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Dietary Segregation between Breeding Tern Species on the Persian Gulf Islands, Iran

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Abstract.—The dietary compositions of the three most abundant tern species breeding on Nakhilu and Omol-Karam Islands in the Persian Gulf were investigated to determine the dietary segregation between sympatric breeders. Chick dietary samples were collected from Bridled Tern (*Sterna anaethetus*), Lesser Crested Tern (*S. bengalensis*) and Swift Tern (*S. bergii*) in the 2010 and 2011 breeding seasons. Fish prey dominated the diet of the community (99% of prey consumed), although shrimps (primarily the Green Tiger prawn (*Penaeus semisulcatus*) were present in the food samples from Lesser Crested and Swift tern chicks. Regurgitates of Bridled Tern contained on average 12.48 ± 1.13 prey items (Range = 3-30, *n* = 31), Lesser Crested Tern contained 1.14 ± 0.01 (Range = 1-6, *n* = 365) and Swift Tern contained 1.08 ± 0.01 (Range = 1-4, *n* = 132). Pianka Overlap Index (O_{jk}) in food type was highest between Lesser Crested Tern and Swift Tern (0.98), while there was less similarity between Bridled Tern and Lesser Crested Tern (0.21) and Bridled Tern and Swift Tern (0.16) prey items. The results showed significant difference between the prey selected among the three tern species studied here in weight and length. Prey length and weight increased from 1-2-week-old chicks to 5-6-week-old chicks in both the Lesser Crested and Swift terns. Although there is high dietary overlap in Lesser Crested and Swift terns, they are segregated in terms of prey size, which likely reduces competition for prey. Although, there was some overlap between the diets of the three tern species, diet segregation on the basis of prey species and prey size are the main factors that should contribute to reduced competitive interactions for food resources. *Received 11 December 2013, accepted 6 March 2013.*

Key words.—chick diet, ontogenetic, Persian Gulf, regurgitate, *Sterna* spp., terns.

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In seabird species, studies of the diet have been conducted mostly during the breeding season when seabirds return to the nest site to feed chicks (Masello *et al.* 2010). Many studies have been focused on the intra-specific segregation in diet and foraging habits of a single species in relation to sex (Lewis *et al.* 2002; Catry *et al.* 2005; Bearhop *et al.* 2006; Weimerskirch *et al.* 2009). Many studies have been carried out on the influence of social interactions in mixed-species associations (Quinn and Ueta 2008; Campobello *et al.* 2012). Despite the importance of assessing diet segregation in seabird assemblages, few studies have addressed diet in multi-species colonies (Fasola and Canova 1991; Catry *et al.* 2009; Masello *et al.* 2010; Dunlop 2011).

Dietary studies of seabirds have shown low diversity in diet composition at high latitude marine systems, with a few main prey items making up the mass of the diet by quantity (Courtney and Blokpoel 1980; Laugksch and Adams 1993; Lynnes *et al.* 2002; Wilson 2010). For instance, 90% of the diet of Common Terns (*Sterna hirundo*) nesting on the lower Great Lakes was composed of alewife (*Alosa pseudoharengus*) and smelts from the Osmeridae family (Courtney and Blokpoel 1980). Diet composition has been shown to be more diverse in low latitude marine systems, with many prey items contributing to the diet (Ashmole and Ashmole 1967; Shealer 2002; Catry *et al.* 2009; McLeay *et al.* 2009). Previous studies of subtropical and tropical seabird communities suggest that, despite the high diversity of prey consumed, seabird diet is mostly dominated by a few prey groups (Ashmole and Ashmole 1967;

Diamond 1983; Surman and Wooller 2003; Spear *et al.* 2007). In tropical and subtropical waterbird communities, species (particularly tern species) tend to segregate on the basis of prey species (Surman and Wooller 2003; Dunlop 2011) and prey size (Ashmole and Ashmole 1967; Catry *et al.* 2009).

Studies focusing on the diet composition of seabird communities are essential to understanding many aspects of the foraging ecology of seabirds, such as potential competition for food, foraging site fidelity and energetic considerations and resources (Catry *et al.* 2009). No data have been published on the dietary composition of breeding waterbird species in the subtropical waters of the Persian Gulf. This study investigated the dietary composition of chicks of the Bridled Tern (*Sterna anaethetus*), Lesser Crested Tern (*S. bengalensis*) and Swift Tern (*S. bergii*) on the Mond Islands (Nakhilu and Omol-Karam Islands) in the northern Persian Gulf during their breeding seasons in 2010 and 2011. The Lesser Crested Tern is the most abundant breeding species (21,000-23,000 pairs), followed by Bridled Terns (17,000-19,000 pairs) and Swift Terns (2,300-2,700 pairs) (Tayefeh *et al.* 2013). Based on the life-history traits of each species, these three tern species were inshore feeders with different feeding methods: in-flight contact dipping in the Bridled Tern (Dunlop and Surman 2012) and plunge-diving in Lesser Crested and Swift terns (Fasola *et al.* 1989; McLeay *et al.* 2009).

We hypothesized that there is intra-specific segregation in diet composition and prey size between Bridled, Lesser Crested and Swift terns to lessen competition for food between species in the breeding areas. The objectives of this study were to: 1) examine prey diversity in the diets of chicks of terns on Nakhilu and Omol-Karam Islands; 2) assess overlap in diet composition and prey size among species; and 3) examine ontogenetic differences in prey composition and prey sizes of close breeding species of Lesser Crested Tern and Swift Terns.

METHODS

Study Area

This study was conducted on Nakhilu and Omol-Karam Islands, northern Persian Gulf, Iran (Fig. 1) during the breeding seasons of the Bridled, Lesser Crested and Swift terns during June, July and August 2010 and 2011. The Persian Gulf is a shallow, marginal semi-enclosed sea, with an area of 239,000 km^2 located in Western Asia between Iran and the Arabian Peninsula (24° N to 30° N and 48° E to 56° E). The Persian Gulf is 989 km in length, and most of the northern coastline lies within Iran. The waters overall are very shallow, with a maximum depth of 100 m and a mean depth of 36 m. Water temperatures in the Persian Gulf indicate high seasonal variations, with temperatures rising to 35 °C in summer and falling to 15 °C in winter (Reynolds 1993; Hosseinibalam *et al.* 2011). The surface waters of the Persian Gulf show a wide range of salinities from 37.15 to 43.95 g/L with a mean of 40.02 g/L (Emara 2010). The uninhabited Islands of Nakhilu and Omol-Karam support large nesting colonies of waterbirds (Scott 2007; Tayefeh *et al.* 2011) and have been designated as Important Bird Areas in the Middle East (Evans 1994; Scott 2007). Biogeographically, these islands lie in the Western Palearctic region, although much of the bird fauna of the Persian Gulf coast has affinities with the Oriental region (Cramp *et al.* 1985; Newton 2007; Tayefeh *et al.* 2012).

Diet Sampling

Nakhilu and Omol-Karam Islands were visited every week during the breeding seasons. Food samples of Bridled Tern, Lesser Crested Tern and Swift Tern were obtained by inducing chicks to regurgitate. Tern chicks regurgitate spontaneously when handled or when held upside down (Catry *et al.* 2009; McLeay *et al.* 2009). Regurgitate samples were collected from Bridled Tern chicks in June and July 2010 and 2011 on Nakhilu Island while chicks were at the nest. Samples were obtained from chicks of different ages

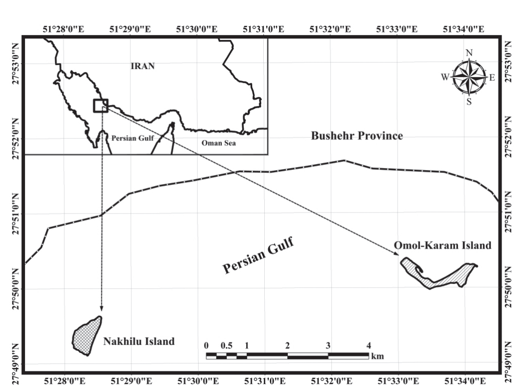

Figure 1. Map of the northern Persian Gulf showing Nakhilu and Omol-Karam Islands, Iran, where the diets of the Bridled, Lesser Crested and Swift terns were studied.

(from 1 to 8 weeks old). Data on the dietary composition of the Lesser Crested Tern and Swift Tern chicks were collected in June-August 2010 and 2011 on Nakhilu Island and in June-July 2010 on Omol-Karam Island. Neither of these species bred on Omol-Karam Island in 2011. During the nestling phase of Lesser Crested and Swift terns, we observed chick food deliveries with a telescope from a blind near the colonies. If they had recently eaten, chicks regurgitated easily if disturbed. In addition, food discarded by the Lesser Crested Terns and Swift Terns and the remains of prey items were collected within the colonies because they often provide further evidence of which prey items have been taken (Sutherland 2004).

Chicks of the Lesser Crested Tern and Swift Tern leave their colonies to form crèches 2-5 days after hatching. During the post-nestling phase, the sampling method involved the collection of regurgitate samples (Shealer 2002; Sutherland 2004; McLeay *et al.* 2009). Regurgitate samples were collected on a regular basis when the chicks were 1-2 weeks old, 3-4 weeks old and 5-6 weeks old (McLeay *et al.* 2009). The samples were collected during daylight, when the chicks within a crèche were rounded up. If they had recently eaten, chicks regurgitated easily during this process. For each sample, regurgitated prey items were collected separately in plastic bags, and labeled and preserved in a cool place in the field and later frozen.

In the laboratory, individual prey items were identified, measured and weighed. Fish items were identified by experts of the Iran Shrimp Research Center, Boushehr, Iran. In this study, items of prey were identified only to family level since identification to species level of samples from families such as the Engraulidae and Clupeidae was not always possible. Regurgitates and individual prey items were weighed to ± 0.01 g using a digital balance. The total length of each item was measured ± 1 mm from the tip of the snout along the mid-line to the posterior edge of the caudal fin-fold.

Analysis

Dietary data for the three tern species were pooled for 2010 and 2011 because of the small regurgitate sample size for the Bridled Tern in each breeding season and because the Lesser Crested Terns and Swift Terns did not breed on Omol-Karam Island in 2011. For these reasons, seasonal variation in dietary composition was not analyzed. Statistical analyses were performed using SPSS statistics (SPSS, Inc. 2001). Data were tested for assumptions of normality using Skewness and Kurtosis. Since the assumption of normality for both weight and length of prey was violated, data were analyzed using square root transformations. Only the transformed weight of Bridled Terns showed a non-normal distribution. Therefore, to compare among the three tern species, a Kruskal-Wallis one-way analysis of variance was conducted for transformed length and weight, respectively. Pairwise comparison was carried out using the Tukey honest significant difference (HSD) test for transformed length and Mann-Whitney-U test for weight.

To assess ontogenetic differences in prey mass and length between the Lesser Crested Tern and Swift Tern, t-test was considered. Prey frequency mass and length frequency distribution analyses were undertaken using Microsoft EXCEL and SPSS (SPSS, Inc. 2001) with $P < 0.05$ used as the threshold of significance. The average weight and length of the prey are reported ± SE. The specific numerical frequencies of each prey family in this study were used as factors. Prey composition overlap between species was measured using Pianka Overlap Index (Pianka 1973) and based on the numerical frequency of each prey family, where:

$$O_{jk} = \sum_{i=1}^{n} (P_{ji} \times P_{ki}) / \left(\sum_{i=1}^{n} (P_{ji}^2 \times P_{ki}^2) / 2 \right)$$

P_{ji} and P_{ki} are the proportions of the resource i used by bird species j and k, respectively. The index is symmetrical and assumes values between 0 and 1. A value of 0 suggests that the two species have no common prey, 1 indicates complete overlap (when two species consume exactly the same prey), and intermediate values show partial overlap in resource utilization. An overlap index > 0.6 was treated arbitrarily as a significant overlap in the diet of the two species compared (Diamond 1983; Catry *et al.* 2009).

RESULTS

Prey Items

A total of 387 prey items were identified in the 31 Bridled Tern regurgitates. The regurgitates contained on average 12.48 ± 1.13 (Range = 3-30, n = 31) prey items. The weights of the regurgitates varied between 4.1 and 16.7 g, with a mean of 7.24 ± 0.49 g. In the case of the Lesser Crested Tern, 98 regurgitates and eight nest discards were collected on Nakhilu Island in 2010 and 2011, and 267 regurgitates and six nest discards were collected on Omol-Karam Island in 2010. Of the total of 365 regurgitates, 325 (89%) contained one prey item, 32 (9%) contained two items, five (1%) contained three items, two (< 1%) contained four items and one (< 1%) contained six items. In 2010, 132 regurgitates and eight nest discards of the Swift Tern were collected on Omol-Karam Island. In 2011, few Swift Tern chicks were found in crèches on Nakhilu Island and no Swift Terns were found breeding on Omol-Karam Island. Of the 132 Swift Tern regurgitates, 124 contained one prey item, six contained two items, two contained three items and two contained four items.

Diet Composition

Of the 387 prey items of the Bridled Tern, 62% were from the family Mugilidae, 33% from Engraulidae, 2% from Clupeidae, and 3% from other prey families (Table 1). Overall, the regurgitates and nest discards from the Lesser Crested Tern on Omol-Karam and Nakhilu Islands in 2010 and 2011 contained 432 prey items from 13 families. Of the 432 prey items, 426 (98.6%) were from the teleost families and six (1.4%) were shrimps (primarily the Green Tiger prawn (*Penaeus semisulcatus*) in the Penaeidae family). Four of the 13 prey families accounted for 82.6% of the prey items: Scianidae (35.2%), Engraulidae (21.5%), Clupeidae (21.0%), and Mullidae (4.9%). The remainder were from 10 other prey families. Among the total of 151 prey items of the Swift Tern, 35% were from the Scianidae, 26% from the Clupeidae, and 15% from the Engraulidae, with the remainder coming from eight other prey families (Table 1). Using frequencies of prey items common to both bird species, Pianka Overlap Index (O_{jk}) was highest between the Lesser Crested Tern and the Swift Tern (0.98). There were less similarity between the Bridled Tern and the Lesser Crested Tern (0.21) and Swift Tern (0.16).

Prey Size

Prey items of the Bridled Tern weighed between 0.1 and 4.4 g with the mean fish prey of 0.59 ± 0.03 g (Table 2). Of the 387 prey items, 373 items weighed between 0.1-1.9 g (96%) and 14 (4%) items weighed more than 2 g (Fig. 2). The mean fish prey length was 45.78 ± 0.72 (Range = 21-118 mm, n = 373; Table 2). Of the total prey items, 39% were 20-39 mm length, 49% were 40-59 mm and 12% were 60-79 mm. The mean fish prey length of Lesser Crested Tern chicks was 76.77 ± 0.93 (Range = 39-131 mm, n = 426; Table 2). Of the total prey items, 20% were 40-59 mm length, 37% were 60-79 mm, 30% were 80-99 and 10% were 100-119 mm (Fig. 2). Prey weight varied between 0.5 g and 18.5 g, with a mean weight of 5.12 ± 0.18 (Table 2). Of the 427 Lesser Crested Tern prey items, 19% were 0.0-1.9 g, 29% were

Table 1. Number of individuals (n) and relative abundance (RA) of prey families identified from regurgitations and nest discards taken from the Bridled Tern, Lesser Crested Tern and Swift Tern breeding in the Mond Islands, Northern Persian Gulf, Iran, during the 2010 and 2011 breeding seasons.

	Bridled Tern		Lesser Crested Tern		Swift Tern	
Families	*n*	RA (%)	*n*	RA (%)	*n*	RA (%)
Clupeidae	8	2.07	91	21.06	39	25.83
Engraulidae	127	32.82	93	21.53	23	15.23
Plotocidae	0	0.00	1	0.23	0	0.00
Hemiramphidae	1	0.26	0	0.00	0	0.00
Exocoetidae	0	0.00	0	0.00	1	0.66
Teraponidae	0	0.00	2	0.46	0	0.00
Apogonidae	1	0.26	0	0.00	0	0.00
Carangidae	0	0.00	4	0.93	3	1.99
Nemiptridae	0	0.00	6	1.39	2	1.32
Leiognathidae	1	0.26	2	0.46	1	0.66
Scianidae	0	0.00	152	35.19	52	34.44
Mullidae	3	0.78	21	4.86	9	5.96
Sparidae	0	0.00	3	0.69	4	2.65
Cepolidae	0	0.00	2	0.46	0	0.00
Mugilidae	238	61.50	0	0.00	0	0.00
Atherinidae	3	0.78	0	0.00	0	0.00
Polynemidae	0	0.00	12	2.78	5	3.31
Unidentified fish	5	1.29	37	8.56	11	7.28
Shrimp	0	0.00	6	1.39	1	0.66
Total	387	100.00	432	100.00	151	100.00

Table 2. Mean (± SE) wet weight (g) and length (mm) of dietary samples collected from Bridled Tern chicks on Nakhilu Island in 2010 and 2011 and Lesser Crested Tern and Swift Tern chicks on Omol-Karam Island in 2010. Means in the same column followed by the different letter are significantly different ($P < 0.05$).

	Total Length (mm)		Weight (g)	
Species	Mean (± SE)	Range	Mean (± SE)	Range
Bridled Tern (n = 378)	45.78 ± 0.72 a	21-118	0.59 ± 0.03 a	0.1-4.40
Lesser Crested Tern (n = 426)	76.77 ± 0.93 b	39-131	5.13 ± 0.18 b	0.5-18.50
Swift Tern (n = 150)	91.11 ± 1.74 c	42-156	8.37 ± 0.41 c	1.1-32.50

2.0-3.9 g, 18% were 4.0-5.9 g, 13% were 6.0-7.9 g and the remainder more than 8 g (Fig. 2). For Swift Tern, fish prey length varied between 42 and 156 mm, with a mean length of 91.11 ± 1.74 (Table 2). Of the 150 Swift Tern prey items (excluding shrimp), 8% were less than 60 mm in length, 26% were 60-79 mm, 37% were 80-99 mm, 22% were 100-119 mm and the remainder (8%) were more than 120 mm in length (Fig. 2). The mean prey weight was 8.37 ± 0.41 g (Range = 1.1-32.5 g, n = 150). Of the total prey items, 10% were less than 4 g, 27% were 4.0-5.9 g, 17% were 6.0-7.9 g, 25% were 8.0-9.9 g and the remainder were more than 10 g (Fig. 2).

The analysis showed that there was a significant difference between the weight (χ^2_2 = 676.04, $P < 0.001$) and length ($F_{2,961}$ = 532.13, $P < 0.001$) of prey items among the three tern species. The prey items in Swift Tern regurgitates were significantly heavier than those in Lesser Crested Tern (Z = -7.80, $P < 0.001$) and Bridled Tern (Z = -23.73, $P < 0.001$). Similarly, Swift Tern chicks consumed longer prey than Lesser Crested Tern and Bridled Tern chicks ($P < 0.001$). Moreover, the prey items in Lesser Crested Tern regurgitates were significantly heavier (Z = -17.94, $P < 0.001$) and longer ($P < 0.001$) than those in Bridled Tern regurgitates. There was little overlap in the length and weight of prey items taken by Bridled Terns compared with prey items taken by Lesser Crested Terns and Swift Terns, but some overlap was found in the diet of Lesser Crested Terns and Swift Terns (Fig. 2).

The overlap between the closely related Lesser Crested Tern and Swift Tern species could be due to the differences in the age of the chicks. The mean (± SE) of total length and weight of prey items of Lesser Crested Tern and Swift Tern chicks in three age categories on Omol-Karam Island are given in Tables 3 and 4. The one-way analysis of variance showed that there was a significant difference between the lengths and weights of prey in different chick age categories for Lesser Crested Tern ($F_{2,297}$ length = 38.54, $P < 0.001$; $F_{2,296}$ weight = 15.68, $P < 0.001$) and Swift Tern ($F_{2,147}$ length = 38.07, $P < 0.001$; $F_{2,147}$ weight = 23.33, $P < 0.001$). The *post hoc* multiple comparisons by Tukey HSD indicated that prey length and weight for both species increased with age from 1-2 weeks to 5-6 weeks ($P < 0.001$). The length of prey items in Swift Tern regurgitates was significantly longer than in Lesser Crested Tern regurgitates in each age class (0-14, 15-28 and > 28 days; Table 2). Similarly, the weight of Swift Tern prey items was significantly heavier than those of the Lesser Crested Tern in each age class (Table 3). Percent frequency distributions, by length (mm) and weight (g), of Lesser Crested Tern and Swift Tern chicks in different age categories are given in Figs. 3 and 4, respectively. The results indicate that chicks of the Lesser Crested Tern in each age category received shorter and lighter prey compared to Swift Tern chicks of the same age.

DISCUSSION

This study profiles the diet of the three most abundant species of tern chicks on Nakhilu and Omol-Karam in the Mond Islands in the northern Persian Gulf. There was considerable variation between the composition of the diet of the Bridled Tern, Lesser Crested Tern and Swift Tern. This finding is consistent with a previous study of an assemblage of these three tern species on the Lowendal

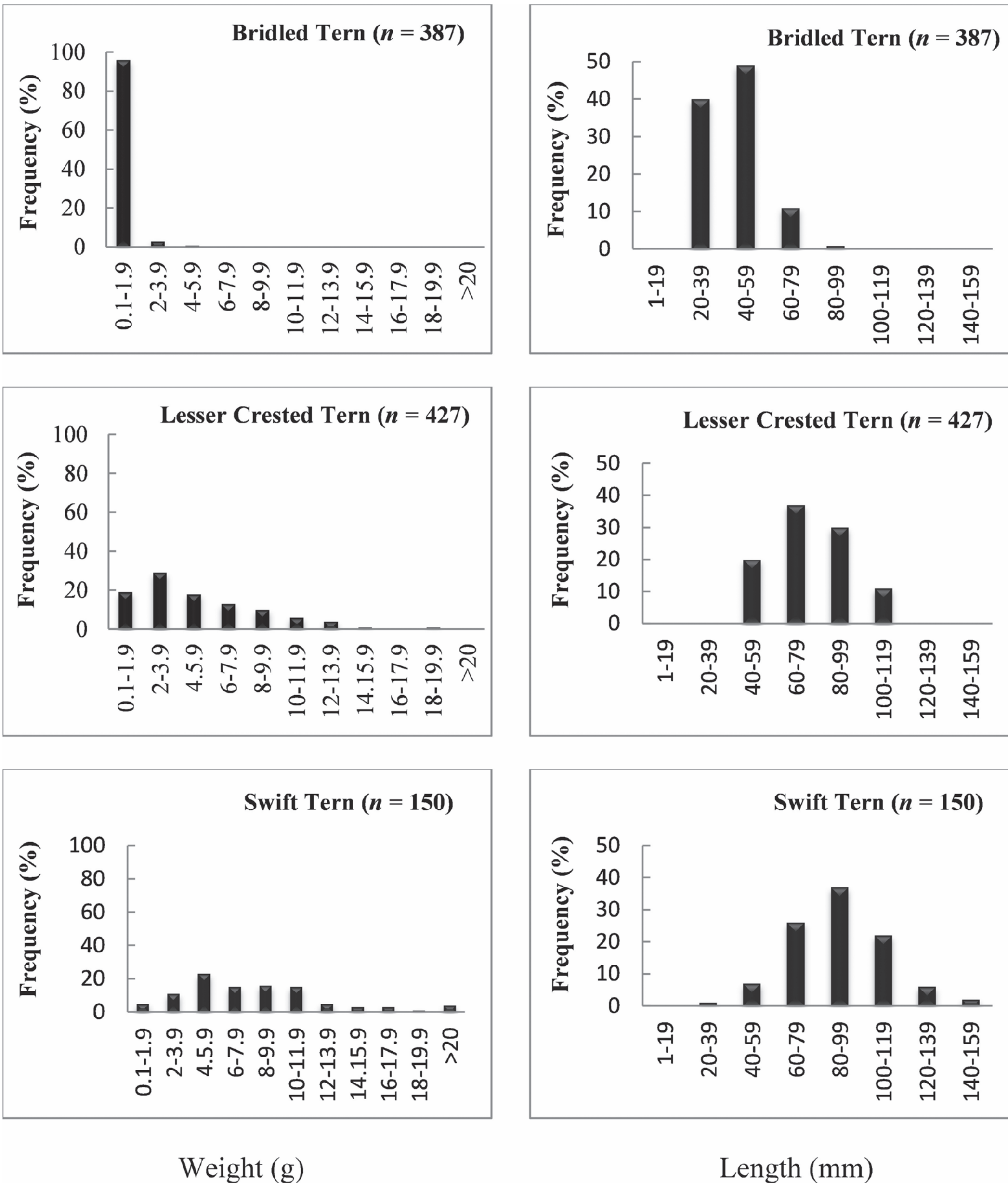

Figure 2. Percent frequency distribution by weight (g) in left column and length (mm) in right column of whole prey in regurgitates taken from Bridled Tern chicks on Nakhilu Island in 2010 and 2011 and Lesser Crested Tern and Swift Tern chicks on Omol-Karam Island in 2010.

Islands, Australia (Nicholson 2002). The low overlap in diet between Bridled Terns and Lesser Crested and Swift terns might be related to differences in behavioral feeding strategies and life history traits (Hamer *et al.* 2002; Shealer 2002). The present study showed some overlap between the diets of these three tern species (Table 1). Despite such overlap between species, diet segregation on the basis of prey species, which was found for the Bridled Tern compared to the Lesser Crested Tern and Swift Tern, is an important factor for avoiding competition for food resources.

Overall, diet composition of the seabird community of the Mond Islands in a sub-

Table 3. Total length (mm) of prey items of Lesser Crested Tern and Swift Tern chicks in three age categories on Omol-Karam Island in 2010. Means in the same column followed by the different letter are significantly different ($P < 0.05$).

	Total Length (mm)			
Age	Lesser Crested Tern	Swift Tern	*T*-value	*P*-value
0-14	61.22 ± 1.52 a (n = 46)	72.14 ± 1.86 a (n = 29)	-4.518	< 0.001
15-28	69.78 ± 1.47 b (n = 109)	84.33 ± 2.18 b (n = 48)	-5.450	< 0.001
> 28	83.13 ± 1.57 c (n = 143)	103.11 ± 2.43 c (n = 73)	-7.110	< 0.001

tropical region was less diverse than that found in tropical communities such as in Western Australia (Dunlop 1997, 2011), the Lowendal Islands (Nicholson 2002) and the Great Barrier Reef Marine Park off the northeastern coast of Australia (Hulsman 1977). Many studies have shown that seabird species in temperate and high latitude systems have low diversity in diet composition, with their diets containing fewer prey species (Laugksch and Adams 1993; Lynnes *et al.* 2002; Wilson 2010). Studies on seabirds originally from a tropical region but breeding in a subtropical region showed that they are opportunistic predators (Seki and Harrison 1989; Surman and Wooller 2003). They apparently feed on almost anything of an appropriate size that becomes available in the water near the breeding and roosting areas. Their opportunistic behavior is evidenced by greater prey diversity than other seabirds at higher latitudes, with dominant prey items available and reliably present for most of the breeding season.

There was overlap in the size and weight of the prey taken by all three tern species, with the mean length indicating that Bridled Terns fed most frequently on the shortest prey items, followed by Lesser Crested Terns, with Swift Terns most often taking the largest prey (Table 4). Surman and Wooller (2003) and McLeay *et al.* (2009) found a significant positive correlation between mean prey length and adult body mass, with larger birds consuming larger prey. Body size differentiation, as it affects prey size, has proven to be a primary aspect of community assembly rules (Cody 1974; Spear and Ainley 2007), and this seems to be the case for these three tern species in the Mond Islands as well.

Diet segregation on the basis of prey length and weight, which was found for the three tern species in this study, suggests that seabird body size, morphology and foraging strategies used by each species reduce competitive interactions for food resources (Nicholson 2002; Catry *et al.* 2009). Although Swift Terns and Lesser Crested Terns ate prey of similar taxa and had some overlapping prey size, the much smaller numbers of Swift Terns (10% of Lesser Crested Terns) would have further reduced competition for prey. Moreover, the high dietary overlap (in diet composition) in Lesser Crested Terns and Swift Terns was segregated in terms of prey size (Fig. 2).

The observed increase in the Lesser Crested Tern and Swift Tern chick prey size over the course of the chick-provisioning period (Tables 3 and 4) showed that parents are constrained in their foraging behavior by the need to choose prey according to the

Table 4. Weight (g) of prey items of Lesser Crested Tern and Swift Tern chicks in three age categories on Omol-Karam Island in 2010. Means in the same column followed by the different letter are significantly different ($P <$ 0.05).

	Weight (g)			
Age	Lesser Crested Tern	Swift Tern	*T*-value	*P*-value
0-14	2.50 ± 0.16 a (n = 46)	4.22 ± 0.38 a (n = 29)	-4.169	< 0.001
15-28	4.47 ± 0.31 b (n = 109)	7.72 ± 0.50 b (n = 48)	-5.061	< 0.001
> 28	5.47 ± 0.29 c (n = 143)	10.65 ± 0.65 c (n = 73)	-8.400	< 0.001

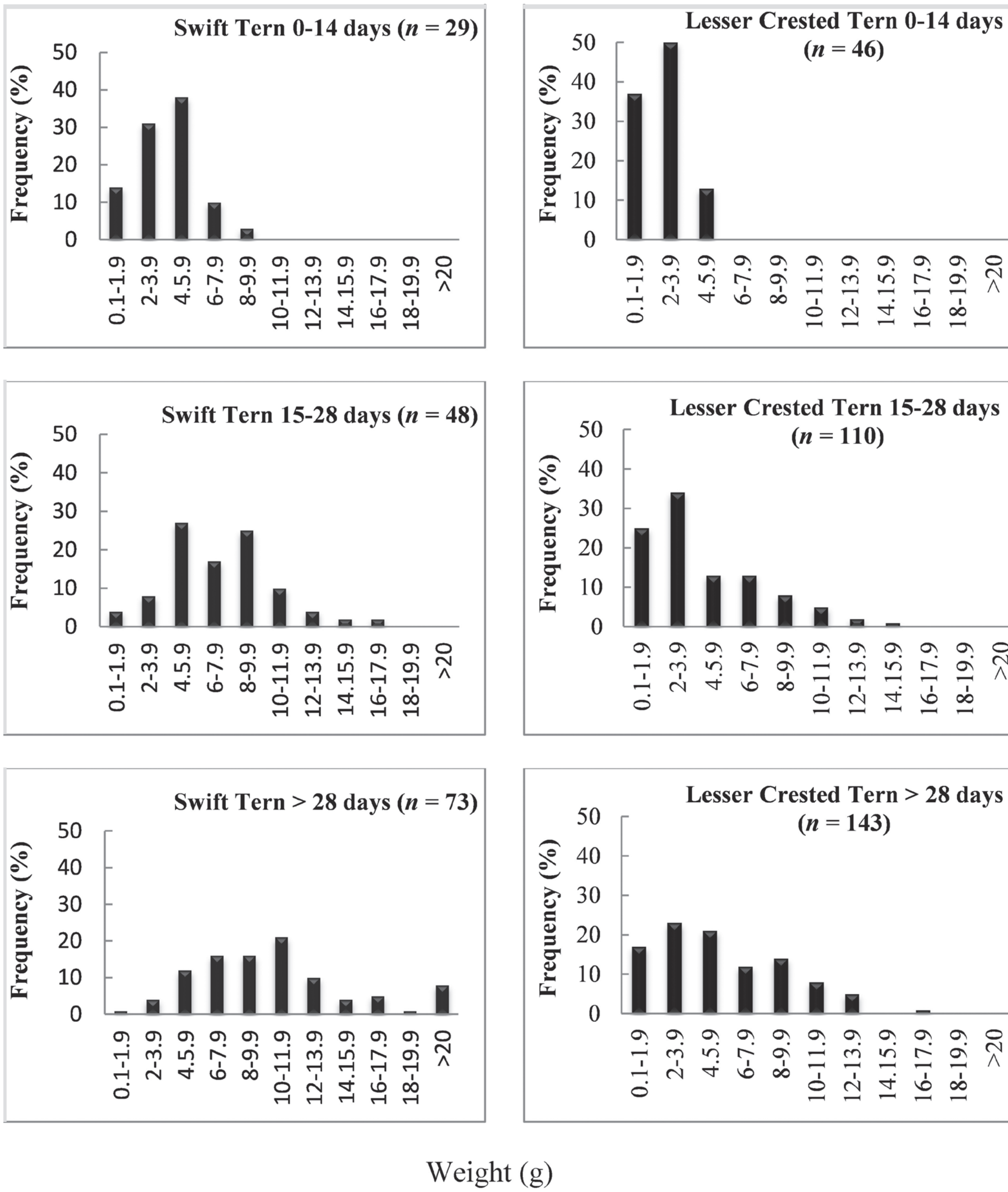

Figure 3. Percent frequency distribution by weight (g) of whole prey in regurgitates taken from Lesser Crested Tern and Swift Tern chicks in three age categories (0-14, 15-28 and > 28 days) on Omol-Karam Island in 2010.

physical ingestion abilities of chicks during the early provisioning period (McLeay *et al.* 2009). Lesser Crested Tern and Swift Tern chicks are small in comparison to many seabird species, having approximately 10% of adult body mass and weighing between 20 and 40 g when hatched (F. H. Tayefeh, pers. obs.). They are limited immediately after hatching in the size of the prey that they can consume. As the chicks grow, energetic demands increase and adults may either deliver larger prey and/or increase the rate of fish delivered.

This study supports the findings of previous studies on Swift Terns (Hulsman *et al.* 1989; McLeay *et al.* 2009) and other tern species (Ramos *et al.* 1998; Shealer 1998) and indicates that adult Lesser Crested and Swift

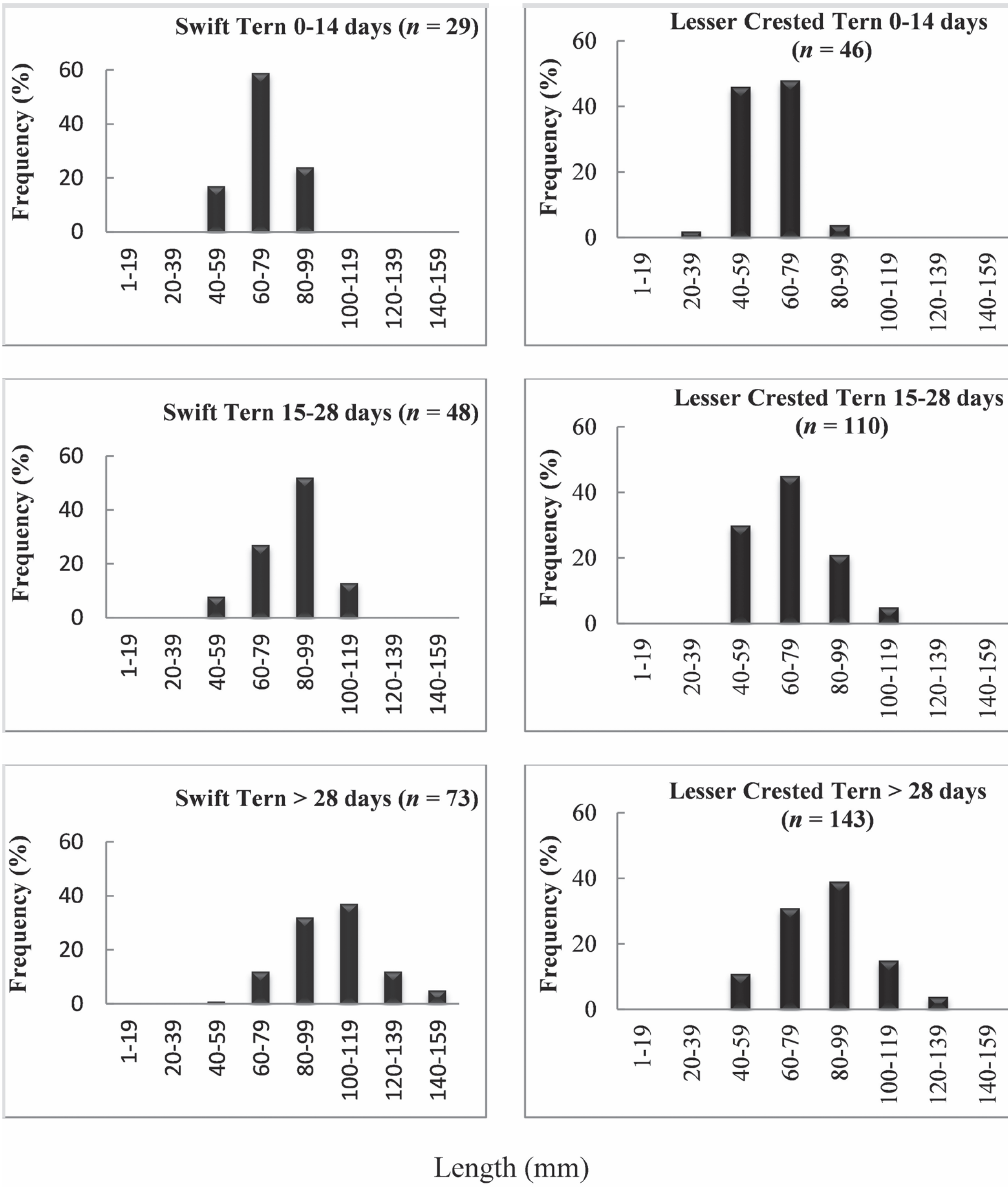

Figure 4. Percent frequency distribution by length (mm) of whole prey in regurgitates taken from Lesser Crested Tern and Swift Tern chicks in three age categories (0-14, 15-28 and > 28 days) on Omol-Karam Island in 2010.

terns adjust the size of the prey provided to their chicks as the chicks grow throughout the nestling period (Saino *et al.* 1994; Fasola and Siano 1995). Seabirds provisioning their chicks at a central place must regulate their foraging behavior according to the distance of the feeding areas from their nesting areas, their own prey requirements and the changing dietary requirements of their chicks (McLeay *et al.* 2009). For single-prey loaders, such as Lesser Crested and Swift terns, central-place foraging models predict that adults should increase the amount of energy delivered to their chicks, which corresponds to the amount of time they spend away from the colony (Leopold *et al.* 1996; McLeay *et al.* 2009).

In common with other studies in tropical breeding locations (Surman and Wooller 2003; Spear *et al.* 2007; Jaquemet *et al.* 2008), the terns examined here consumed mostly the larval and juvenile life stages of fish species. Studies of the reproductive cycle of fishes in Persian Gulf waters has shown that the abundance of fish larvae is highest in spring and early summer (Vosoughi *et al.* 2010; Hakimelahi *et al.* 2011), which synchronizes with the breeding of seabirds (Tayefeh *et al.* 2011). The prominence of the larval stages of some fish families in the diets of the three tern species studied indicates a considerable abundance of these fish species in waters adjacent to the breeding colonies. The Motaf Region in the vicinity of Nakhilu and Omol-Karam Islands is amongst the most important fishing ground in the Persian Gulf, with the highest catch rates of fishes (catch per unit area) and with a fish biomass of 7,800 kg/NM^2 (Valinassab *et al.* 2006).

The data gathered during this study provided no direct evidence of competition for food among the three tern species studied within the seabird community of the Mond Islands, Persian Gulf. According to the niche theory, the segregation in the n-dimensional niche hyper-volume between sympatric and competing populations or species is necessary for their co-existence (Hutchinson 1959; Holt 2009).

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