest shortly after hatching, and are capable of flight within three to four weeks (Boland & Alsuhaibany, 2020; Cheah & Ng, 2008; Jennings, 2010).

The breeding ecology and incubation behaviour of the Little Tern on the Arabian Peninsula remains poorly understood, particularly in a region characterized by intense heat and substantial temperature fluctuations between day and night during the summer. To address this knowledge gap, the present study aimed to (1) document key aspects of the breeding ecology at the colony in the Sabkhat Al-Fasl Lagoons, Saudi Arabia, including a description of the nesting area, mapping of nest locations, recording of clutch sizes, and documentation of egg-laying dates; (2) conduct continuous 24-hour monitoring of incubation behaviour, evaluating the influence of ground temperature and sun direction on incubating adults; and (3) identify behavioural strategies employed by parents to prevent eggs from reaching lethal temperatures under extreme environmental conditions.

METHODS

Study area

The Sabkhat Al-Fasl Lagoons, situated on the southwestern border of Jubail Industrial City in eastern Saudi Arabia, are designated as an important protected bird area by BirdLife International (BirdLife International, 2024). Covering an area of approximately 7 × 5 km, the lagoons receive and store excess wastewater from Jubail Industrial City. Water levels are generally very shallow, typically not exceeding 50 cm, except in the southern part, where depths can reach up to 1 m. In the southern part of the Sabkhat Al-Fasl Lagoons, the dominant vegetation is the common reed *Phragmites australis*, while salt-tolerant species such as *Halopeplis perfoliate* and *Zygophyllum coccineum* are more prevalent in the eastern and western areas. The western section also includes an old farm, a golf course, and several company buildings (Fig. 1).

Field observations

This study was conducted during the terns' breeding season in 2015/16. In 2015, the first visit took place from 22–29 March, followed by a second visit from 31 May–06 June. In 2016, the first visit took place from 28 May–05 June, and the second visit from 12–18 July. Nest surveys were conducted by walking along the dykes, unpaved roads, and flat areas of the lagoons, using 8×42 binoculars. Nests were located either by direct observation or by observing flushed incubating adults return to their nests. The coordinates of the nest were recorded with a handheld Garmin eTrex GPS unit.

Muted trail cameras (Bushnell 8MP Trophy Cam Black LED; Overland Park, USA) were used to monitor adult nest attendance behaviour on eight randomly selected nests and to identify potential threats or disturbances over a 24-hour period. Nests were selected

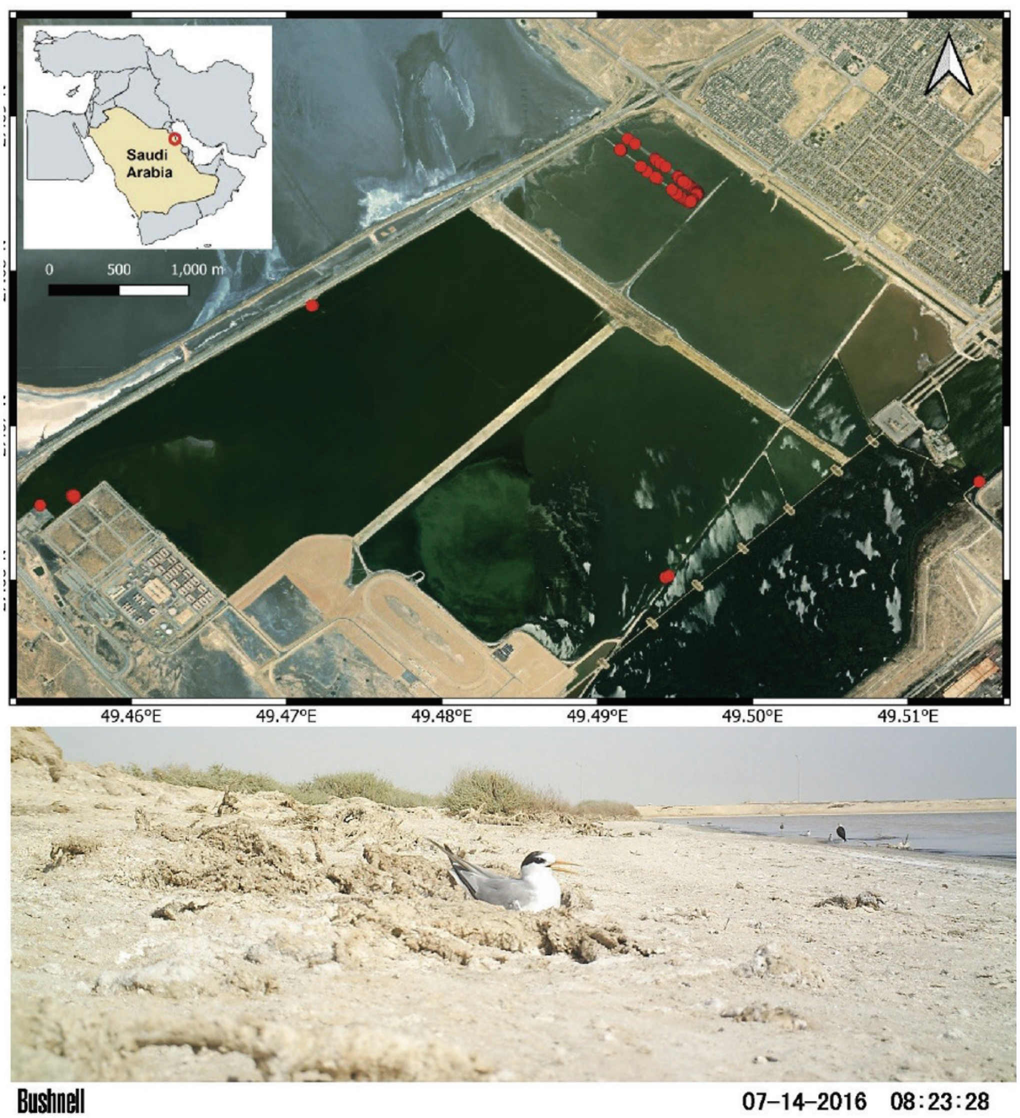

Fig. 1. Map of the Sabkhat Al-Fasl Lagoons, Saudi Arabia, created using QGIS v. 3.40, an open-source program (QGIS Development Team, 2022), showing the locations of Little Tern *Sternula albifrons* nests (red dots). The inset image highlights the study species, characterized by its distinctive white forehead that extends behind the eye, distinguishing it from Saunders's Tern *Sternula saundersi.*

using the Excel *randbetween* function. Cameras were positioned approximately 1.5 m from each nest and programmed to capture images at one-minute intervals. Equipped with infrared sensors, they also recorded nocturnal activity. Installation was carried out with minimal disturbance, allowing the adults to return to their nests within a few minutes; the entire setup process took approximately 10 minutes.

Ground surface temperature was measured using a HOBO® U10-001 data logger (Onset Computer Corporation; Bourne, Massachusetts, USA), which recorded data at one-minute intervals for 24 hours at each nest. The data logger was placed on the ground in an open area approximately 1 m from each nest scrape. To minimize any potential impact of the cameras on parental behaviours and to give the parents time to acclimate to the camera's presence, the first two hours of data from each nest were excluded from the analysis. In total, over 11,520 images were analysed.

Statistical analyses

A 24-hour recording was used as the unit of analysis for each nest (n = 8 nests), with each recording divided into 12 two-hour periods. Following the methods of AlRashidi et al. (2010, 2011) and AlRashidi (2016), two behavioural variables were calculated for each period: (1) nest attendance, defined as the percentage of time the eggs were incubated by either parent; and (2) orientation, defined as the percentage of time the incubating adults faced each of the four cardinal directions (north, south, east, and west).

To assess the influence of ground temperature on nest attendance, linear mixed-effects models were used (AlRashidi et al., 2010, 2011; AlRashidi, 2016; Pinheiro & Bates, 2000). Nest identity was included as a random effect to account for the non-independence of adults' incubating behaviour across two-hour periods within the same nest. The model included a random intercept for each nest, time period as a fixed factor, and ground temperature as a second-degree orthogonal polynomial covariate, as avian incubation behaviour and ambient temperature are not linearly related (Conway & Martin, 2000). The correlation between the time period and ground temperature was also included, as the effect of temperature on incubation may vary throughout the day (AlRashidi et al., 2010).

Linear mixed-effects models were also used to examine the effect of sunlight direction on the orientation of incubating parents, with nest identity again treated as a random effect (AlRashidi, 2016). The initial model included the following fixed effects: the four cardinal directions (a factor with four levels); time period; ground temperature (as a second-degree orthogonal polynomial); and the interaction between direction, time period, and ground temperature. Both response variables—nest attendance and orientation—were arcsine square-root transformed to achieve normality. Four additional fixed effects that could influence the behaviour of incubating adults were considered: year (covariate), nest discovery date (expressed as the number of days since 01 March; covariate), distance from the water's edge (covariate), and habitat type (a factor with three levels: saltmarsh, rocky, and dyke). However, none of these fixed effects were significant and were excluded from the final models during the model selection process. Model fitting was performed using the maximum likelihood method, and model selection was conducted using the ANOVA function (Crawley, 2007). All statistical analyses and figure creation were carried out in R version 4.4.2 (R Core Team, 2024).

RESULTS

Natural history

A total of 147 nests were found during the study—15 in 2015 and 132 in 2016. The disparity in nest numbers between the two years may be attributed to the timing of field visits. In 2015, visits occurred earlier in the season, so nests initiated later would not have been included.

During the first visit of 2015 (22–29 March), 50 individuals were observed, but no nests or chicks were found. The 15 nests were discovered during a second visit, conducted from 31 May–06 June. Of these nests, two were located in the saltmarsh, three in a 4-m^2 rocky area surrounded by water except for a narrow corridor on the northern side, and 10 in another 8-m^2 rocky area, also surrounded by water. Each nest had a clutch size of two eggs.

In 2016, 280 individuals were observed, and 111 nests were found during the first visit, conducted from 28 May–05 June. Clutch sizes for these nests were as follows: 27 contained one egg, 50 had two eggs, and 34 had three eggs. During the second visit, from 12–18 July, 21 additional nests were discovered: five nests contained one egg and 16 nests contained two eggs. The majority of nests (119 in total) were located on a dyke in the northern part of the study site, stretching ~1.5 km in length and ~5 m wide, surrounded by water on all sides (Fig. 1). Additionally, 13 nests were found in a saltmarsh area of approximately 15 m^2, also surrounded by water.

All 147 nests were located in fully exposed sites with no vegetation cover. The distance from the nests to the nearest bushes ranged 11–17 m (median = 13 m), and the distance to the water's edge ranged 2–10 m (median = 4 m). On 29 May 2016, 12 chicks were observed, estimated to be between four and six weeks. By 13 July 2016, six nests remained active, suggesting that egg-laying may commence as early as late March and extend into early July.

Fate and threats

In 2015, the fate of only one nest was determined: it was depredated by a Red Fox *Vulpes vulpes*, as recorded by a camera trap. A Red Fox burrow was located in the northeastern part of the lagoons, where a female fox and her three cubs were observed. In 2016, the fate of 39 nests was determined: eggs in nine nests successfully hatched, while eggs in 30 nests were depredated by Red Foxes, as indicated by tracks found around the nests. All of the successfully hatched nests were located on the dyke, suggesting that the dyke may offer a safer nesting environment than the saltmarsh. The water surrounding the dyke was approximately 50 cm deeper than that surrounding the saltmarsh, which may have contributed to its relative safety.

Temperature variations

The variations in ground surface temperature were extreme (Fig. 2A, Table 1). The lowest temperature, 24.58 °C, occurred during the coldest period (04h00–05h59) on 04 June 2016, while the highest temperature, 54.56 °C, was recorded during the hottest period (12h00–13h59) on 13 July 2016.

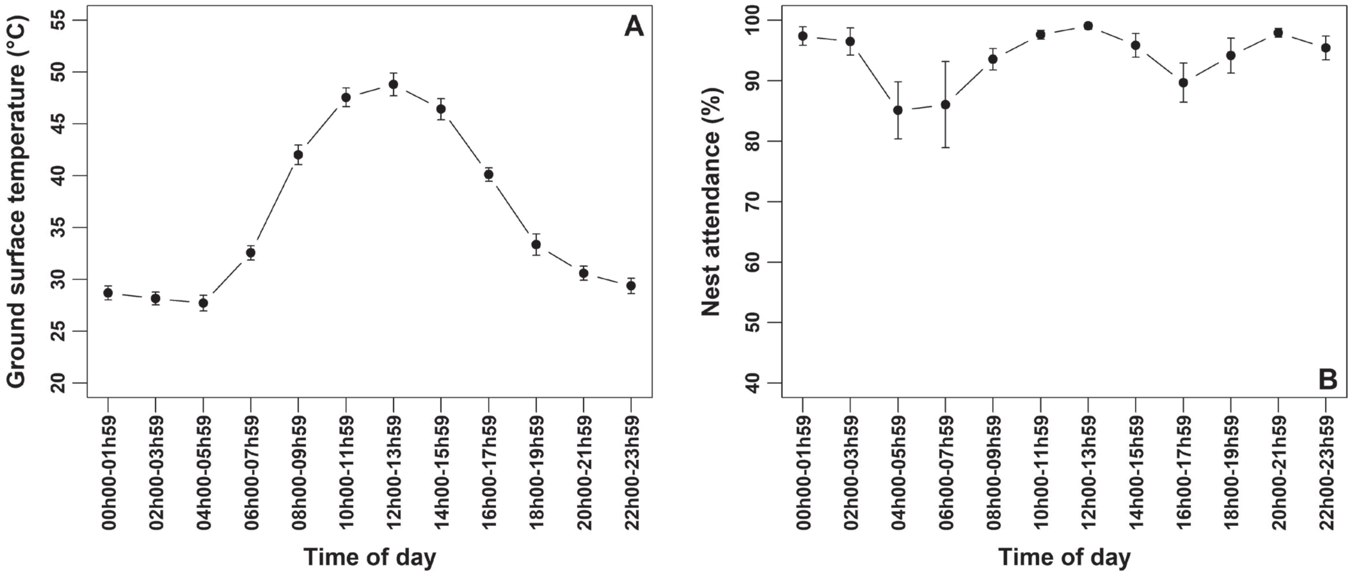

Fig. 2. (A) Ground surface temperatures measured in an open area approximately 1 m from each nest scrape (mean ± standard error for each two-hour time period, $n = 8$). The minimum nighttime temperature was 24.58 °C, while the maximum daytime temperature reached 54.56 °C. (B) Percentage of time spent attending the nest by Little Terns *Sternula albifrons* relative to ground surface temperature (°C) over two-hour time periods ($n = 8$).

TABLE 1
Mean (± standard error [SE]) ground surface temperatures, nest attendance (%), and orientation of incubating adults (%) during two-hour intervals ($n = 8$ nests)

Time of day	Ground surface temperature		Nest attendance %		Orientation of incubating adults %							
					East		West		North		South	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
00h00–01h59	28.70	0.67	97.40	1.52	19.90	8.97	47.71	16.30	17.19	9.65	13.02	10.62
02h00–03h59	28.17	0.62	96.46	2.25	0.83	0.63	25.21	6.89	49.38	9.86	21.04	9.06
04h00–05h59	27.72	0.76	85.10	4.70	3.85	2.68	31.04	9.42	35.31	11.58	15.10	7.15
06h00–07h59	32.57	0.68	86.04	7.12	5.21	2.39	44.17	10.00	25.94	11.58	10.73	3.85
08h00–09h59	42.03	0.95	93.54	1.77	4.48	2.92	36.88	13.12	45.73	14.25	6.46	4.03
10h00–11h59	47.56	0.91	97.60	0.75	31.25	13.48	6.35	2.98	58.13	14.54	1.88	1.27
12h00–13h59	48.80	1.09	99.06	0.53	58.44	16.39	0.52	0.41	39.58	16.42	0.52	0.41
14h00–15h59	46.43	1.02	95.83	1.96	67.60	15.68	0.00	0.00	28.23	14.29	0.10	0.10
16h00–17h59	40.13	0.65	89.69	3.24	53.23	13.25	0.42	0.22	34.48	14.05	1.67	1.44
18h00–19h59	33.35	1.03	94.17	2.89	30.17	17.62	15.33	7.54	46.50	13.53	2.17	1.96
20h00–21h59	30.60	0.69	97.92	0.72	6.35	3.39	43.02	8.79	35.94	11.07	12.71	6.55
22h00–23h59	29.38	0.73	95.42	1.95	22.60	8.25	27.92	9.23	25.31	10.07	19.69	9.24

Incubation behaviours

The mean incubation coverage across the full day was 93.90% ± 1.33% ($n = 8$ nests). Ground temperature significantly influenced nest attendance (Fig. 2B; Tables 1, 2). Nighttime nest attendance, from 18h00 to 03h59, averaged 94.32% ± 1.16%, while daytime attendance, from 04h00 to 17h59, averaged 93.63% ± 1.66%. The highest attendance occurred at night, with nest attendance exceeding 94% in each 2-hour period (Fig. 2B). During the day, nest attendance exceeded 94% only during the hottest hours: 10h00 to 11h59, 12h00 to 13h59, and 14h00 to 15h59 (Fig. 2B, Table 1).

The position of the sun influenced incubation behaviours (Figs. 3A, B; Tables 1, 2). Incubating adults primarily oriented themselves toward the west or north, avoiding the east and south during early morning (Figs. 3A, B; Table 1). In the first period of the hottest part of the day (10h00 to 11h59), they faced north more frequently than any other direction. However, during the subsequent hottest periods (12h00–13h59 and 14h00–15h59), they shifted to face east

TABLE 2
Minimal mixed-effects models were used to analyse nest attendance (%) and the orientation of incubating adults (%) (n = 8 nests) [a]

Explanatory variables	Response variables					
	Nest attendance (%)			Incubating adults' orientation %		
	df	*F*	*P*	*df*	*F*	*P*
Time period	–	–	–	1.349	8.283	.004
Ground surface temperature	2.83	3.4298	0.037	2.349	22.126	< .001
Sun direction	–	–	–	3.349	6.846	< .001
Sun direction × time period	–	–	–	3.349	3.538	.015
Sun direction × ground surface temperature	–	–	–	6.349	14.199	< .001

[a] Ground temperature was included in the models as a second-degree orthogonal polynomial. The degrees of freedom (*df*) are reported as numerator and denominator, respectively. The dash indicates that the variable was either eliminated during the model selection process or was not included in the initial model.

more often than north (Figs. 3A, B; Table 1). Notably, no birds were observed facing south or west during the hottest part of the day (Figs. 3A, B; Table 1). At night, from 18h00 to 03h59, no clear orientation pattern emerged, with all proportions of incubating adults' orientation remaining below 50% (Figs. 3A, B; Table 1).

Both parents participated in incubation, as indicated by camera footage showing changeovers, during which one parent relieved the other. These changeovers occurred during both daytime and nighttime but were more frequent during the hottest parts of the day. The camera footage also revealed that incubating adults regularly engaged in belly soaking (wetting their ventral feathers), particularly during the hottest hours.

DISCUSSION

This study suggests that the Little Tern population in the Sabkhat Al-Fasl Lagoons accounts for more than half of the total population on the Arabian Peninsula. Jennings (2010) estimated that ~200 pairs breed in the region and noted that the population may expand significantly in eastern and central Arabia in the coming years. However, he also pointed out that Little Tern and Saunders's Tern *Sternula saundersi*—the latter found in the Red Sea—were previously considered a single species, leading to confusion in older records. Their close resemblance further complicates efforts to distinguish between the two species (Boland & Alsuhaibany, 2020; Mullarney & Campbell, 2023) (Fig. 1), making accurate population estimates for Little Terns more challenging. Therefore, ongoing monitoring of this bird's population in the Arabian Peninsula is essential to ensure up-to-date breeding population data.

Little Terns prefer to nest in open areas devoid of bushes. Like many other ground-nesting seabirds, they rely more on egg crypsis than on aggressive anti-predator behaviours to safeguard their nests from depredation (Haskell, 1996). Nesting in exposed sites may allow incubating parents to leave their nests upon detecting an approaching predator, making it more difficult for the predator to locate nests. However, the bright white coloration of adults may increase their visibility to predators during incubation. By choosing open nest sites, they may be better positioned to spot approaching threats early enough to escape, leading the predator away from the nest. Haskell (1996) noted that bright colours can attract predators to nests, and that the risk of depredation varies depending on nest site characteristics.

The egg-laying date of Little Terns at the Sabkhat Al-Fasl Lagoons extends from late March to early July, which is longer than the timeline reported by Jennings (2010). Jennings noted that the species typically arrives at breeding sites in February and March,

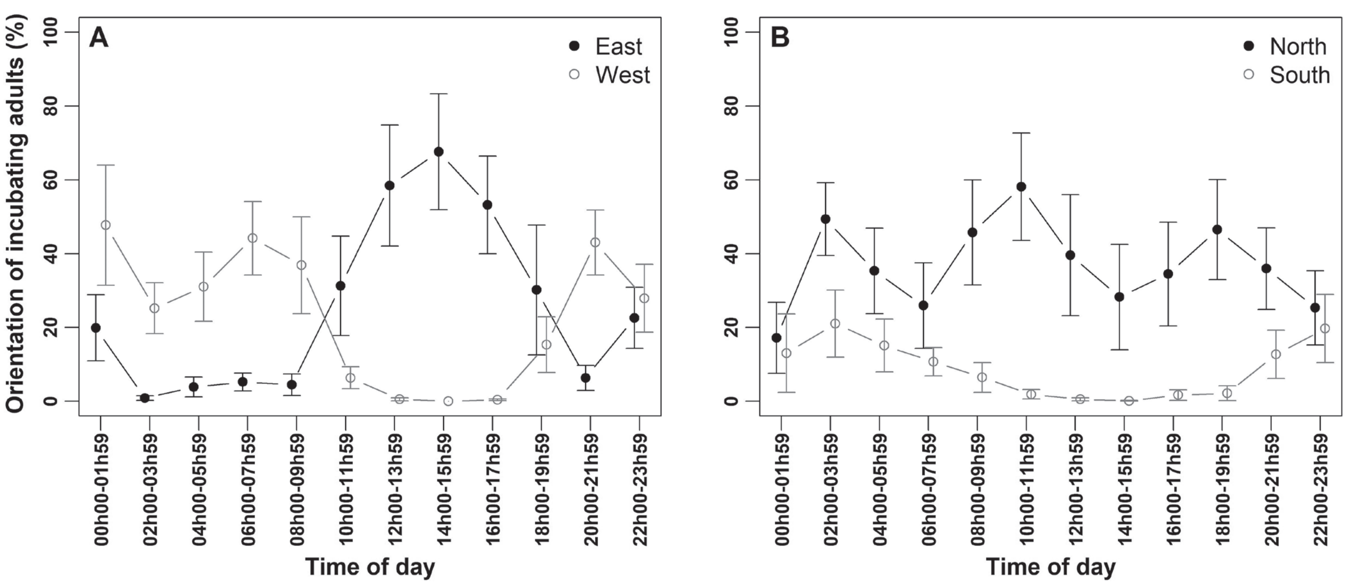

Fig. 3. Orientation of incubating adults (%) during two-hour periods (n = 8). (A) Orientation towards east and west. (B) Orientation towards north and south. Means are presented ± standard error (SE).

with the first eggs being laid in April. He also observed that in the eastern region of Saudi Arabia, some clutches are still being incubated as late as June, and that the typical clutch size is two or three eggs. In the present study, clutch sizes ranged from one to three eggs. Nests with a single egg may indicate either an incomplete nest or a failed egg from a previously hatched clutch. The Red Fox appears to be the primary cause of nesting failure, as also observed in New South Wales, Australia (National Parks and Wildlife Service, 2003).

Little Terns appeared to increase their nest attendance when the temperatures deviated from the optimal egg temperature. Such adaptive behaviour may be particularly important in regions like the Arabian Peninsula, where extreme temperature fluctuations between day and night are common and can pose significant challenges to egg survival. In most avian species, the optimal egg temperature is typically 36–40.5 °C (Webb 1987), a critical range for proper embryo development. Deviations from this range can increase the risk of embryo mortality, and the increased nest attendance observed in Little Terns likely serves as a strategy to buffer the eggs from these extreme temperatures. This finding aligns with previous research (AlRashidi & Shobrak, 2015) on the closely related Saunders's Tern, conducted in the similarly extreme environment of the Farasan Islands. However, Little Terns exhibited higher incubation activity during midday in the Sabkhat Al-Fasl lagoons compared to the Saunders's Terns, while their incubation effort decreased at night. This discrepancy may be due to differences in ground temperatures between the two study sites and the respective times of year. The current study was conducted from March to July, whereas the previous research occurred in March, when nighttime temperatures dropped below 25 °C and midday temperatures did not exceed 48 °C.

Incubating terns avoided facing the sun, a behavioural adaptation that may be crucial for preventing egg overheating. By positioning their bodies between the eggs and direct sunlight, the parents maximize shade over the eggs. Additionally, this behaviour may help reduce water evaporation from their soaked bellies by minimizing exposure to direct sunlight. This finding is consistent with previous research by AlRashidi (2016), who studied Lesser Crested Terns *Thalasseus bengalensis* and found that most incubating terns faced west in the morning and gradually rotated clockwise until they were facing east by the evening. The previous study was conducted in another extremely hot environment on Jana Island, located about 50 km east of the current study site.

In this study, the specific roles of male and female terns during incubation could not be determined, as the sexes could not be distinguished morphologically. However, both parents participated in incubation, as evidenced by the frequent changeovers observed during the hottest parts of the day. One camera recorded an instance of one parent delivering a small fish to its incubating partner, indicating that one parent may contribute more to incubation than the other. Similar behaviours have been reported by Cheah & Ng (2008), as well as in the closely related Saunders's Tern, as noted by Jennings (2010) and Almalki (2021). Further investigation is needed to clarify the roles of each parent during incubation. This could be accomplished by ringing both parents, collecting blood samples for sex determination, and subsequently monitoring their incubation behaviours. Documentation of these and other adaptive behaviors would enhance our understanding of the strategies that Little Terns use to cope with the extreme environmental conditions.

DECLARATION OF CONFLICTS OF INTEREST

The author declares no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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