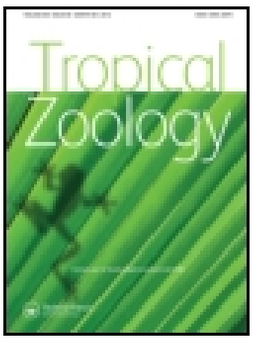

Tropical Zoology

ISSN: 0394-6975 (Print) 1970-9528 (Online) Journal homepage: http://www.tandfonline.com/loi/ttzo20

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To cite this article: Farhad H. Tayefeh, Mohamed Zakaria, Hamid Amini, Razieh Ghayoumi & Abolghasem Khaleghizadeh (2017): Colony site characteristics of sympatric breeding tern species on the Mond Islands, the Persian Gulf, Tropical Zoology, DOI: 10.1080/03946975.2017.1361199

To link to this article: http://dx.doi.org/10.1080/03946975.2017.1361199

Published online: 18 Aug 2017.

Colony site characteristics of sympatric breeding tern species, 2017
https://doi.org/10.1080/03946975.2017.1361199

Colony site characteristics of sympatric breeding tern species on the Mond Islands, the Persian Gulf

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(Received 06 February 2016; accepted 24 July 2017; first published online 18 August 2017)

We have investigated characteristics of colony site of three sympatric breeding tern species on small islands of a subtropical region, the Persian Gulf. The three most populous ground-nesting waterbird species – Bridled Tern *Onychoprion anaethetus*, Lesser *Thalasseus bengalensis* and Greater *Thalasseus bergii* Crested Terns – were studied during the 2009–2011 breeding seasons. The average area size of mixed colonies was 454 m^2. The density of nests of the Bridled Tern was 846 nests/ha. The proportion of the number of nests in a mixed colony for Lesser Crested Tern (5546 nests) was approximately 10-fold compared to the Greater Crested Tern (542 nests). The density of Bridled Tern nests/ha was significantly higher in areas with 50–75% vegetation cover (>1200 nests/ha) than in areas of <5% vegetation cover (72–105 nests/ha) ($p < 0.05$). Mixed colonies of the Lesser and Greater Crested Terns were located on unvegetated land, at an average distance of 4.1 m to vegetation, and on sandy soil (79.4% on average) and above high spring tide water lines (0.59 m on average). There were more potential nesting areas than occupied areas for the mixed colonies of the Lesser and Greater Crested Terns, indicated that they did not face nest site limitation.

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Keywords: colony site; island; Persian Gulf; waterbird; tern

Introduction

Most seabird species breed in large multispecific colonies (Coulson 2002; Sutherland et al. 2004; Rönkä et al. 2011). Due to the benefits and costs of reproductive synchronicity, most seabird species are colonial and have simultaneous reproductive cycles within colonies (Schreiber and Burger 2002). Seabirds colonies are often found on small and remote offshore islands (Coulson 2002; Sutherland 2006) because of availability of food resources (Colchero et al. 2010), avoiding access of predators to their nest and probably less human disturbances (Burger and Gochfeld 1993; Hernández-Matías et al. 2003). The occurrence of many waterbird species nesting together in a small area suggests that competition may occur between species for particular sites, and certainly there is a plethora of aggressive encounters occurring among neighbors in any waterbird colony (Coulson 2002).

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The Persian Gulf is the extension of the Indian Ocean and possesses many inhabited and uninhabited offshore islands that support hundreds of thousands of wintering birds and are key habitats for ground-nesting waterbirds (Scott 2007; Tayefeh, Zakaria, Amini et al. 2013). In the Iranian part of the Persian Gulf, islands without human settlements such as the Mond Islands (including Khan, Nakhilu and Omol-Karam islands) and Sheedvar, Bani-Farour, Ghabr-e Nakhoda and Dara islands provide comparatively safe breeding and wintering areas for many migratory waterbirds (Scott 2007; Tayfeh et al. 2011; Tayefeh, Zakaria, Amini et al. 2013). The species selected for this study were three most populous sympatric waterbird species at the Mond Islands, namely the semi-precocial Bridled Tern *Onychoprion anaethetus* (Scopoli, 1786), the precocial Lesser Crested Tern *Thalasseus bengalensis* (Lesson, 1831) (hereafter LCT) and the precocial Greater Crested Tern *Thalasseus bergii* (Lichtenstein, 1823) (hereafter GCT) (Tayefeh et al. 2011, Tayefeh, Zakaria, Amini et al. 2013). Other breeding seabirds on islands of the Persian Gulf include the Crab Plover *Dromas ardeola* Paykull, 1805, Caspian Tern *Hydroprogne caspia* (Pallas, 1770), Gull-billed Tern *Gelochelidon nilotica* (Gmelin, 1789), White-cheeked Tern *Sterna repressa* Herbert, 1916, Kentish Plover *Charadrius alexandrinus* Linnaeus, 1758, Striated Heron *Butorides striata* (Linnaeus, 1758) and Western Reef Heron *Egretta gularis* (Bosc, 1792) (Tayefeh et al. 2011, Tayefeh, Zakaria, Amini et al. 2013).

The overall aim of this study was to describe characteristics of colonial breeding terns and how sympatric colonial breeding terns interact with similar breeding species which nest together on a particular island or a group of small islands in the Persian Gulf. The specific objectives of this research were: (1) to measure colony size and nest count of tern species, (2) to provide characteristics of colony site (including substrate components, slope, height from tides and distance to the nearest vegetation) of three most populous ground-nesting waterbird species, (3) to find effects of different vegetation cover classes on distribution of tern nest and (4) to describe nesting habitat partitioning of these tern species. These were set to take possible conservation measures for populations of tern species that breed syntopically in colonies.

Methods

Study area

This study was conducted on Nakhilu and Omol-Karam islands, part of the Mond Islands, northern Persian Gulf, Iran between late March and the end of August from 2009 to 2011. Nakhilu and Omol-Karam islands are located in Dayyer-Nakhilu Marine National Park. These two islands along with Khan and Tahmadon islands have also been designated as an Important Bird Area (Evans 1994). Two main seasons are prevalent: hot and dry summers from May to October and comparatively cool winters from November to March. June to August are the hottest months here, with temperatures rising to more than 50°C and the humidity exceeding 80%. Annual precipitation in the area averages 196.9 mm and is limited almost entirely to the winter rainfall. Tides in the Persian Gulf are complex, and the dominant pattern varies from being primarily semi-diurnal to diurnal.

The Mond Islands have no commercial use for the time being. Because of the suitable soil texture, vegetation cover, well-nutrition surrounded water and non-existence of natural and human predators, these islands are safe and suitable for nesting waterbird and sea-turtles (Tayefeh et al. 2011, Tayefeh, Zakaria, Amini et al. 2013). These islands are uninhabited by humans and are only used as resting area for the local fishermen as well as shelter during seasonal storms. With an area of 75 ha, Omol-Karam Island is located only 1.5 km

off the western coast of Poozeh Masheh. Omol-Karam is flat with less variation in the elevation (maximum 8 m). Nakhilu Island is about 35 ha and reaches 34.2 and 36.2 ha during the low tide and high tide, respectively. The highest point of this island is about 3 m asl.

Colony size and nest count

A systematic sampling method was performed to assess the number of Bridled Tern nests/ha and a stratified random sampling method to estimate the population size of large colonies comprising more than 1000 nests of LCT and GCT as described by Tayefeh et al. (2011) and Tayefeh, Zakaria, Amini et al. (2013). Some Bridled Terns used burrow nests of the Crab Plover. We used burrowscope to check nests of the Bridled Tern. For the Bridled Tern in nesting areas with over 5% vegetation cover, sampling quadrates (20 × 20 m) were

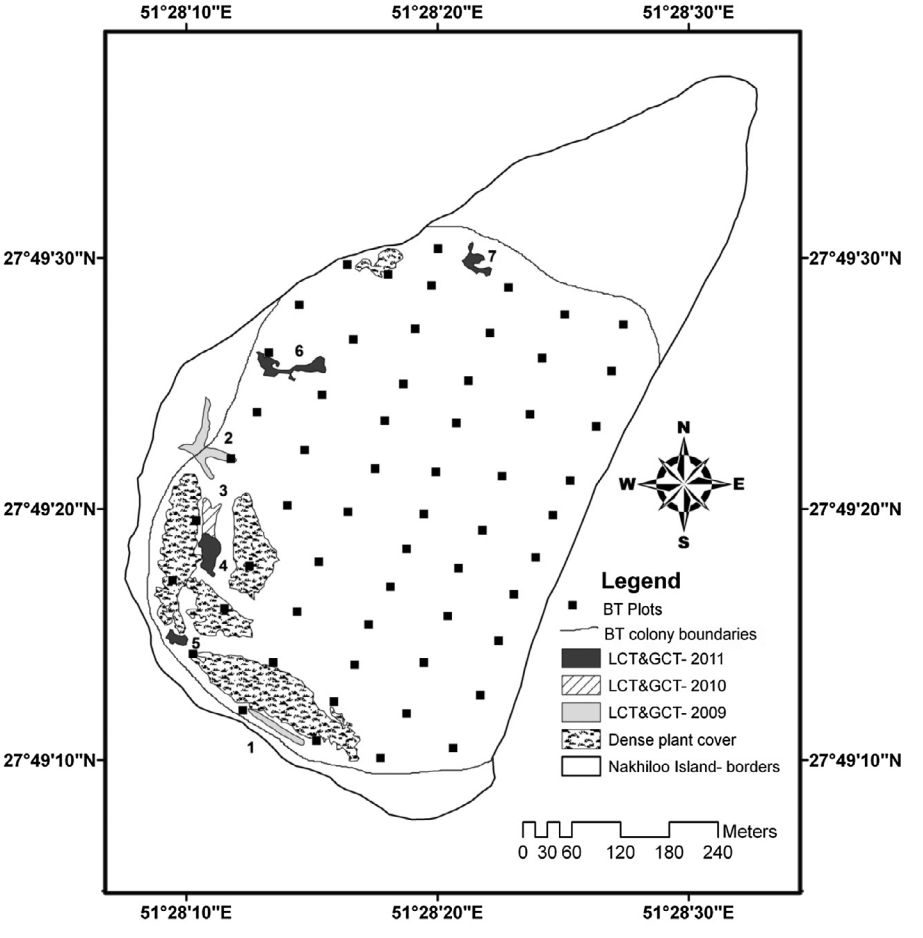

Figure 1. The location of mixed species colonies of Lesser Crested Tern and Greater Crested Tern on Nakhilu Island from 2009 to 2011. Solid squares represent plotted points (or quadrates) within breeding area of the Bridled Tern that had vegetation cover more than 5%. The dense plant cover with more than 75% vegetation were not suitable for the Bridled Tern. Numbers represent colony numbers shown in Table 1.

placed along linear transects paralleled 50 m apart (Figure 1). The vegetation cover of each quadrate was estimated in four classes (5–25%, 25–50%, 50–75% and more than 75%).

Colony site characteristics

Here a colony site is defined as where many nests are dispersed closely together surrounded by sea or land where no similar nest of the same species is present. To quantify colony site characteristics and inter-species spacing, the following variables were measured at the colony site: (1) the length and width of each colony site; (2) the percentage of soil components of top 5 cm of the breeding substrate (substrate components were classified as clay, silt and sand by the Borazjan Soil Laboratory, Bushehr Province); (3) the percentage of the nearest vegetation cover having at least 5% plant cover; (4) the distance of nests to the nearest vegetation having at least 5% plant cover; (5) the height of the nearest vegetation; (6) the distance to the nearest neighbor nest from other occupied nests and the species occupying the nests; (7) the slope (%) of each colony site using clinometers; (8) the orientation of the slope of each colony site (in eight cardinal and inter-cardinal directions: N, NE, E, SE, S, SW, W and NW); (9) the height of each colony site from the current water line (CWL) which is defined as the height of the water at the time of egg-laying; (10) the distance of each colony site from CWL; (11) the height of each colony site from the highest spring tide line (HSTL), i.e. the point recorded when the water reaches its maximum tidal height on each island; (12) the distance of each colony site from HSTL; and (13) the distance to the nearest main colony (Burger and Gochfeld 1986; Fasola and Canova 1991, 1992; Valle and Scarton 1999). To determine the impacts of vegetation cover, the nest density of the Bridled Tern on Nakhilu Island was calculated in different vegetation cover classes in 2010 and 2011 (Figure 1).

Data analysis

Independent sample *t*-test between two groups and One-way Analysis of Variance between more than two groups were used to compare the mean values of nests/ha between years and colonies. Data were analyzed using SPSS 16.0.1 software (SPSS, Inc. 2001). The Tukey *post hoc* multiple test (HSD) was used in cases the groups showed significant differences. Welch's test was used to compare the mean number of Bridled Tern nests per hectare in different cover classes because of unequal sample sizes and also the non-homogenity of variance in each class. The values are reported as mean ± SE. The level of significance was set at 0.05.

Results

Breeding areas of the Bridled Tern during the three breeding seasons of the present study overlapped each other on Nakhilu Island. On this island, of the 211 Crap Plover burrows checked in 2010, 32% (68 burrows) contained the Bridled Tern eggs while in 2011, 54% (48 clutches in 89 burrows) were occupied. Characteristics of colony sites of mixed colonies of LCT and GCT on Nakhilu and Omol-Karam Islands during the breeding seasons from 2009 to 2011 are shown in Table 1. In 2011, breeding colonies of the LCT and GCT were not found on Omol-Karam Island because of the presence of the Golden Jackal, *Canis aureus* entered from the mainland during the low winter tide waters. Therefore, they bred only on Nakhilu Island in this year.

Table 1. Colony site characteristics of mixed colonies of the Lesser and Greater Crested Terns on Nakhilu and Omol-Karam Islands in 2009, 2010 and 2011.

		2009			2010			2011				
Parameters of colony		Nakhilu 1	Nakhilu 2	Omol-Karam 1	Omol-Karam 1	Omol-Karam 2	Nakhilu 3	Nakhilu4	Nakhilu5	Nakhilu6	Nakhilu7	Average
Location		27°49′10″N 51°28′13″E	27°49′21″N 51°28′11″E	27°50′01″N 51°33′47″E	27°50′01″N 51°33′36″E	27°49′59″N 51°33′28″E	57°49′19″N 51°28′10″E	27°49′17″N 51°28′11″E	27°49′14″N 51°28′09″E	27°49′26″N 51°28′15″E	27°49′29″N 51°28′21″E	
Maximum length of colony		76	97	172	162	46	77	58	78	25	35	82.6
Maximum width of colony		5	14	8	7	21	19	37	33	18	18	18
Colony size (m^2)		243	520	680	525	361	640	638	202	553	183	454.5
Orientation of the colony slope		SW	–	S	S	S	–	–	–	–	–	
Slope of colony (%)		15	0	18	18	22	0	0	0	0	0	7.3
Height of colony from CWL (m)		0.3	1.3	0.3	0.3	0.3	1.4	1.8	1	1.8	1.2	0.97
Height of colony from HSTL (m)		0	1.1	0	−0.2	−0.2	1.2	1.4	0.4	1.5	0.7	0.59
Distance of colony from CWL (m)		8	42	3	3	3	87	77	42	32	54	35.1
Distance of colony from HSTL (m)		−1	31	0	−2	−2	108	108	35	18	47	34.2
Percentage of substrate components	Sand	92.6	94.4	47.6	44	49.9	91.2	91.8	92.3	95.9	93.4	79.4
	Silt	3.5	1.7	52.1	52.5	49.5	3.1	8	3.9	4	5.9	18.5
	Clay	3.9	3.9	0.3	0.8	0.6	5.7	0.2	3.8	0.1	0.7	2.1
Distance to the nearest vegetation (m)		3	12	1.5	0.6	2.4	6.1	1.8	1.4	6.9	5.4	4.11

(*Continued*)

Table 1. (*Continued*)

	2009			2010			2011				
Parameters of colony	Nakhilu 1	Nakhilu 2	Omol-Karam 1	Omol-Karam 1	Omol-Karam 2	Nakhilu 3	Nakhilu4	Nakhilu5	Nakhilu6	Nakhilu7	Average
Height of the nearest vegetation (m)	0.5	0.4	0.56	0.5	0.4	0.5	0.56	0.45	0.7	0.6	0.52
Vegetation cover %	0	0	0	0	0	<5	<5	0	0	0	–
No. of Lesser Crested Tern nests	3,901	7,936	9,650	7,834	4,780	4,685	6,890	2,040	5,751	1,993	5546
No. of Greater Crested Tern nests	341	1,546	456	2,207	125	140	10	192	206	22	542.5
Distance to nearest colony (m)	320	320	–	103	103	–	87	87	93	93	120.6
Distance to nearest sub–colony (m)	–	23	6.5	–	–		8	6.7	–	12.5	5.67
Distance to the nearest inter-specific neighbor nest (m)	3.7	12.3	0.6	0.6	7.4	7	1.85	1.9	7	5.5	4.78

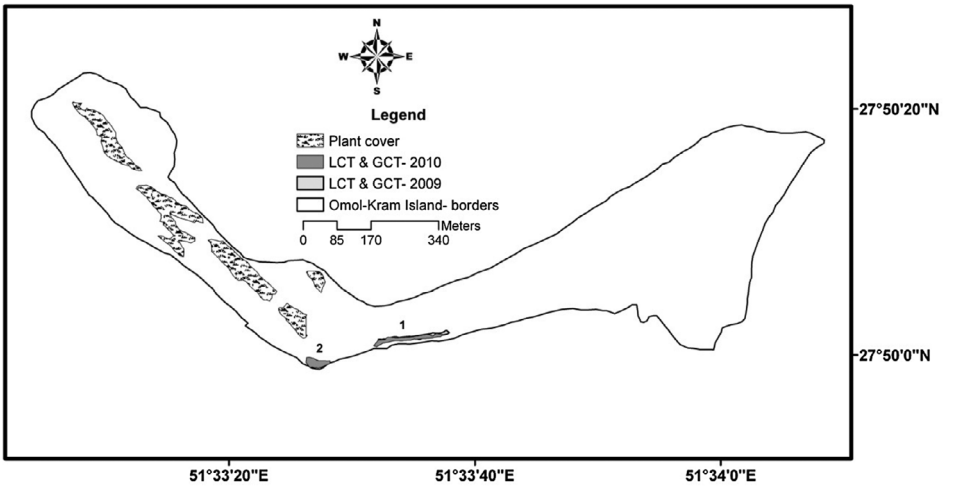

Figure 2. Locations of mixed species colonies of the Lesser Crested Tern and Greater Crested Tern on Omol-Karam Island from 2009 to 2011. Areas of mixed colonies in 2009 and 2010 are overlapped.

Physical features of nesting site

Abundance of suitable nesting ground on Nakhilu Island compared to Omol-Karam Island led to the formation of colonies and sub-colonies with different sizes and shapes. The shape of colonies on Nakhilu Island was elongated and denticulated with some marginal nests (Figure 1) while on Omol-Karam Island there were less marginal nests (Figure 2) compared to Nakhilu Island. On Omol-Karam Island, the 2009 colony and the first colony of 2010 of LCT and GCT were almost overlapped and prolonged to more than 160 m along the coastline (Figure 2). The second colony of Omol-Karam Island in 2010 and colony 4 on Nakhilu Island in 2011 were more rounded (Figures 1 and 2).

All colonies of LCT and GCT were at least 0.3 m above CWL at a distance of 3–87 m (Table 1), although they were exposed to the high spring tide water (0.6 m on average). On Omol-Karam Island, more than 10% of the 2009 colony and 25% of the first colony and 33% of the second colony in 2010 were flooded by the high spring tide water.

The slope of nest sites favored by the Bridled Tern was flat and placed at least 15 m from the high spring water line. However the slope of sites used by the LCT and GCT varied from flat to less than 22% which prevented their eggs from slipping down the slope. On Omol-Karam Island, LCT and GCT colonies were surrounded by vegetation structures and water in the south of the island (Figure 2). On Nakhilu Island, LCT and GCT colonies were located on sandy soil (more than 90% sand), whereas the substrate components on Omol-Karam were silt (49–52%) and sand (44–47%) (Table 1).

Vegetation

On Nakhilu Island, Bridled Terns nested in the shade of bushes, plants, ruined buildings, unused construction materials, in open areas near vegetation and in the burrows left by the Crab Plover. Most nests were in the shade of vegetation cover. The LCT and GCT nested on Nakhilu Island in areas less than 5% vegetation cover (Table 1). The grass cover, if existed, was soon scorched by excrement around the nests. The LCT and GCT colonies were placed at a distance of 0.6–12 m from the nearest vegetation structure (Table 1).

Table 2. Bridled Tern nest densities in habitats with different vegetation densities in 2010 and 2011 on Nakhilu Island.

Vegetation cover classes	No. of quadrates (% of total)	Mean no. of nests/ quadrate	Mean no. of nests per hectare
2010			
<5%	–	–	105.81
5–25%	24 (41%)	16.17 ± 1.67	$404.17 \pm 41.69_{a}$
25–50%	23 (39%)	37.3 ± 2.69	$932.61 \pm 67.3_{b}$
50–75%	9 (15%)	48.67 ± 4.05	$1216.67 \pm 101.21_{c}$
>75%	3 (5%)	17 ± 2.52	$425 \pm 62.92_{a}$
2011			
<5%	–	–	72.91
5–25%	26 (58%)	27.04 ± 2.43	$675.95 \pm 60.84_{a}$
25–50%	9 (20%)	46.44 ± 4.36	$1161.11 \pm 109.62_{b}$
50–75%	7 (15%)	51.14 ± 4.38	$1278.57 \pm 109.44_{b}$
>75%	3 (7%)	14.67 ± 3.18	$366.67 \pm 79.49_{a}$

Note:
The letter in subscript shows the significance of the groups at 5%. Same letter means no significance.

The mean values of Bridled Tern nests/ha in areas with vegetation cover classes were significantly different in 2010 (using Welch's test, $W_{3,11.138} = 27.054$, $p < 0.01$) and in 2011 ($W_{3,10.059} = 18.283$, $p < 0.01$). In 2010, Tukey test showed that the mean number of Bridled Tern nests/ha in areas with 50–75% vegetation cover was significantly higher than areas of other classes. In 2011, the Bridled Tern nest density of areas with 25–50% and 50–75% was similar and significantly higher than the other classes ($p > 0.05$). Breeding areas of the Bridled Tern with more than 5% vegetation cover decreased from 24.4 ha in 2009 to19.79 ha in 2011. Also, the areas with less than 5% vegetation cover were measured 2.6, 4.4 and 7.2 ha in 2009, 2010 and 2011, respectively. The rest of Nakhilu Island was unvegetated and no Bridled Tern nests were found. The Bridled Tern nest density in each class of vegetation cover during the 2010 and 2011 breeding seasons (Table 2) showed that 41% ($n = 23$) of quadrates were located in areas with 5–25% vegetation cover in 2010 while it increased to 58% ($n = 26$) in 2011. In contrast, areas with 25–50% vegetation cover decreased in 2011 (20%, $n = 9$) compared to 2010 (39%, $n = 23$). The numbers of quadrates located in areas with 50–75% and more than 75% vegetation cover did not differ between 2010 and 2011.

Distance from inter- and intra-specific nests

The minimum and maximum distances between the main colonies on Nakhilu Island were recorded 87 and 320 m, respectively, while the least distance to the nearest sub-colony was 6.5 m on Omol-Karam Island (Table 1). Also the least nearest neighbor nest of LCT and GCT was observed on Omol-Karam Island (0.6 m, Table 1). The nearest neighbor nests of other than LCT and GCT were of the Bridled Tern and Crab Plover that nested at a distance of 1.5 and 2.8 m, respectively.

Discussion

Vegetation

During the study period, the major part of Omol-Karam Island was not suitable for nesting of the Bridled Tern, LCT and GCT due to high dense vegetation cover and tidal water affected most part of the island. The vegetation cover was the most important factor that supported the Bridled Tern eggs and chicks as noted by Hulsman and Langham (1985) and considerable difference between Bridled Tern nests in vegetated and unvegetated areas on Nakhilu Island. It seems that the vegetation cover could protect eggs and chicks from the sunlight and prevents them from drowning in the humidity and rolling by wind. Without such a cover, eggs and young would be vulnerable to ground-dwelling predators such as lizards and rats, as well as avian predators such as Ruddy Turnstone *Arenaria interpres* (Linnaeus, 1758) which feeds on the Bridled Tern eggs (Garavanta and Wooller 2000; Chatto 2001).

The Bridled Tern nested in open areas (<5% vegetation cover) mostly at the end of the laying period when most of the vegetation cover has colonized. A possible hypothesis to explain this case is that the preferred area is occupied by adults with higher quality (indicated by having bigger body size) that exclude others (Coulson 1968). Consequently, individuals with lower quality would be forced to disperse in low-quality habitats at peripheral areas (Saliva and Burger 1989; Coulson 2002), while experienced breeders are commonly the first ones to return to their breeding sites at the beginning of the breeding season and occupy more suitable habitats in the central area (Hamer et al. 2002). Possibly, younger Bridled Terns with less experience build their nest in the marginal and less suitable habitats compared with the experienced birds.

Pluri- and mono-specific colonies

Bridled Terns were found associated with the Crab Plover (Tayefeh, Zakaria, De Marchi et al. 2013) and nest close to other breeding species, including, the White-cheeked Tern and Western Reef Heron on Nakhilu and Omol-Karam islands. In Australia, Bridled Terns potentially share their habitat with other species such as Black-naped Tern *Sterna sumatrana* Raffles, 1822, Roseate Tern *Sterna dougallii* Montagu, 1813, Caspian Tern and Wedge-tailed Shearwater *Ardenna pacifica* (Gmelin, 1789) as well as Silver Gull *Chroicocephalus novaehollandiae* Stephens, 1826 (Higgins and Davies 1996; Chatto 2001). Colonies of mixed species of the LCT and GCT were situated near the more aggressive species against predators, i.e. the Bridled Tern. It is thought that these mixed colonies may benefit from the presence of Bridled Terns by preventing predators from approaching the colonies as described by Langham and Hulsman (1986).

The LCT and GCT were reported as a mixed-species colonialist (Cramp et al. 1985; Nicholson 2002; Scott 2007; Tayefeh et al. 2011, Tayefeh, Zakaria, Amini et al. 2013). The LCT nested among the earlier breeders of the GCT colonies (Nicholson 2002). The many studies on mixed-species colonies indicate that the individuals of one species in the colony aggressively protect the entire colony from predators (Fuchs 1977; Götmark and Andersson 1980; Pius and Leberg 1998; Quinn and Ueta 2008). The GCT is comparatively large and more aggressive than the LCT (Cramp et al. 1985). In the mixed-species colonies, GCT usually respond immediately, aggressively, and in large proportions toward predators (Langham and Hulsman 1986). On the other hand, the huge number of the LCT at the same colonies can help the formation of a large colony which is thought to be one adaptive behavior to the predation (Lack 1968). Anti-predator behavior such as increase

in mobbing and vigilance may become more effective with increasing colony size (Elgar 1989; Pius and Leberg 1998; Frafjord 2011) and reducing an individual's risk of predation by confusing the predators (Arroyo et al. 2001; Morrell et al. 2011). Ward and Zahavi (1973) also showed that mixed colonies might function as information-centers for finding food resources by following each other to access food sources. All the three tern species of our study involved collecting food in the same way (Tayefeh et al. 2014). Furthermore, the GCT and LCT feed on highly aggregated and abundant food patches whose locations are unpredictable in space and time.

Conclusion

The main habitat factor which influences local distribution of tern species as ground-nesting waterbirds was the vegetation cover that was similarly noted for some terns by Kotliar and Burger (1986), Fasola and Canova (1991), Valle and Scarton (1999), and Hamer et al. (2002). Findings of the present study suggest that there could be some sorts of segregation between nesting habitats of mixed colonies of the LCT and GCT and other breeding species. Aggressive Bridled Terns occupied only empty burrows of Crab Plovers, whereas they increased alertness with mobbing and vigilance. It was observed that the breeding period of these three tern species on the Mond Islands were synchronized in common with tropical and subtropical breeding grounds elsewhere. The synchronization in assemblages of breeding species in this study indicated that the timing of breeding cannot reduce intra-specific interactions; however, findings of this study showed no direct evidence of competition for breeding sites between the studied species on the Mond Islands. Mixed colonies of LCT and GLT were benefited from the presence of the aggressive species against predators (i.e. Bridled Tern) in the nearby areas and the LCT and GCT interacted with huge number of the LCT and relatively more aggressive behavior of the GCT.

Acknowledgments

We are grateful for the logistical and financial support of this work provided by the Department of the Environment (DOE) Provincial Office, Bushehr, Iran. For assistance in the field, we thank Gholamreza Faghih, Hossein Jafari, Sadegh Poursalem, Sirous Karami, Aghayar Moradi and Mostafa Foladi.

Disclosure statement

No potential conflict of interest was reported by the authors.

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