Reproductive Performance of the Socotra Cormorant *Phalacrocorax nigrogularis* on Siniya Island, United Arab Emirates: Planted Trees Increase Hatching Success

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**Abstract.**—The Socotra Cormorant *Phalacrocorax nigrogularis* is a little studied, regional endemic seabird restricted to the Arabian Gulf region threatened by anthropogenic disturbance. The global population is estimated at 110,000 breeding pairs. The Siniya Island colony, the largest in the United Arab Emirates (~15,500 breeding pairs), was studied during the 2011 breeding season to determine baseline reproductive parameters and the effect of exotic trees on reproductive performance. Mean nesting density was 0.92 nests/m² and shaded areas had significantly higher density (1.05/m²) compared to unshaded areas (0.75/m²). Mean clutch size was 2.4 eggs/nest and did not differ between shaded and unshaded areas. Mean egg volume was significantly higher in shaded (49.56 cm³) compared to unshaded areas (48.5 cm³). Hatching success was significantly higher in shaded (65.1%) compared to unshaded areas (46.6%). Fledging success was 65.6% and did not differ between shaded and unshaded areas. Chicks creched under trees soon after leaving their nests and this likely increased fledging success, regardless of whether chicks came from shaded or unshaded areas. Overall reproductive success was 1.7 chicks/nest. Higher egg volumes and hatching success under shaded areas suggest that plantations had a beneficial effect on the cormorants on Siniya Island and could be of conservation value. Further studies are required to determine what habitat features linked with these trees specifically aid in enhancing reproductive performance. Received 3 April 2012, accepted 30 July 2012.

**Key words.**—breeding success, fledging success, hatching success, *Phalacrocorax nigrogularis*, reproductive performance, reproductive success, Socotra Cormorant.

The Arabian Gulf is a shallow marine ecosystem with high salinity (Sheppard 1993), high temperatures and rapid water turnover (Kampf and Sadrinasab 2006). Many offshore islands within this harsh environment serve as breeding colonies for seabirds that are threatened by disturbance, construction and oilrig installations (Gardner and Howarth 2009; Aspinal 2010; Jennings 2010). The Socotra Cormorant is a regionally endemic seabird restricted to the Arabian Gulf and Gulf of Oman (BirdLife International 2010; Jennings 2010). All known subpopulations are declining and the global population is estimated at 110,000 breeding pairs (Jennings 2010). Breeding biology, habitat characteristics and ecology of this species are poorly studied. Many colonies have become extinct and the species is currently categorized as ‘Vulnerable’ (BirdLife International 2010). Approximately 34% of the global population breeds in the United Arab Emirates (Aspinal 1995; Nelson 2005; Jennings 2010) and breeding activity is limited to eleven colonies (Jennings 2010).

Socotra Cormorants nest on flat islands with sandy-gravel substrates that lack vegetation (Aspinal 1995; BirdLife International 2010) with colonies typically having thousands of individuals (Jennings 2010). Breeding may take place from September to mid-March and 2-3 eggs are laid directly on the gravel, ledges or among boulders (Aspinal 1995; King 2004; Jennings 2010). Nesting density can be high with individual nests touching one another. Many offshore islands have been planted with non-native trees including *Acacia* spp. and *Prosopis juliflora* in the early 1980s. Many seabirds prefer to nest under vegetation cover to avoid predation or inclement weather (Yorio et al. 1995; Olsson et al. 2001; Catry et al. 2003; Pattern et al. 2005). Exposure to high temperature may influence avian incubation behavior, which in turn may affect reproductive performance (Woinarski 1973; Conway and Martin 1999; Yasue and Dearden 2006). Selection of shaded nesting sites in arid environments, where temperatures frequently exceed 45°C, could potentially increase nesting success (Yorio 1995) and prevent mortality of embryos in exposed clutches (Yasue and Dearden 2006).
One island with planted exotic trees, located in Umm Al Quwain, UAE, has been historically used by Socotra Cormorants as a breeding colony (Jennings 2010). Socotra Cormorants continue to breed on this island both under trees and on open, gravel plains affording the opportunity to examine the effects of tree cover on reproductive performance.

The objectives of this study were to 1) quantify nesting density and reproductive performance and 2) determine the impact of tree cover on the reproductive performance of the Socotra Cormorant to better understand the effects of anthropogenic modification of the nesting habitat on the species.

**Methods**

**Study Site**

Siniya Island (25°36'20.63"N 55°36'28.85"E) hosts the largest breeding population of Socotra Cormorants in UAE, estimated at 15,500 b.p. (Fig. 1) The island is surrounded by shallow water areas and sediment deposits. The colony of cormorants is restricted to the north-central part of the island. The habitat consists of mixed desert scrub or gravel and plantations of Acacia spp. and *Prosopis juliflora*. Mangroves *Avicennia marina*, occur in patches, and *Haloxylon-Arthrocnemum macrostachyum* scrub complex borders the periphery of the island.

A study was conducted from September to December 2011. Fourteen 5 m by 5 m plots were chosen in unshaded or shaded (under tree) areas. Plots were selected based on ease of vision, location relative to the colony and access to study plots with the least disturbance to individuals. On the first visit, plots were marked with markers on prominent features such as large rocks, tree stumps and trees. Egg measurements (maximum length, maximum breadth) were then taken from 5-10 randomly chosen nests in each plot. Photographs of each plot were taken from a distance of 5 m with a Canon 40D with 70-200 mm lens and a Tokina 12-24 mm lens from an elevated position at an oblique angle. The use of an elevated position coupled with a high megapixel camera and a dedicated photographic program allowed great detail to be retained, allowing the counting of individual eggs and chicks to be undertaken accurately. Photography was used, rather than direct observations, to limit the time spent near individual plots. On each subsequent visit, photographs of the plots were taken from the same position and were discontinued when no nests were visible in the designated plot area. Photographs were taken at 14-day intervals to further reduce disturbance to incubating or attending adults. Visits to the colony occurred four days a week, for three to ten hours a day for the duration of the breeding season. When birds were flushed from plots, the researchers waited nearby (within 20m) until some birds had returned, to prevent eggs or chicks from being depredated. No instances of predation occurred during these monitoring activities.

All photographs were analyzed and sharpened using Adobe Bridge and Adobe Photoshop CS4. Hatching success (proportion of eggs that hatched successfully) and fledging success (proportion of chicks that fledged) were determined from the photographs. Chicks were considered fledged after they were absent from the nest at the age of 33 days. Egg volume calculations used the following formula developed by Narushin (2005):

\[
\text{Egg volume} = (0.6057 - 0.0018B)LB^2
\]

Where \( L = \text{maximum length} \) and \( B = \text{maximum breadth} \).

Nesting density and egg volume in relation to habitat type (open versus shaded) were compared using One Way ANOVA (Sokal and Rohlf 2012). When the assumptions of normality of One Way ANOVA were not met, randomization methods with 1,000 replications were used (Sokal and Rohlf 2012). Clutch size was compared between open and shaded areas using Mood’s Median test. Hatching success and fledging success were compared in open and shaded areas using the Fisher’s Exact Test. In each case, significance was set at \( \alpha = 0.05 \). Overall reproductive success was defined as number of fledglings per nest and was calculated for all plots.

**Results**

Overall density of nests was 0.92±0.09 nests/m². Densities of nests were significantly higher in shaded areas compared to open areas (Table 1). Eggs were elongate, ovoid and egg volume was significantly larger in shaded areas compared to open areas (Table 1). Clutch size was 2.4 ± 0.04 eggs/nest and had a median of 2 eggs/nest (Table 1), however clutch size did not differ between shaded and open areas (Table 1). Overall hatching success was 58.7% with significantly higher hatching success occurring in shaded
nests (65.1%). Fledging success, calculated for a small subset of nests, was 65.6% and did not vary between shaded and unshaded areas (Table 1). Thus, pooled reproductive success (shaded and unshaded plots) was 1.7 chicks/nest and was not comparable between open and shaded nests due to small sample size.

### DISCUSSION

Habitat alteration can have both positive and negative effects on breeding seabirds (Schreiber and Burger 2002; Nelson 2005). In this study, Socotra Cormorants were recorded nesting under *Acacia-Prosopis juliflora* plantations illustrating their adaptability to habitat alteration. Estimates of hatching success and fledging success provided a baseline for the species. Cormorants nesting under trees had significantly higher nesting density, egg volume and hatching success, suggesting that tree cover could be improving overall reproductive success in this colony.

Socotra Cormorants generally nest either in small groups of hundreds of nests or in large, dense groups of thousands of nests (Nelson 2005; Sullivan et al. 2006; Crawford et al. 2007). Colonies elsewhere in UAE (all in Abu Dhabi Emirate) fall into the first category, largely due to declines caused by disturbance (Symens et al. 1993; Aspinal 1995; Jennings 2010). Estimates of nest density on Siniya Island were 0.48-1.32 nests/m² which was lower than those reported earlier (4-6 nests/m²; Nelson 2005). The Siniya Island colony apparently has substantial unoccupied habitat suitable for breeding (S. B. Muzaffar, unpublished data). Provided that food supplies remain abundant, the colony has the potential to expand over the remaining available habitat suitable (Schreiber and Burger 2002; Barati et al. 2008).

Shade provided by trees could reduce ambient temperature and this could be an important determinant of nest site selection on Siniya Island. Daytime temperatures on unshaded areas regularly exceeded 45°C, making overheating a major problem during incubation (August). Socotra Cormorants shade their eggs to keep them cool (Jennings 2010) and shade from trees could further reduce dehydration or hatching failure (Conway and Martin 1999; Yasue and Dearden 2006). Mean egg volume in this study was significantly higher in shaded plots and since larger egg volume has been related to increased hatchability (e.g. Weidinger 1996), eggs in shaded areas had a greater chance of hatching compared to those in unshaded areas. The notion is consistent with the observation that eggs in shaded areas in this study also had significantly higher hatching success. Kelp Gulls *Larus dominicanus* breeding under shade from trees have also shown higher hatching success compared to those in unshaded areas (García-Borboroglu and Yorio 2004). Adult cormorants compete for better quality breeding habitat and the most experienced (older) individuals breed in the best habitats (Nelson 2005). In addition, egg volume and hatching success increase with age (Nelson 2005) Thus, it is suggested that shade provided better nesting areas which were occupied by older Socotra Cormorants that produced larger eggs leading to increased hatching success.

### Table 1. Nesting density and reproductive variables of Socotra Cormorants in relation to habitat on Siniya Island, Umm Al Quwain, UAE.

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>Mean ± SE</th>
<th>Unshaded</th>
<th>Shaded</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nest density (nests/m²)</td>
<td>14</td>
<td>0.92 ± 0.09</td>
<td>0.75</td>
<td>1.05</td>
<td>0.01</td>
<td>a</td>
</tr>
<tr>
<td>Egg volume (cm³)</td>
<td>440</td>
<td>49.0 ± 0.25</td>
<td>48.50</td>
<td>49.56</td>
<td>4.56</td>
<td>0.036</td>
</tr>
<tr>
<td>Clutch size (numbers/nest)</td>
<td>318</td>
<td>2.43 ± 0.04</td>
<td>2.41</td>
<td>2.44</td>
<td>0.1</td>
<td>0.749</td>
</tr>
<tr>
<td>Hatching success (%)</td>
<td>773</td>
<td>58.70</td>
<td>46.60</td>
<td>65.10</td>
<td>&lt;0.001</td>
<td>b</td>
</tr>
<tr>
<td>Fledging success (%)</td>
<td>340</td>
<td>65.60</td>
<td>64.80</td>
<td>65.80</td>
<td>0.889</td>
<td>b</td>
</tr>
<tr>
<td>Reproductive success (chicks/nest)</td>
<td>131</td>
<td>1.70</td>
<td>0.92 ± 0.09</td>
<td>0.75</td>
<td>1.05</td>
<td>0.01a</td>
</tr>
</tbody>
</table>

One Way ANOVA assumptions not met; 1000 randomizations performed.
Fisher’s Exact test.
Observed overall hatching success of 58.7% and fledging success of 65.6% are within ranges observed in the Phalacrocoracidae (hatching success 25-80%, fledging success 22-95%, Nelson 2005). Reproductive success was estimated at 1.7 fledglings/nest and this was comparable to other cormorant species ranging from 0.3-2.5 fledglings/nest (e.g. Neotropic Cormorants, *P. brasilianus* 1.65/nest; European Shags, *P. aristotelis*, 1.87/nest; Double-crested Cormorants, 1.78/nest in San Francisco Bay) and were likely affected by year, location and predation (Nelson 2005).

Estimation of fledging success in the present study was inadequate since the protocol did not allow tracking of large numbers of eggs to fledging. Socotra Cormorant chicks are unable to thermoregulate adequately and susceptible to mortality when exposed to high temperatures (Jennings 2010). Most chicks were observed to be crching under trees regardless of whether their nest was in a shaded or unshaded area (S. B. Muzaffar, unpublished data) and this is probably by why no difference in fledging success could be detected in these two habitat types. Observed fledging success on Siniya Island is likely high compared to other colonies that lack trees. Thus, by extension, it is speculated that reproductive success observed here is also higher than in other colonies. In addition, high hatching success is often offset by low fledging success (and therefore reproductive success) due to a combination of environmental factors (Regehr and Montevecchi 1997; Weimerskirch *et al.* 2001). Therefore, years with poor food supplies or weather conditions could result in higher reproductive success in Socotra Cormorants nesting in shaded areas only. There is no evidence to indicate that there was any food shortage during 2011 and thousands of chicks in the entire colony fledged successfully (S. B. Muzaffar, unpublished data). Hypotheses relating to breeding success need to be tested by conducting long-term studies on reproductive performance in relation to environmental variables on this and other colonies. At present there is no comparable data in the published literature on reproductive performance of Socotra Cormorants (Nelson 2005; Jennings 2010). Better estimates of fledging success could help to determine the role of trees in altering reproductive success. *Prosopis juliflora* is an invasive exotic tree (El-Keblawy and Al-Rawai 2007) and this study represents its potential positive effect on a declining native species.

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