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Monitoring of Populations of Breeding Terns and Crab Plovers on the Iranian Islands of the Persian Gulf

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Abstract
Despite the importance of the colonial breeding waterbirds in the Persian Gulf, few surveys have been carried out on populations of breeding waterbirds on the islands of northern Persian Gulf. This survey was conducted from late March to the end of August in 2011 and 2012. Data were compared with the previous study conducted in 2010. The results showed that of the ten breeding waterbird species on the northern Persian Gulf islands, three tern species and Crab Plover *Droma ardeola* are much the most numerous. The Bridled Tern *Sterna anaethetus* is the most abundant species (62,000–82,000 pairs), followed by Lesser Crested Tern *Sterna bengalensis* (27,000–28,000) and Crab Plover *Dromas ardeola* (13,000–19,000), while the Swift Tern *Sterna bergii* has a relatively small breeding population (2,800–3,200 pairs). There were significant differences in Bridled Tern nest densities between Sheedvar, Bani Farour and Nakhilu in 2011 ($F_{2,142}$= 52.830, P<0.01) and 2012 ($F_{2,151}$= 25.878, P<0.01). The highest nest density was recorded at Nakhilu Island, while the lowest was found on Sheedvar Island. Most of the breeding Lesser Crested Terns were found on Nakhilu Island. It seems that the breeding population of the Crab Plover on Dara Island in 2011 was the world's largest colony of Crab Plovers ever found. The largest fluctuations took place in the breeding population of Bridled Terns on Bani Farour Island, but small fluctuations were recorded in the populations of other species during the 2011 and 2012 breeding seasons. It is concluded that drought, flooding and the presence of Golden Jackal *Canis aureus* were the three main natural phenomena affecting the population fluctuations of the terns. Further monitoring of populations, including investigation of reproduction and mortality rates during the breeding season, is necessary in order to recommend appropriate measures for the conservation management of the breeding waterbird populations.

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1. Introduction

Waterbird populations around the world are continually decreasing due to the loss and degradation of habitats and their unsustainable use as a result of human activities (Schreiber & Burger 2002; Delany & Scott 2006; Ronka *et al.* 2011). The recently published 'Waterbird Population Estimates, Fifth Edition: Summary Report, 2012' (Wetlands International 2012) has revealed that 38% of waterbird populations are decreasing or have become extinct, 20% are increasing, 39% are stable and 3% are fluctuating. In Asia, there is clearly an urgent need to accelerate the processes necessary for the conservation of waterbird populations as 50% of waterbird populations have declined.

Situated in the Western Palearctic faunal region, tangential to the Indo-Malayan (Oriental) region and within the influence of the Ethiopian (Afro-tropical) region, Iran possesses a variety of fauna unequalled in other parts of the Middle East or Southwest Asia (Firouz 2005). Although the Persian Gulf lies in the Western Palearctic region biologically, much of its bird fauna has high affinity with the Indo-Malayan (Oriental) region (Cramp *et al.* 1983; Boere & Lenten 1998; Wei *et al.* 2009). Several common Oriental species reach the northwestern extremity of their ranges in the south of Iran. At least nine waterbird species typical of the Indian Ocean breed on islands in the Persian Gulf (Scott 1989; Tayefeh *et al*. 2011). Being located along the West Asia - East Africa flyway, these islands are important not only as breeding sites for waterbirds, but also as wintering and stopover sites for migrating birds, particularly shorebirds and seabirds.

Uninhabited islands of the northern Persian Gulf hold internationally important numbers of ground nesting waterbirds and have been designated as Important Bird Areas (IBAs) in the Middle East (Evans 1994; Scott 2007). The Persian Gulf has increasingly come under pressure from development associated with the oil and natural gas industry (Nouri *et al.* 2007), as the Persian Gulf together with its coastal zone is known to be one of the world biggest resources of crude oil and natural gas (Sale *et al*. 2011). The impact of oil spills on birds and the destruction of their habitat caused by oil and gas infrastructure, extraction wells, super tankers and the war between countries located in the Persian Gulf region cannot be ignored.

Unfortunately, knowledge of waterbirds in the Persian Gulf is still limited (Roselaar & Aliabadian 2007; Tayefeh *et al.* 2011), as only a few breeding season surveys of waterbird populations have been carried out on the islands (Ticehurst *et al.* 1925; Løppenthin 1951; Gallagher *et al.* 1984; Scott 2007; Behrouzi-Rad & Tayfeh 2008). The first recorded survey of breeding waterbirds was carried out by Ticehurst *et al*. (1925) in 1905 and 1923. Five decades later, in the 1970s, a survey of the populations of breeding waterbirds on the some of the Iranian islands in the Persian Gulf was undertaken by the Iran Department of the Environment (DOE) (Scott 2007). In the last 35 years, relatively little information has been published on the breeding waterbirds of the Persian Gulf islands (Boushehr and Hormozgan Provincial Offices of DOE unpubl. data; Behrouzi-Rad & Tayfeh 2008, Behrouzi-Rad & Berhouzi-Rad 2011). A census of breeding waterbirds was carried out by Tayefeh *et al*. (2011) on seven of the 25 Iranian islands in the Persian Gulf in 2010. These authors found that over 120,000 pairs of nine waterbird species were breeding on the northern Persian Gulf islands. The survey revealed that some islands, such as Larak and Tahmadon which were surveyed during the early 20th century, have become unsuitable for breeding colonies of waterbirds.

The objectives of this study were: 1) to provide data on the populations of breeding waterbirds, 2) to estimate nest densities of the most abundant ground-nesting waterbirds, 3) to compare breeding species diversity and the population sizes of waterbirds with the results from previous surveys, and 4) to indicate the importance of the northern Persian Gulf islands as secure breeding sites for waterbirds and thus for the protection of biodiversity. The study area consisted of seven islands that were potentially suitable for breeding waterbirds (Tayefeh *et al*. 2011). The islands were surveyed during the 2011 and 2012 breeding seasons. The size and trends of the waterbird populations on each island can be used to assess whether or not these islands need higher levels of legal protection. Also they can be used as indicators for the assessment of environmental health in the Persian Gulf.

2. Material and Methods

The main study area comprised seven Iranian islands in the northern Persian Gulf: Bani Farour, Sheedvar, Omol-Karam, Nakhilu, Khan, Ghabr-e Nakhoda and Dara (Fig. 1). Ghabr-e Nakhoda Island, with an area of 21.9 ha, was the smallest island in the study area, while Sheedvar Island, with an area of 98 ha, was the largest. The islands all have approximately the same mean temperature, relative humidity and annual rainfall. Two main seasons are prevalent: comparatively cool winters from November to March, and hot, dry summers from May to October. The months of June, July and August are the hottest months, with temperatures rising to more than 50°C and a maximum humidity exceeding 80%.

Field surveys were conducted each year between late March and the end of August. The species of greatest interest in this study were three species of terns and the Crab

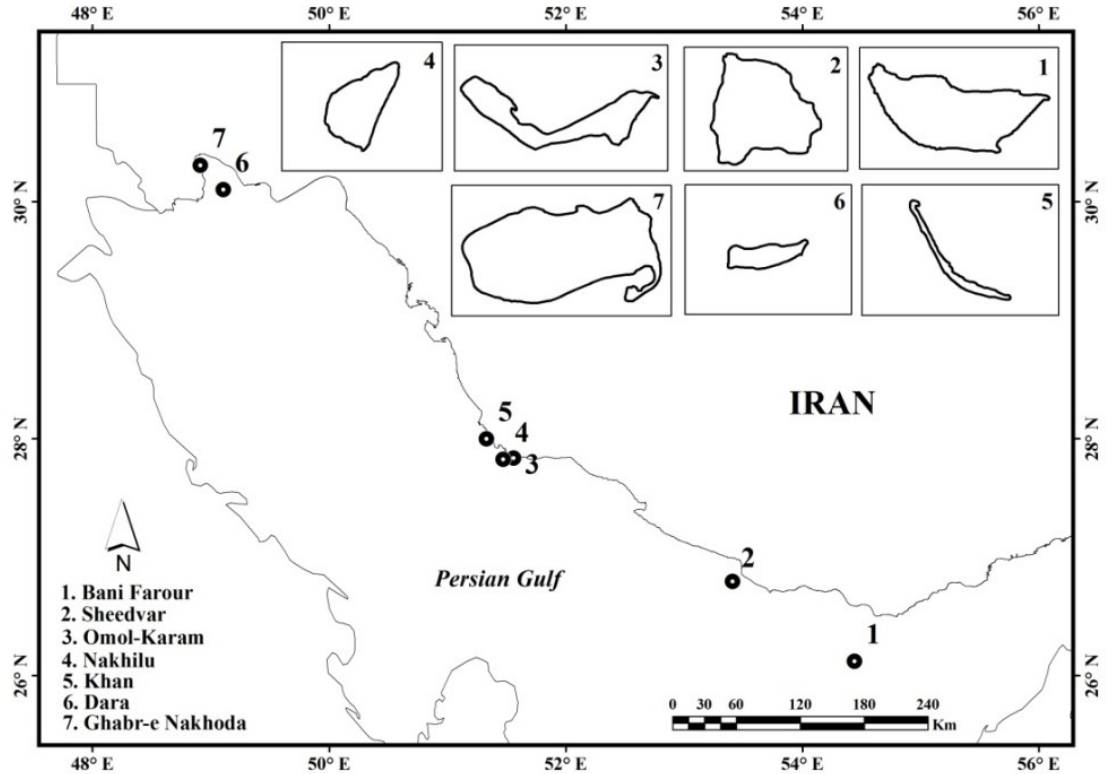

Fig. 1. Location of breeding sites of waterbirds on seven Iranian islands in the Persian Gulf.

Plover. The number of breeding pairs was calculated on the basis of Apparently Occupied Nest-sites (AONs), i.e. nests with eggs or apparently active nests prior to egg-laying (Bibby *et al*. 2000; Gibbons & Gregory 2006; McGowan *et al*. 2008; Seavy & Reynolds 2009). Each AON was considered to indicate a pair of breeding birds. The complete nest count method (Steinkamp *et al.* 2003; Sutherland *et al*. 2006) was used for the Crab Plover and at small colonies and sub-colonies of the other species. At large colonies of Lesser Crested Terns on Nakhilu Island, a stratified random sampling method was used to develop an estimate of population size (Steinkamp *et al.* 2003; Sutherland *et al.* 2004; Schwarz 2011). Quadrates of 1×1 m were used for Lesser Crested Tern colonies on Nakhilu Island. Also, a systematic sampling method (Morrison 2008; Schwarz 2011) was used to estimate the number of breeding pairs of Bridled Terns on Sheedvar, Bani Farour and Nakhilu islands. In order to develop these estimates, the total area occupied by each colony was established. Quadrates of 20×20 m on Nakhilu Island and 10×10 m on Sheedvar and Bani Farour Islands were used. To avoid overestimating the number of nests, the highest Mean Incubation Counts during the nesting season (MIC_{max}) were used at each colony (Seavy & Reynolds 2009), i.e. the nest count for Bridled Terns was conducted during late incubation and early in the chick period when almost one fourth of the eggs had hatched. The methods used in this study are described in detail in Tayefeh *et al*. (2011).

To avoid desertion by breeding birds or overheating of the eggs, visits to the colonies were restricted to the early morning between 06:00 h and 09:00 h and evening between 18:00 and 21:00 h, and were less than 15 minutes in duration. All statistical analysis was performed with SPSS 16.0.1 (SPSS Inc. 2001). One-way Analysis of Variance (ANOVA) was used to compare mean values of Bridled Tern nests/ha between different islands and mean values of Lesser Crested Tern nests/m^2 between different colonies. The Tukey *post-hoc* multiple test (HSD) was used as the continuation of ANOVA in cases where the groups showed significance differences for mean comparisons. An independent sample t-test was applied to compare mean values between years. The values are reported as means ± SE. The level of significance was set at 0.05.

3. Results

3.1. Bridled Tern

Nesting colonies of the Bridled Tern were discovered on six islands in the northern Persian Gulf during the 2011 and 2012 breeding seasons (Table 1). More than 98% of the breeding birds were on only three islands: Sheedvar, Bani Farour and Nakhilu islands. In 2011, a comparison between nest densities using One-way ANOVA analysis showed that there was a highly significant difference between these three islands ($F_{2,142}$= 52.830, P<0.01). The Tukey (HSD) revealed that the nest densities on Bani Farour and Nakhilu islands were not significantly different (P= 0.485), but that they were significantly denser than on Sheedvar Island (P<0.01). In 2012, the analysis indicated that there was a significant difference in nest densities between islands ($F_{2,151}$= 25.878, P<0.01). The highest nest density was observed at Nakhilu Island, followed by Bani Farour Island, while the lowest density was found on Sheedvar Island (P<0.05, Table 1). The comparisons of nest densities between the 2011 and 2012 breeding seasons using Independent sample t-test indicated that there was no significant difference on Sheedvar Island (t= –0.818, P= 0.415) and on Nakhilu Island (t= 1.373, P= 175), but nest densities were lower in 2012 than in 2011 on Bani Farour Island (t= 48.94, P<0.01).

3.2. Lesser Crested Tern and Swift Tern

Mixed breeding colonies of Lesser Crested Tern and Swift Tern were found on five of the seven islands surveyed during the 2011 and 2012 breeding seasons (Table 2). The total numbers of Lesser Crested Tern nests were 27,554 and 28,677 in 2011 and 2012, respectively, while those of Swift Tern nests were 2,888 and 3,276. Most of the breeding birds were on Nakhilu Island. In 2011, a total of 21,000 pairs of Lesser Crested Terns bred on Nakhilu Island at four main colonies and several sub-colonies. The results of One-way ANOVA analysis revealed that there were no significant differences between the mean nest densities in the four main colonies of Lesser Crested Terns ($F_{3,125}$= 1.309, P>0.05). On Khan Island, the highest mean incubation count (MIC_{max}) of Lesser Crested Tern nests was estimated at 2,745 at two colonies on 9 and 25 June 2011. The total number of Swift Tern nests was 1,758. Most parts of these colonies were destroyed by a tidal flood and only 136 chicks were counted at the end of the breeding season. Breeding colonies of Lesser Crested Terns and Swift Terns were found on Sheedvar, Bani Farour and Ghabr-e Nakhoda islands during the 2011 breeding season (Table 2). In 2012, Lesser Crested Terns bred together with Swift Terns in several colonies on Nakhilu Island, covering a total area of 2,310 m^2 and with a mean density of 10.73± 0.14 nests/m^2. In total, it was estimated that there were 24,786 Lesser Crested Tern nests and 2,099 Swift Tern nests on Nakhilu Island. The results of an Independent sample t-test indicated that there was no significant difference in the nest density of Lesser Crested Terns on Nakhilu Island between 2011 and 2012 (t= –0.0723, P= 0.470). On Khan Island, 1,409 Lesser Crested Tern nests and 161 Swift Tern nests were counted on 18 June 2012; however, most of these nests were flooded by a high tide and breeding was not successful. Both species also nested on Sheedvar and Bani Farour, but neither species was found nesting on Ghabr-e Nakhoda Island in 2012 (Table 2).

Table 1. Estimated number of breeding pairs of Bridled Tern on the northern Persian Gulf Islands, 2011-2012.

Survey dates	Islands	No. of quadrates	Nesting area (ha)	Mean no. of nests/ha	Estimated total no. of nests
2011					
7 June	Sheedvar	67 (10×10 m)	86	216.42±29.13[a]	18,621±2,505
9 June	Bani Farour	33 (10×10 m)	60.8	754.55±74.89[b]	45,843±4,553
18 June	Nakhilu	45 (20×20 m)	19.79	846.11±61.37[b]	16,742 ± 1,212 + 525 outlier nests
19 June	Omol-Karam				100
23 May	Ghabr-e Nakhoda				250
24 May	Dara				900
Total					**82,981**
2012					
21 June	Sheedvar	73 (10×10 m)	86	245.21±19.80[a]	21,088±1,703
23 June	Bani Farour	46 (10×10 m)	60.8	506.52±38.75[b]	3,0796±2,356
19 June	Nakhilu	35 (20×20 m)	22.4	694.29±91.97[c]	15,552±2,060 + 131 outlier nests
20 June	Omol-Karam				84
30 May	Ghabr-e Nakhoda				233
30 May	Dara				650
Total					**68,534**

Note: Means in the same column followed by the same letter are not significantly different at the P<0.05 as determined by Tukey (HSD).

Table 2. Estimated number of Lesser Crested Tern *Sterna bengalensis* (LCTE) and Swift Tern *Sterna bergii* (SWTE) nests on the northern Persian Gulf islands, 2011-2012.

Date	Islands (colony no.)	No. of quadrates	LCTE Nesting area (m^2)	Mean value of LCTE nests /quadrate	Total	
					LCTE	SWTE
2011						
7 June	Sheedvar				1,696	205
9 June	Bani Farour				3,206	297
7 June	Nakhilu (1)	41	638	10.80±0.21[a]	6,890	10
7 June	Nakhilu (2)	40	553	10.40±0.27[a]	5,751	206
7 June	Nakhilu (3)	21	202	10.10±0.47[a]	2,040	192
7 June	Nakhilu	Sub-colonies			2,552	22
24 June	Nakhilu (4)	27	183	10.89±0.28[a]	1,993	195
9 June	khan				55	1,236
25 June	Khan				2,690	522
23 May	Ghabr-e Nakhoda				681	2
Total					**27,554**	**2,887**
2012						
21 June	Sheedvar				884	136
23 June	Bani Farour				1,598	880
19 June	Nakhilu	200	2,310	10.73±0.14	24,786	2,099
18 June	Khan				1,409	161
30 May	Ghabr-e Nakhoda				0	0
Total					**28,677**	**3,276**

Note: Means in the same column followed by the same letter are not significantly different at the $P<0.05$ as determined by Tukey (HSD).

Table 3. Estimated number of Crab Plover nests on the northern Persian Gulf islands, 2011–2012.

Survey dates	Islands	Nesting area (m^2)	No. of nests	Nest density (nests/m^2)	Total no. of nests
2011					
6 June	Omol-Karam	6,166	1,585	0.26	
7 June	Nakhilu	3,813	557	0.15	
23 May	Ghabr-e Nakhoda	21,580	2,083	0.10	
24 May	Dara Colony 1	27,696	12,762	0.46	
24 May	Dara Colony 2	10,991	2,227	0.20	**19,214**
2012					
20 June	Omol-Karam	1,330	402	0.30	
19 June	Nakhilu	8,100	1,594	0.20	
30 May	Ghabr-e Nakhoda	21,000	1,306	0.16	
30 May	Dara	Not recorded	10,246	Not recorded	**13,548**

Table 4. Estimated number of nests of 10 waterbird species on the islands of the northern Persian Gulf in 2010 (Tayefeh *et al*. 2011), 2011 and 2012.

Species	2010	2011	2012
Bridled Tern	74,113	82,981	68,534
Lesser Crested Tern	30,799	27,554	28,677
Swift Tern	4,614	2,887	3,276
Crab Plover	8,005	19,214	13,548
Caspian Tern	76	114	5
Gull-billed Tern	139	30	0
White-cheeked Tern	2,197	2,605	2,608
Western Reef Heron	209	180	106
Kentish Plover	15	15	0
Striated Heron	15	1	0
Total	**120,182**	**135,581**	**116,754**

3.3. Crab Plover

Crab Plovers bred only on Nakhilu, Omol-Karam, Ghabr-e Nakhoda and Dara islands during the 2011 and 2012 breeding seasons (Table 3). In total, 19,214 nests of Crab Plovers were recorded on the islands under investigation in 2011. This number had decreased to 13,548 in 2012. On 7 June 2011, 1,585 nests were recorded on Nakhilu Island. On Omol-Karam Island, 557 nests were counted on 6 June 2011. Ghabr-e Nakhoda Island hosted a total of 2,083 pairs of Crab Plover. Furthermore, two breeding colonies of Crab Plovers were found on Dara Island on 24 May 2011. At the larger of these two colonies, there were 12,762 active burrows with an average density of 0.46 nests/m^2. At the smaller colony, 250 m away from the larger colony, there were 2,227 nests in an area of 10,991 m^2. In 2012, totals of 402, 1,594 and 1,306 Crab Plover nests were counted on Omol-Karam, Nakhilu and Ghabr-e Nakhoda Islands, respectively. On 30 May 2012, a total of 10,246 active nests were counted on Dara Island at a single colony.

Some cases of re-nesting were observed near the main Crab Plover colonies. In late July 2011, a new colony was discovered containing 79 burrows, close to the main colony on Nakhilu Island. Of 50 burrows randomly checked using a burrowscope, 22 burrows contained eggs, three burrows contained chicks between four and five weeks old, and the rest (50%) were empty. At the same time, another new colony containing 112 burrows was found 100 m away from the main colony. No eggs were found in the burrows, but there were some chicks between two and five weeks old. In early August 2011, a new colony with at least 5,000 burrows was established 100 m away from the main colony on Dara Island. Most burrows were empty, but some of them contained eggs and chicks between three and five weeks old.

4. Discussion

During 2011 and 2012, ten species of waterbird were found breeding on the seven islands under investigation. In addition to the four species discussed above, these were Western Reef Heron *Egretta gularis*, White-cheeked Tern *Sterna repressa*, Caspian Tern *Sterna caspia*, Gull-billed Tern *Gelochelidon nilotica*, Kentish Plover *Charadrius alexandrinus* and Striated Heron *Butorides striatus*. Western Reef Heron was the most abundant species while Striated Heron was the least. The populations of all ten species in 2011 and 2012 are compared with those in 2010 in Table 4.

4.1. Fluctuations in populations

Negligible fluctuations occurred in the total breeding population of waterbirds on the seven islands in 2010, 2011 and 2012 (Table 4). Most of fluctuation took place in the breeding population of Bridled Terns on Bani Farour Island (Table 1). In 2010, the total number of breeding pairs of Bridled Terns was estimated at 29,400 (Tayefeh *et al*. 2011). This increased to 45,000 pairs in 2011 and decreased again to 30,000 pairs in 2012, a reduction of 33% in the population compared with 2011. On Sheedvar Island, the total AONs of Bridled Terns showed a decrease of 29.7% in 2011 and 20.4% in 2012 compared with 2010 (Tayefeh *et al*. 2011). The factors involved in this fluctuation are not yet known. As this species nests in the shade, often under the bushes, the density of nests/ha is affected by the level of vegetation cover on the island, which depends itself on several factors including drought and precipitation. It seems that some part of the breeding population of Bridled Terns on Sheedvar Island in 2010 shifted to Bani Farour Island, 130 km away, in 2011. Moreover, yearly fluctuations in the mean number of nests/ha on Bani Farour Island and Sheedvar Island may possibly be attributed to the small quadrate sizes and smaller

sample sizes in 2011 and 2012, resulting in smaller total sample sizes covering less than 1% of the breeding areas. This was due to the use of an inappropriate sampling method in the dense vegetation on the island, and difficulty in finding nests under the bushes. The discovery of huge colonies of Crab Plovers on Dara Island in 2011 and 2012 (Table 3) is particularly interesting. The colony of Dara Island is the world's largest colony of Crab Plovers ever found (Cramp *et al*. 1985; De Marchi *et al*. 2006, Scott 2007; Tayefeh *et al*. 2011; Javed *et al*. 2012). Our results confirm the importance of the Persian Gulf islands for breeding Crab Plovers as they provide suitable and protected breeding sites for almost half the world population of 60,000–80,000 birds (Wetlands International 2006).

4.2. Effect of natural phenomena

Drought and predation are two natural phenomena that can have negative effects on nest density and the numbers of terns nesting on the islands. The total population of Bridled Terns on Nakhilu Island was relatively stable over the three years 2010-2012. However, the total breeding area in 2011 was only 19.8 ha compared with 22.4 ha in 2010 and 2012, apparently because a drought had affected the vegetation cover on that part of the island where the bird chose to lay eggs under bushes. In contrast, the density of nests in 2011 (846 nests/ha) was slightly higher than in 2010 (735 nests/ha; Tayefeh *et al*. 2011) and 2012 (694 nests/ha; Table 1). Apparently the birds had increased their nesting density in 2011 to compensate for the reduction in suitable nesting areas. Thus the total numbers nesting in 2010, 2011 and 2012 remained relatively stable.

The total numbers of Lesser Crested Tern nests in 2011 and 2012 were almost the same and slightly fewer than in 2010 (Table 4). Most of the terns were found breeding on Nakhilu Island in 2011 (70%, Table 2) and 2012 (86%, Table 2). In 2010, almost equal numbers of Lesser Crested Terns were breeding on Omol-Karam and Nakhilu Island (Tayefeh *et al.* 2011), but in 2011 and 2012, there were no nests on Omol-Karam owing to the presence of Golden Jackals *Canis aureus*. The breeding population of this tern on Bani Farour Island decreased from 7,800 pairs in 2010 to 3,200 pairs in 2011 and only 1,600 pairs in 2012, but the reason for this is unknown. Small numbers of Lesser Crested Terns also bred on Sheedvar and Ghabr-e Nakhoda islands in 2010 and 2011 and on Sheedvar Island in 2012. Swift Terns bred on Omol-Karam Island in 2010, but did not do so in 2011 and 2012 because of the presence of Golden Jackals.

As in 2010, most parts of the colonies of Lesser Crested Tern and Swift Tern on Khan Island were flooded and destroyed during high spring tides in 2011 and 2012. Because of its very low elevation, most of the surface of Khan Island is covered by the highest tides which wash out tern nests. Although it would seem that Khan Island is not a suitable place for terns to breed, small numbers of Lesser Crested Terns and Swift Terns usually attempt to breed and are sometimes successful.

4.3. Colony movements and site suitability

The total breeding population of Swift Terns decreased from 1,900 pairs in 2010 to 297 pairs in 2011 and 136 pairs in 2012. Most of the breeding Swift Terns shifted to Khan Island in 2011 (61%, Table 2) and to Nakhilu Island in 2012 (64%, Table 2). Although, Swift Tern and Lesser Crested Tern are philopatric, there is evidence that they will move away from their natal breeding sites to nest in colonies elsewhere (Tayefeh *et al*. 2012). Despite the absence of Lesser Crested Terns and Swift Terns on Omol-Karam Island and a large decrease in the breeding populations on some islands during this study, the total number of nests in the whole study area showed little

fluctuation between 2010, 2011 and 2012 (Table 4). Lesser Crested Terns and Swift Terns presumably prefer to breed on Nakhilu Island because of the absence of Golden Jackals. This study further confirms the importance of Nakhilu Island as a safe nesting site for these tern species. In 2005-2007, Behrouzi-Rad & Tayefeh (2008) found 12,000–16,000 Lesser Crested Tern nests and 254–1,300 Swift Tern nests on Nakhilu Island, but none on Omol-Karam because of the presence of Golden Jackals. Clearly, as long as Golden Jackals are present, Omol-Karam Island will not be a suitable place for terns to breed.

4.4. Nest-site selection by the Crab Plover

The Crab Plover breeds on only four of the seven islands under investigation, namely Nakhilu, Omol-Karam, Ghabr-e Nakhoda and Dara islands. The total breeding population on the two nearby islands of Nakhilu and Omol-Karam was 2,142 pairs in 2011 and 1,996 pairs 2012, which is slightly fewer than in 2010, when there were 2,323 pairs (Tayefeh *et al*. 2011). In 2011, only 26% of the Crab Plovers bred on Nakhilu Island while the rest nested on Omol-Karam Island. In contrast, in 2012, 80% of the Crab Plover nests were found on Nakhilu Island. Tayefeh *et al*. (2011) reported that Crab Plovers bred in almost equal numbers on these two islands in 2010. Shifting between Nakhilu and Omol-Karam islands in different years and also occupying new locations on each island supports the hypothesis that Crab Plovers nest at high densities because they are truly colonial and do not show a high degree of site-fidelity (Chiozzi *et al*. 2011). Moreover, the area suitable for digging burrows was only partially used in any one year. The annual shift of the colony between islands or to a new location on the same island may be a response to previous occupancy that has rendered the former sites less suitable for digging new burrows. On Ghabr-e Nakhoda Island, 2,155 pairs of Crab Plovers in 2010 increased to 2,308 pairs in 2011 but decreased to 1,300 pairs in 2012, a decline of more than 43%. Fluctuations in the population on Ghabr-e Nakhoda Island may be due to the lack of potentially new nesting grounds on this small island (21.9 ha). Almost 90% of the island surface is covered by Crab Plover nests and suitable nesting sites are restricted to areas within the old nesting sites.

5. Conservation

There are many potential reasons for fluctuation in the breeding populations of waterbirds in a particular place between years such as human exploitation, food availability, predation and natural events (Bibby *et al.* 2000; Seavy & Reynolds 2009; Steinkamp *et al.* 2003), in addition to possible differences in survey and census methods (McGowan *et al.* 2008). Human exploitation, including fishing and outdoor recreation, is becoming increasingly popular. Aside from the human disturbance, these activities may have an adverse effect on the vegetation cover, soil texture and colonial breeding systems especially at the beginning of the breeding season and during the chick rearing period. Tayefeh *et al*. (2011) reported that thousands of crabs moved from the sea to the tern colonies and fed on eggs and new hatched chicks. It seemed that this event was taking place when the parents were away from the nests because of the presence of fishermen and other visitors. Egg collecting, hunting of adult birds (only on Ghabr-e Nakhoda and Dara Islands) and the destruction of burrows as a consequence of human activities on the island were the main causes of nest failure in the Crab Plover colonies. Natural events such as very high tides, predation, storms and climate change might also have an adverse effect on breeding colonies of waterbirds. Among natural events, drought can play an important role as a limiting factor by

affecting vegetation cover on the islands, particularly for species such as the Bridled Tern and Crab Plover which depend on plants for shade during the nesting season.

With a total of 116,000 – 135,000 pairs of ten waterbird species breeding on the northern Persian Gulf islands, it is apparent that these islands play an important role in the protection of biodiversity in the region. All of these sites should be designated as Ramsar sites and given adequate protection, e.g. as Biosphere Reserves. With the provision of more wardens and wardening facilities, better protection of the islands would be achieved, thereby preventing any potential habitat destruction. During the breeding season, it is necessary to prevent all kinds of disturbance on the islands where terns and Crab Plovers breed, e.g. egg-collecting by local people and uncontrolled visits by fishermen and other persons. The distribution and population sizes of breeding waterbirds on the Persian Gulf islands should be monitored annually, and long-term studies of specific aspects of the breeding biology of the waterbirds should be carried out to assess their population status and guide management actions.

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