Chick Growth Patterns of Three Sympatric Tern Species on the Persian Gulf Islands

Submitted to the "Bird Numbers 2016-Birds in a changing World" Conference, Halle, Germany

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Abstract

This study compares the chick growth rates of the Bridled Tern *Sterna anaethetus*, Lesser Crested Tern *Sterna bengalensis* and Greater Crested Tern *Sterna bergii* as the three most abundant sympatric seabird species on Nakhilu Island, Persian Gulf, Iran, to determine different effects of the prolonged growth period of Bridled Tern (8 weeks) against the rapid growth period of Lesser and Greater Crested Terns (6 weeks). In 2010 and 2011, data collection took place during the chick rearing stage of each species on Nakhilu Island. Chicks and adults were captured, weighed and their wing, tail, tarsus and bill and head to bill length were measured in one-week intervals. The results showed that the body weight of chicks of all three tern species increased from hatching to the 5th week ($p<0.01$). The most rapid period of gaining weight occurred during the first and second week after hatching. For the Bridled Tern the hatching to fledging period takes about eight weeks, while it was shorter for the Lesser Crested Tern and Greater Crested Tern. The average ratio of the fledging weight to the adult weight was calculated 1.01 for Bridled Tern while it was 0.85 and 0.96 for Lesser Crested Tern and Greater Crested Tern respectively. When fledging, the wing and tail lengths of Bridled Tern chicks was up to 70%, and bill length up to 80%, of the measurements of adult birds, but for Greater and Lesser Crested Terns remained incomplete. The study result supports the hypothesis that the growth rate represents an optimum balance between the low energy requirements and short development time. This hypothesis would predict that variation in the growth rate between species should be related to the rate of predation and patterns of energy consumption.

1. Introduction

Collecting information on breeding biology of birds is among the most studied topics in the field of evolutionary biology and ecology (Hansell, 2000; Hamer *et al.*, 2002; Lima, 2009). This fact reflects the many comparative study on the life-history characteristics of birds, mainly as they relate to the reproduction. Life history traits can be used to construct models to predict what kinds of traits will be favored in different environments. Patterns of growth in avian chicks have been studied primarily because of their relationships with the ecology and evolutionary history of different species (Ricklefs, 1968a, 1979; Ricklefs & White, 1981; Visser, 2002). Variations in growth patterns of different species reflect adaptation to energetic constraints or to other ecological factors. In contrast, among individuals of a species, variation in growth rates reflects variation in the individual performance or variability in environmental factors (Ricklefs, 1979; Langham, 1983).

Monitoring of chick growth rates over consecutive breeding seasons provides an indication of food availability and environmental factors between and within breeding seasons (Langham, 1972; Visser, 2002). There is a selection for rapid independence of chicks, which should decrease variation in the growth rate. Intra-specific growth patterns can be variable and also flexible because of environmental variability and competing selective pressures (Cooch *et al.*, 1991).

Patterns of growth in seabird chicks have been studied for many species e.g. Langham, 1983; Hulsman & Langham, 1985; Langham & Hulsman, 1986; Nisbet *et al.*, 1995; Villard & Bretagnolle, 2010), but comparatively few studies have addressed variations among sympatric species in a particular region (Hulsman, 1977; Ricklefs & White, 1981; Nicholson, 2002). In seabirds whose chicks are fed by parents, variation in the growth rate is resulted primarily from variation in quality and characteristics of the parents (Furness, 1983; Nisbet *et al.*, 1995). Also, differences in the growth of chicks reflect variations in the use of available resources within an area. It is accepted that the growth rate matches the rate at which parents are able to provide food for their growing chicks. If food is not available in enough quantity, chicks may grow poorly or starve to death (Ricklefs *et al.*, 1987).

The hypothesis that the growth rate represents an optimum balance between the selection for low rates of energy requirements and short development time predicting that the variation in the growth rate between species should be related to the predation rate and the pattern of energy consumption (Ricklefs, 1979). Features of breeding indicated by seabirds may be considered as anti-predator and other adaptations (Hulsman & Langham, 1985; Lima, 2009).

Uninhabited offshore islands in the Persian Gulf support many thousands of nesting seabirds (Scott 2007, Tayefeh *et al*. 2011, 2013). The selected species for this study were the semi-precocial Bridled Tern *Sterna anaethetus*, the precocial Lesser Crested Tern *Sterna bengalensis* and the precocial Greater Crested Tern *Sterna bergii* as the three most abundant sympatric seabird species on Nakhilu Island, the northern Persian Gulf, Iran. In 2010 and 2011, the population of these species was 21,000–23,000 pairs Lesser Crested Tern, followed by 17,000–19,000 pairs Bridled Tern, while the Greater Crested Tern had the smallest breeding population of 2,400–2,500 pairs (Tayefeh *et al*. 2011, 2013).

Investigation on growth patterns of the Bridled Tern chicks have been studied by Hulsman & Langham (1985) on One Tree Island in Queensland, Australia. This study showed that Bridled Terns have a prolonged period of growth compared with that of other tern species of their similar body size. This finding was confirmed by Nicholson (2002). Villard and Bretagnolle (2010) have also found that chicks reached their asymptotic weight (132 g) at 37 days and the wing length was the most reliable predictor of the chick age. Patterns of growth in Lesser and Greater Crested Terns was studied by Nicholson (2002), although the first investigation on the breeding biology of the Greater Crested Tern was published by Langham and Hulsman (1986).

No information has been published on the chick growth patterns of the seabirds in the Persian Gulf. The main objective of this research was to study chick growth patterns of the Bridled Tern, Lesser Crested Tern and Greater Crested Tern on Nakhilu Island, the northern Persian Gulf, Iran. However, the specific objectives were: 1) to describe the chick growth patterns in tern species breeding in colonies syntopically, 2) to compare the chick growth rate of tern species with each other, and 3) to investigate factors affecting on the chick growth of these species during the 2009–2011 breeding seasons. The comparison of species breeding sympatrically provides valuable information that can address key questions about breeding strategies of colonial seabirds in subtropical regions.

2. Methods

2.1. Study Area

Nakhilu Island (27° 49' N, 51° 28' E) is located at a distance of 72 miles (133 km) from Bushehr city, south of Iran (Fig. 1). The island is located in the south-eastern of Tahmadon Island and south-western of Omol-Karam Island with about 1.4 and 4.3 miles distance, respectively. The island area is measured about 35 ha, which reaches to 34.2 and 36.2 ha during the low and high tides, respectively. The highest point of the island is about 3 m

higher than the sea level. The main vegetation of Nakhilu included *Atriplex* which often grows in sparse to dense masses. Three types of vegetation, however, occur on Nakhilu; 1) *Atriplex leucoclada*, 2) *Cyperus conglomeratus-Halopyrum mucronatum* that occur in the sandy hills together with *Scrophularia sp*., *Cicer sp*. and *Heliotropium sp*., and 3) *Arthrocnemum macrostachyum* that occurs seasonally in the east of this island. The fauna of Nakhilu includes abundant *Ratus ratus*, reptiles such as *Chalcides occellatus* and *Cyrtopodion scabrum* and sea turtles. The island is basically originated from clash of the sea bed ruggedness and the sediments of the Mond River. Nakhilu Island is uninhabited and is only used as resting areas for the local fishermen and as shelter during seasonal storms.

2.2. Chick growth

Field trips for data collection during the chick rearing phases of breeding took place from June to August of 2010 and 2011. Data on the length and weight were collected for chicks in 1-week age class such that newly chicks reported as aged 1-day old and week 1 reports averages for birds 8±3 days old, week 2 for chicks 15±3, etc (Keitt *et al.*, 2003). Data were collected for the Bridled Tern from breeding sites with 5%–50% vegetation cover during the hatching and chick rearing periods (June–July) of 2010 and 2011. In the vegetated areas, chicks rarely left their nests till they were able to fly. The reason why the study was done only in the afore mentioned type of habitats with that particular vegetation density was due to the following behavior of chicks; 1) In 2009, it was observed that in the area with less than 5% cover, chicks left nests earlier than other sites, in order to find safe places to hide from predators and to shelter for protection from the sunlight. This finding was in line with the findings of Villard and Bretagnolle (2010); 2) Marked chicks were hard to find in the areas with more than 50% vegetation cover as chicks moved in tunnels under the vegetation (Hulsman & Langham, 1985).

From 12 to 14 June 2010 and 20 to 22 June 2011, nests of Bridled Terns were checked and newly hatched chicks were selected in our marked nests. Chicks were marked using numbered plastic colored leg bands in the first catch, then weighed and measured. Weighing and measuring took place in a weekly basis yet. From the third week onwards chicks were bounded with numbered metal rings which allowed the recognition of individual chicks. To obtain the required number of chicks, the marked chicks were weighed and measured along with some other chicks that were assumed to be in the same age as marked ones based on their similarities to the known age chick features. Foraging is apparently mostly diurnal, with an occasional feeding which takes place shortly after the sunset (Hulsman & Langham, 1985; Garavanta & Wooller, 2000; Nicholson, 2002). In order to prevent the regurgitation of food, chick measurements took place in the early morning immediately after the dawn when parents left their nests to foraging areas while there was enough light to find chicks under the vegetation.

To estimate the growth rate of the Lesser and Greater Crested Terns chicks, data were collected simultaneously, as they nested together within the same colony. Measurements took place at midnight to minimize overheating effects on chicks and the prevention of food regurgitation as they were fed mostly during daylight and before dusk (Langham & Hulsman, 1986; Nicholson, 2002). Weekly measurements began from 16–17 June 2010 and 20–22 June 2011 on Nakhilu Island. The Lesser and Greater Crested Terns chicks hatch synchronously so; it was possible to find a group of same-age chicks to monitor their growth.

Up to 100 newly chicks of each species at their first day of age were banded using numbered plastic colored leg bands, then weighed and measured. Banding of chicks continued during the data collection using metal rings. Finding banded chicks in the limited area of the Nakhilu Island was considered as an advantage for the researcher to find the marked chicks. Chicks in the crèche were corralled and captured; as each chick was measured

it was assigned to a chick category based on its feather development and similarity with the known age chicks (marked chicks).

Moreover, to compare the growth of chicks and adult sizes, morphological characters and the weight of adults were measured during the early incubation period due to the loss of mass by breeding birds, observed especially during the nestling period (Chastel *et al.*, 1995). Bridled Terns were captured at their nest during the night due to the ease of capturing them in the dense vegetation area within bushes. Lesser and Greater Crested Terns were captured at their colony during the night hours. The capture device was consisted of a set of two nylon mist-net suspended between three poles next to each other at 45 degrees. Net dimensions were approximately 2 m high by 20 m long while, the bottom of the net was placed on the ground. Some studies demonstrated that body condition must be calculated separately for male and female because pooling the sexes produces significant intra- and inter-sexual bias (Williams *et al.*, 2007). However in this study, it was not possible to determine the sexes based on morphology (Cramp *et al.*, 1985).

Adults of all species were weighed (±0.1g) with a digital electronic weighing balance. Birds were placed in cloth bags for weighing. The weight of the bag was measured after each use and subtracted from the gross weight (bird + bag) to obtain the bird weight (gross weight – bag weight = bird weight). The balance was placed in a box in order to reduce the effect of wind (Ricklefs, 1979).

The length of inner tarsus (the length of the tarsometatarsal bone, measured from the angle of the foot bent to 90 degrees to the notch of the intertarsal joint), bill length (bill tip to feathering at base of bill), head to bill (the distance between the back of the skull and the tip of the bill) of chicks of all four species were measured (±0.01mm) with digital calipers. Their tail (defined as the distance from the base to the tip of the longest tail feathers) and wing chord length (distance from the carpal joint to the tip of the longest primary on the closed wing) were measured (±1mm) using a stopped stainless-steel ruler (Rising & Somers, 1989; Gosler, 2004; Goodenough *et al.*, 2010).

2.3. Data analysis

In this study, due to mobility of Lesser Crested Tern and Greater Crested Tern chicks and impossiblity of catching all Bridled Tern marked chicks in the following weeks, the growth rate of these species could not be described by repeated measurements of the same individuals. Instead, an indication of the growth rate for each species was determined by graphing weight and linear measurements. Although, a logistic model of growth has been found to provide the best descriptions of Bridled Tern chicks (Langham, 1983; Hulsman & Langham, 1985; Garavanta & Wooller, 2000; Nicholson, 2002; Villard & Bretagnolle, 2010), due to the dense vegetation and difficulty of finding some Bridled Tern chicks, it was not possible to fit data from each chick to a complete growth curves. Following ANOVA, the *post hoc* multiple comparisons by Tukey (HSD) were used to compare values between chick categories. For the growth rate of chicks of studied species the normality of the data was tested by Skewness-Kurtosis, Kolmogorov-Smirnov and Shapiro-Wilk tests. Outliers were searched for by checking box plots and Mahalanobis distances (Tabachnick & Fidell, 2007) and outliers data of each parameters were removed. All statistical analysis was performed using the SPSS 16.0.1 software (SPSS Inc., Chicago) with the α-level set at 0.05. All values reported are means±SE.

3. Results

3.1. Bridled Tern

The mean (±SE) linear dimensions and body weight of Bridled Tern chicks grouped in age categories (classified as newborn, 1, 2, 3, 4, 5, 6, 7, 8 weeks with ±3-day intervals and adults)

measured on Nakhilu Island (combined data of 2010 and 2011 are shown in Table 1). The *post hoc* multiple comparisons by Tukey (HSD) indicated that the body weight of chicks increased by 5th week. There was no significant difference in the body weight between 5, 6, 7 and 8 weeks old chicks and adults ($p>0.05$). The time taken to reach the half of the adult body weight was two weeks, which is at least six weeks prior to the fledging. Chicks had their most rapid period of weight gain in their first and second weeks of the development, beginning at 14 g and increasing up to 27 g in the first week and 54 g in the second weeks. The highest weight recorded was 127.2 g for chicks 8 weeks old, heavier than the highest adult weight recorded (125 g, Fig. 2). About 18% of chicks (45 of a total of 246) were heavier than the mean adult weight (104.8 g, Table 1).

There was no significant differences in the wing length between newborn and one week old chicks ($p>0.05$). However, the length of wings significantly increased from the second week up to the fledging. The mean wing length for 8th week chicks was 218.3 mm, which is 86% of the adult wing length (255.7 mm, Table 1). The longest wing recorded was 247 mm and belonged to a chick in its 8th weeks, more than 10% of adult wing recorded (5 adults of a total of 51, Fig. 2). The half adult wing length was attained between weeks 5 and 6.

The tail began from the third week of hatching and continued until the fledging. The mean tail length for 8 weeks old chicks was 106.4 mm, which is 66% of the mean adult tail length (164.6 mm, Table 1). The half adult tail length was attained approximately 7 weeks after hatching. The longest tail was recorded 118 mm and belonged to a chick in the week 8 (Fig. 2), 16% shorter than the longest adult tail recorded (141 mm, Fig. 2). The inner tarsus length increased significantly from newborn to the 4th week of the development. There were no significant differences between the inner tarsus length of chicks in weeks 4, 5, 6, 7, 8 and adults ($p>0.05$). At least 16% ($n=47$) of chicks had longer tarsus compared to the mean adult tarsus length (22.1 mm, Table 1).

The bill length and head to bill length of the Bridled Tern chicks increased significantly in all chick categories and in comparison to adults (Table 1). The mean bill length for week 8 of chicks was 33.54 mm, which is 80% of the adult bill length (42.1 mm, Table 1). The longest chick bill length of 37.3 mm was recorded in its 8th week (Fig. 2). The half adult bill length was attained in the 3rd week after hatching. The mean head to bill length for week 8 chicks was 70.14 mm, which is 85% of the adult head to bill length (82.41 mm, Table 1). The longest chick head to bill length of 73.3 mm was recorded at the age of 8 weeks (Fig. 2), it was approximately the same size of the shortest adult head to bill recorded (73.9 mm, Fig. 2).

3.2. Lesser Crested Tern

The mean (±SE) linear dimensions and the body weight of Lesser Crested Tern chicks grouped in age categories (classified as newborn, 1, 2, 3, 4, 5, 6, 7, 8 weeks with ±3-day intervals and adults) measured on Nakhilu Island (combined data of 2010 and 2011 are shown in Table 2). The body weight of chicks increased from newborn to 5th week of age ($p<0.01$), but there was no significant difference in the body weight between 5 and 6 weeks old chicks ($p>0.05$). The most rapid period of weight gain was in their first and second weeks of the development, beginning at 24 g and increasing up to 44 g in the first week and 62 g in the second week after hatching (Fig. 3). The time taken to reach the half adult weight was three weeks, which is 21–28 days prior to the fledging. The highest body weight was recorded for chicks of 6 weeks (197.1 g, Fig. 3), higher than the mean adult body weight (188.5 g, Table 2).

The data analysis indicated that the wing length significantly increased in all chick categories and adults. The longest wing length for the Lesser Crested tern chicks recorded was 216 mm and belonged to chicks 6 weeks old (Fig. 3), smaller than the mean adult wing length (300.9 mm, Table 2). The half adult wing length attained between weeks 5 and 6. The

mean bill length for chicks of week 6 was 36 mm, which is 69% of the adult bill length (52 mm, Table 2).

There was no significant differences in the tail length of newborn, first and second weeks ($p>0.05$), the tail began to grow from the third week after hatching and continued until the fledging. The longest tail recorded was 89 mm and belonged to six weeks old chicks (Fig. 3), smaller than the mean adult tail length (141.2 mm, Table 2). The half adult tail length attained in 6th week, which is the week prior to the fledging. The inner tarsus length significantly increased from hatching to 3rd week of the development. There were no significant differences between the inner tarsus length of chicks in weeks 4, 5, 6 and adults ($p>0.05$). The tarsus length for chicks of week 6 was 26.32 mm, which is the same of adult tarsus (26.23 mm, Table 2). Some 23% of the chicks had longer tarsus compared to the mean adult tarsus length while the longest tarsus recorded was 28.81 mm and belonged to chicks of 6 weeks old (Fig. 3). The tarsus of newborn was longer than the half adult tarsus length.

Our results showed that the bill length and head to bill length increased significantly from hatching to 6 weeks old chicks. The longest chick bill length of 39.69 mm was recorded at the age of 6 weeks (Fig. 3). The mean head to bill length for week 6 was 79 mm, which is 80% of the adult head to bill length (98 mm, Table 2). The longest chick head to bill length of 83.54 mm was recorded at the age of 6 weeks (Fig. 3). The half adult bill length attained between weeks 2 and 3 but it was one week for the half adult head to bill length (Fig. 3).

3.3. Greater Crested Tern

The mean (±SE) linear dimensions and the body weight of Greater Crested Tern chicks grouped in age categories (classified as newborn, 1, 2, 3, 4, 5, 6, 7, 8 weeks with ±3-days intervals and adults) measured on Nakhilu Island (combined data of 2010 and 2011 are shown in Table 3). The *post hoc* multiple comparisons by Tukey (HSD) indicated that the body weight of chicks increased from newborn by 5th week ($p<0.01$). There was no significant difference between the body weight of 5 and 6 weeks old chicks ($p>0.05$). The body weight of adults and chicks was almost the same in 6th week ($p>0.05$) and slightly heavier than 5 weeks old chicks ($p<0.05$). The time taken to reach the half adult body weight was three weeks, which is 21–28 days prior to the fledging. The Greater Crested Tern chicks had their most rapid period of weight gain in their first and second weeks of the development, beginning at 39 g and increasing up to 71 g in the first week and 116 g in the second weeks (Fig. 4). The highest body weight recorded was 375 g for chicks of 6 weeks old, heavier than the mean adult weight (342.6 g, Table 3).

There was no significant differences in the wing length between the newborn and one week old chicks ($p>0.05$) and first week old ones compared to second week old chicks ($p>0.05$). The length of wings significantly increased from second week up to the fledging. The mean wing length for 6 weeks chicks was 239.85 mm, which is 62% of the adult wing length (385 mm, Table 3). The longest wing was recorded 292 mm and belonged to a chick in its 6th week of age (Fig. 4). The half adult wing length attained between weeks 5 and 6. Moreover, the growth of tail was diagnosed from 4th week of the development and it does not attain its full size until weeks after the fledging. The mean tail length for 6 weeks chicks was 87.95 mm, which is 47% of the adult tail length (184 mm, Table 3). The longest wing was recorded 124 mm and belonged to a chick in its 6th week of age (Fig. 4).

The inner tarsus length increased significantly from newborn chicks to 4th week of the development ($p<0.01$). The most rapid period of length gain for tarsus was in the first and second week of the development while it was 25 mm for chicks of 1 week old and 29 mm for 2 weeks old ones (Fig. 4), equivalent to 66% and 76% of the mean adult tarsus length (38.25 mm), respectively. There were no significant differences between the inner tarsus length of chicks in weeks 4, 5 and 6 of age. The tarsus length of adults was significantly longer than all

chick categories ($p<0.01$). The longest tarsus recorded was 35.55 mm, which was longer than the mean tarsus length of chicks of six weeks old (34.14 mm) and shorter than the adults tarsus length (38.25 mm, Table 3).

The bill length and head to bill length of the Greater Crested Tern chicks increased significantly in all chick categories and in comparison to adults. The mean bill length for six weeks old chicks was 46.34 mm, which is 66% of the adult bill length (69.92 mm, Table 3). The longest chick bill length of 51.34 mm was recorded at the age of 6 weeks (Fig. 4). The half adult bill length attained four weeks after hatching. The mean head to bill length for chicks of week 6 was 98.14 mm, which is 77% of the adult head to bill length (127.62 mm, Table 3). The longest chick head to bill length of 106.2 mm was recorded at the age of 6 weeks (Fig. 4). The half adult bill length attained immediately after second week of hatching.

4. Discussions

This study compared chick growth patterns between three breeding tern species to determine the different effects of prolonged growth period of Bridle Terns and the rapid growth period of Lesser Crested Terns and Greater Crested Terns. The weight growth described in this study for the Bridled Tern (a peak of approximately 100 g attained at 35 days old) showed different results from the previous studies. The age at which chicks attained peak weight varies in the literature; on the Great Barrier Reef, off north-eastern Australia, an asymptotic weight of 128 g was reached 40 days after hatching (Hulsman & Langham, 1985), on Penguin Island, off south-western Australia, an asymptotic weight of 120 g was reached 53 days after hatching (Garavanta & Wooller, 2000), at the Lowendal Island, western Australia, an asymptotic weight of 117 g was reached at 42 days in 1998 and 112 g at 43 days in 1999 (Nicholson, 2002) and in New Caledonia, eastern Australia, an asymptotic weight of 132 g was reached 37 days after hatching (Villard & Bretagnolle, 2010).

This study showed that chicks reached to their half peak weight when they were 2 weeks old, similar to the results of the Great Barrier Reef and Penguin Island (Hulsman & Langham, 1985; Garavanta & Wooller, 2000) and 3–5 days later than that of Lowendal Island (Nicholson, 2002) and New Caledonia (Villard & Bretagnolle, 2010). This variation may relate to the finding of Garavanta and Wooller (2000) who suggested the growth rates of Bridled Tern chicks are negatively correlated with the distance to feeding sites. In accordance with previous studies (Langham, 1983; Nicholson, 2002), the time taken to reach the half adult weight for Lesser and Greater Crested Terns was 21 days, which is 21–28 days prior to the fledging. Their chicks had most rapid period of gaining weight in their first and second weeks of the development.

The average ratio of the fledging weight to the adult weight were calculated 1.01 (Table 1), 0.85 (Table 2) and 0.96 (Table 3) for the Bridled Tern, Lesser Crested Tern and Greater Crested Terns, respectively. This ratio is similar to the range of 0.60–1.84 measured in 94 species of birds (Ricklefs, 1968b). The ratio for the Lesser and Greater Crested Terns, lower compared with the Bridled Tern, is expected when the life history has evolved under selective pressures to minimize the age at the fledging time. This can be happened in the case of heavy predation, high parasite load, or starvation during the chick phase (Miller, 2010). The most likely explanation for the low weight at the fledging is severe food limitation during the later part of the breeding season due to colonial life, which forces chicks to allocate the limited food for the growth of the body parts (wings and tail) most vital for leaving the colony as soon as possible.

Most interesting was the different growth speed of characters. The Growth of the wing and tail lengths was slow initially among these three tern species. When fledging, the wing and tail lengths of Bridled Tern chicks reached up to 70% and 64% of the adults, respectively. The wing and tail lengths of the Greater and Lesser Crested Terns remained

incomplete at the fledging time (Nicholson, 2002). In all the studied species, the growth of the tarsus length was more rapid, with chicks reaching to the length of the fledglings in the early of their development. Among the three studied species, the Bridled Tern had the lowest growth of the tarsus length in our study. The development of feet in Lesser and Greater Crested Terns compared with Bridled Tern chicks would facilitate the avoidance against predators, as well as being able to move quickly towards the parents when called to feed (Nicholson, 2002).

The bill and head to bill lengths are highly correlated with each other (De Marchi *et al.*, 2012). Bridled Tern young close to the fledging time had a bill length of up to 80% of the adult size while Lesser and Greater Crested Terns close to the fledging time had shorter bill length compared with their adults. It would seem that among the three tern species studied, those which grow more quickly and fledge earlier would reach the lower proportion of the adult size. Indeed, the fact that the bill length did not reach a peak suggests that the growth of the bill continues after the fledging. This might not be a problem because chicks are singletons and do not have to compete with siblings, a situation that favors larger bills (Gil *et al*. 2008). Moreover, unlike most seabird chicks (Colwell 2010), they are not forced to feed by themselves, as they are fed by their parents and probably do not require a fully developed bill until well after they fledge. Even when the chicks have fledged, the parents continue to feed them for several months (Powell *et al.* (2007).

The growth patterns of Bridled Tern chicks could be a function of longer periods between the hatching and the fledging than in the Greater and Lesser Crested Terns, as well as a requirement for survival in more sheltered environment than open areas (Hulsman & Langham, 1985). There are some features in the breeding biology of the Bridled Tern that could affect the vulnerability of eggs and chicks to predation. Most of the Bridled Tern nests were under cover, which prevents aerial predators from taking eggs or chicks (Hulsman & Langham, 1985; Villard & Bretagnolle, 2010). There are active behavioral features such as evasive tactics by chicks, defense of nest by parents and defaecating away from nests (Hulsman & Langham, 1985). The results showed that it takes about eight weeks from the hatching to the fledging for the Bridled Tern while it was recorded six weeks for the Lesser and Greater Crested Terns. This result accords with the hypothesis that the growth rate represents an optimum balance between the selection for low rates of energy requirements and short development time. This hypothesis would predict that variation in the growth rate between species should be related to the predation rate and patterns of energy consumption (Ricklefs, 1979). Additional studies of the chick growth at different colonies in other parts of the breeding range could confirm if such growth patterns is typical of the species or an occasional morphological plasticity in response to uncommon food shortages.

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Table 1. Measurements of weekly intervals for weight (g), wing length, tail, tarsus, bill and head to bill (mm) of Bridled Terns chicks on Nakhilu Island. Data for 2010 and 2011 combined. The bottom row, adult birds, presence data from birds caught at night during the study period in the colony during the incubation phase. Statistics are reported for comparisons between each chick categories using the *post hoc* multiple comparisons by Tukey (HSD) of ANOVA. Values are given as mean±SE.

Age (weeks)	N	Body weight (g)	Wing Length (mm)	Tail (mm)	Tarsus (mm)	Bill Length (mm)	Head to Bill (mm)
Newborn	28	$14.22\pm0.26_{a}$	$17.93\pm0.24_{a}$	$0.00\pm0.00_{a}$	$13.83\pm0.15_{a}$	$12.20\pm0.16_{a}$	$33.48\pm0.21_{a}$
1	27	$27.02\pm0.66_{b}$	$20.81\pm0.50_{a}$	$0.00\pm0.00_{a}$	$17.80\pm0.11_{b}$	$14.43\pm0.22_{b}$	$39.35\pm0.65_{b}$
2	24	$54.21\pm1.12_{c}$	$31.17\pm0.80_{b}$	$1.42\pm0.52_{a}$	$19.29\pm0.18_{c}$	$19.68\pm0.21_{c}$	$49.04\pm0.35_{c}$
3	28	$69.23\pm1.58_{d}$	$41.07\pm2.77_{c}$	$14.93\pm0.68_{b}$	$20.24\pm0.20_{d}$	$21.28\pm0.19_{d}$	$51.41\pm0.64_{d}$
4	25	$89.65\pm1.69_{e}$	$84.44\pm2.42_{d}$	$26.36\pm1.51_{c}$	$21.51\pm0.11_{e}$	$24.07\pm0.17_{e}$	$56.86\pm0.39_{e}$
5	31	$99.67\pm1.98_{f}$	$118.58\pm1.93_{e}$	$44.52\pm1.03_{d}$	$21.60\pm0.10_{e}$	$26.19\pm0.20_{f}$	$61.33\pm0.23_{f}$
6	29	$102.23\pm1.64_{f}$	$154.62\pm2.88_{f}$	$66.76\pm1.81_{e}$	$21.67\pm0.12_{e}$	29.26±0.22g	$63.74\pm0.36_{g}$
7	24	$101.14\pm1.22_{f}$	$185.62\pm3.23_{g}$	$85.42\pm1.85_{f}$	$21.86\pm0.18_{e}$	$31.30\pm0.24_{h}$	$66.43\pm0.60_{h}$
8	30	$105.88\pm1.41_{f}$	$218.30\pm2.30_{h}$	$106.40\pm1.15_{g}$	$21.92\pm0.16_{e}$	$33.54\pm0.26_{i}$	$70.41\pm0.30_{i}$
Adult	**51**	$\mathbf{104.83\pm1.36_{f}}$	$\mathbf{255.69\pm0.91_{i}}$	$\mathbf{164.57\pm1.52_{h}}$	$\mathbf{22.10\pm0.10_{e}}$	$\mathbf{42.09\pm0.23_{j}}$	$\mathbf{82.41\pm0.61_{j}}$

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. Measurements of weekly intervals for weight (g), wing length, tail, tarsus, bill and head to bill (mm) of Lesser Crested Tern on Nakhilu Island. Data for 2010 and 2011 combined. The bottom row, adult birds, presence data from birds caught at night during the study period in the colony during the incubation phase. Statistics are reported for comparisons between each chick categories using the *post hoc* multiple comparisons by Tukey (HSD) of ANOVA. Values are given as mean±SE

Age (weeks)	N	Body weight (g)	Wing Length (mm)	Tail (mm)	Inner Tarsus (mm)	Bill Length (mm)	Head to Bill (mm)
Newborn	43	$24.00\pm0.37_{a}$	$18.09\pm0.39_{a}$	$0.00\pm0.00_{a}$	$14.65\pm0.34_{a}$	$13.02\pm0.12_{a}$	$37.50\pm0.19_{a}$
1	29	$44.88\pm1.45_{b}$	$26.07\pm0.63_{b}$	$0.00\pm0.00_{a}$	$20.61\pm0.30_{b}$	$17.65\pm0.25_{b}$	$48.64\pm0.70_{b}$
2	24	$62.97\pm2.48_{c}$	$35.21\pm1.48_{c}$	$0.00\pm0.00_{a}$	$23.23\pm0.23_{c}$	$20.94\pm0.35_{c}$	$55.95\pm0.71_{c}$
3	19	$84.98\pm2.70_{d}$	$60.68\pm2.19_{d}$	$8.74\pm0.68_{b}$	$24.76\pm0.25_{d}$	$23.87\pm0.39_{d}$	$62.34\pm0.76_{d}$
4	21	$120.88\pm3.51_{e}$	$98.86\pm4.28_{e}$	$24.19\pm1.65_{c}$	$26.07\pm0.18_{e}$	$27.40\pm0.46_{e}$	$67.93\pm0.94_{e}$
5	26	$151.96\pm1.84_{f}$	$135.88\pm2.04_{f}$	$42.85\pm1.24_{d}$	$26.36\pm0.12_{e}$	$31.27\pm0.34_{f}$	$73.58\pm0.29_{f}$
6	48	$159.83\pm1.88_{f}$	$189.33\pm1.75_{g}$	$72.06\pm1.15_{e}$	$26.32\pm0.12_{e}$	$36.22\pm0.20_{g}$	$79.86\pm0.26_{g}$
Adult	**32**	$\mathbf{188.51\pm3.92_{g}}$	$\mathbf{300.94\pm1.4_{h}}$	$\mathbf{141.19\pm1.24_{f}}$	$\mathbf{26.23\pm0.10_{e}}$	$\mathbf{52.89\pm0.35_{h}}$	$\mathbf{98.45\pm0.44_{h}}$

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. Measurements of weekly intervals for weight (g), wing length, tail, tarsus, bill and head to bill (mm) of Greater Crested Terns chicks on Nakhilu Island. Data for 2010 and 2011 combined. The bottom row, adult birds, presence data from birds caught at night during the study period in the colony during the incubation phase. Statistics are reported for comparisons between each chick categories using the *post hoc* multiple comparisons by Tukey (HSD) of ANOVA. Values are given as mean±SE.

Age (weeks)	N	Body weight (g)	Wing Length (mm)	Tail (mm)	Tarsus (mm)	Bill Length (mm)	Head to Bill (mm)
Newborn	22	$39.43\pm0.49_{a}$	$25.18\pm0.35_{a}$	$0.00\pm0.00_{a}$	$18.71\pm0.18_{a}$	$16.24\pm0.19_{a}$	$45.04\pm0.37_{a}$
1	29	$71.86\pm2.14_{b}$	$30.69\pm0.49_{a,b}$	$0.00\pm0.00_{a}$	$25.31\pm0.33_{b}$	$20.16\pm0.26_{b}$	$56.34\pm0.51_{b}$
2	14	$116.14\pm4.54_{c}$	$41.57\pm0.60_{b}$	$0.00\pm0.00_{a}$	$29.05\pm0.36_{c}$	$24.65\pm0.42_{c}$	$63.81\pm0.54_{c}$
3	18	$171.49\pm8.12_{d}$	$64.83\pm3.11_{c}$	$5.39\pm1.23_{a}$	$31.67\pm0.29_{d}$	$29.15\pm0.44_{d}$	$73.70\pm0.69_{d}$
4	18	$243.56\pm4.83_{e}$	$107.50\pm4.18_{d}$	$21.89\pm1.61_{b}$	$33.57\pm0.24_{e}$	$34.80\pm0.53_{e}$	$79.26\pm1.41_{e}$
5	20	$306.44\pm6.60_{f}$	$171.85\pm2.94_{e}$	$48.20\pm1.68_{c}$	$33.82\pm0.23_{e}$	$40.53\pm0.42_{f}$	$91.70\pm0.85_{f}$
6	20	$327.87\pm6.40_{f,g}$	$239.85\pm5.22_{f}$	$87.95\pm3.00_{d}$	$34.14\pm0.33_{e}$	$46.34\pm0.55_{g}$	$98.14\pm1.52_{g}$
Adult	**9**	$\mathbf{342.59\pm8.42_{g}}$	$\mathbf{385.00\pm6.84_{g}}$	$\mathbf{184.67\pm3.17_{e}}$	$\mathbf{38.25\pm0.55_{f}}$	$\mathbf{69.92\pm0.53_{h}}$	$\mathbf{127.62\pm1.58_{h}}$

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).

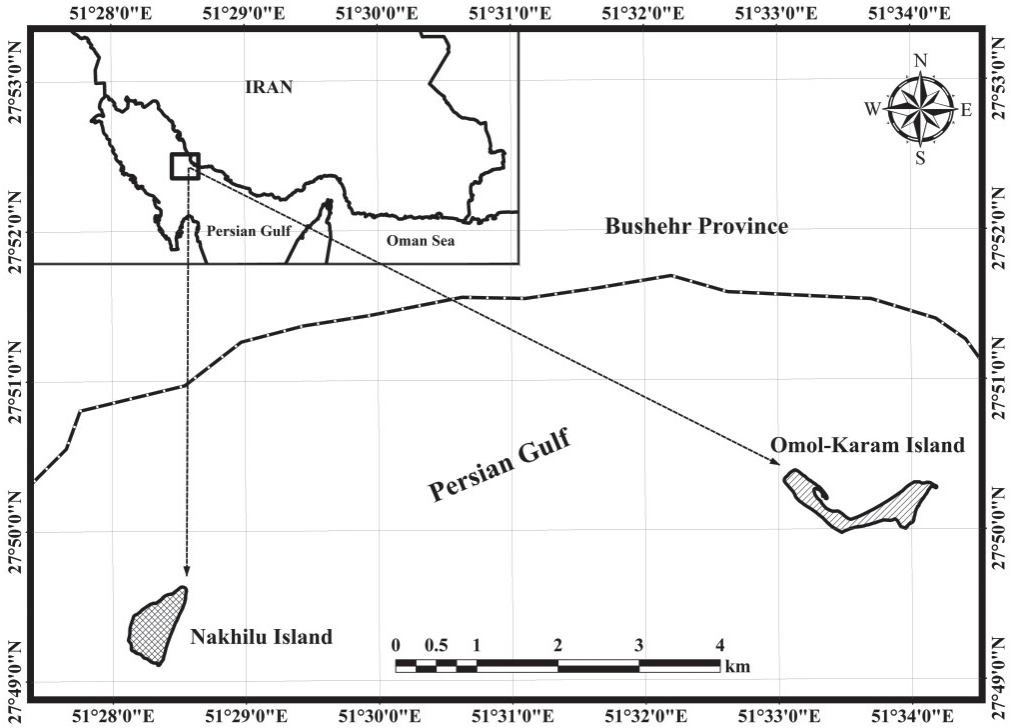

Figure 1. Map of the northern Persian Gulf showing Nakhilu Island, Iran, where the growth patterns of the Bridled, Lesser Crested and Greater Crested terns were studied.

Figure 2. Growth of Bridled Tern body weight, wing length, tail, tarsus, bill and bill + head for each category on Nakhilu Island in 2010 and 2011 combined. Notes: a box represented the interquartile range; a line across the box indicates the median; bars (whiskers) extend from the box to the highest and lowest values; outliers (circle) are illustrated as well.

Figure 3. Growth of Lesser Crested Tern body weight, wing length, tail, tarsus, bill and bill + head for each category on Nakhilu Island in 2010 and 2011 combined. Notes: a box represented the interquartile range; a line across the box indicates the median; bars (whiskers) extend from the box to the highest and lowest values; outliers (circle) are illustrated as well.

Chick age (weeks)

Figure 4. Growth of Greater Crested Tern body weight, wing length, tail, tarsus, bill and bill + head for each category on Nakhilu Island in 2010 and 2011 combined. Notes: a box represented the interquartile range; a line across the box indicates the median; bars (whiskers) extend from the box to the highest and lowest values; outliers (circle) are illustrated as well.