

TIMING OF BREEDING AND DIET OF THE BLACK-FACED CORMORANT *PHALACROCORAX FUSCESCENS*

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Received 20 September 2012, accepted 10 December 2012

SUMMARY

TAYLOR, A.R., DANN, P. & ARNOULD, J.P.Y. 2013. Timing of breeding and diet of the Black-faced Cormorant *Phalacrocorax fuscescens*. *Marine Ornithology* 41: 23–27.

Previous anecdotal reports have suggested that Black-faced Cormorant *Phalacrocorax fuscescens* breeds only in winter in southeastern Australia, but detailed reports confirming this are lacking. Here we examine the timing of breeding in Black-faced Cormorants at Notch Island in northern Bass Strait in 2006. Peak laying occurred during winter (ca 26 July). The diet of Black-faced Cormorants was predominantly fish (97% of identified prey) and varied between breeding and post-breeding periods. Black-faced Cormorants consumed a total of 14 different species with four species having a frequency of occurrence in the diet of $\geq 5\%$ during the breeding season and six species during the post-breeding period. We provide data for the first time on the chronology of breeding of Black-faced Cormorants in one year and give a preliminary description of their diet based on pellet analyses. We propose that late winter breeding may be a strategy to avoid the high ambient temperatures in northern Bass Strait during summer, the associated higher thermoregulatory costs for adults and the increased mortality for chicks.

Key words: Bass Strait, *Phalacrocorax fuscescens*, piscivores, seabirds, winter breeding.

INTRODUCTION

Breeding of seabirds throughout the year is possible in some regions, such as the tropics, that have comparatively low seasonality (Schreiber 2002). But in temperate regions, breeding in winter is uncommon and usually associated with specific local conditions. In Bass Strait (southeastern Australia), most seabird species breed in spring or summer (Marchant and Higgins 1990a) when the availability of important prey species such as Pilchard *Sardinops sagax*, Australian Anchovy *Engraulis australis* and Sandy Sprat *Hyperlophus vittatus* is at its highest (Hobday 1992). However, some seabird species in northern Bass Strait (including coastal Victoria) breed only in winter. For example, Common Diving-Petrels *Pelecanoides urinatrix* throughout the Seal Islands Group (east of Wilsons Promontory) and Pied Cormorants *Phalacrocorax varius* at Lake Borrie (near Werribee, Victoria) have both been recorded breeding during winter months (June/July) (Norman 1973; Marchant and Higgins 1990a, Schumann *et al.* 2008).

The Black-faced Cormorant *Phalacrocorax fuscescens*, one of the largest Phalacrocoracidae in the region, is distributed along the southern coast of Australia from Esperance (Western Australia) to Cape Howe (New South Wales) (Marchant and Higgins 1990b). Anecdotal records have suggested this species breeds only during winter on some islets in northern Bass Strait (Littler 1910, Marchant and Higgins 1990b), and these observations are supported by the cormorants' absence from coastal bays during winter (Dann *et al.* 2003).

However, there have been no detailed studies of the timing of breeding or diet for this species in any location, apart from several

anecdotal reports (Marchant and Higgins 1990b). Accordingly, the aims of this study were to determine the timing of breeding and conduct a preliminary study of the diet of Black-faced Cormorants in northern Bass Strait.

METHODS

Study site and breeding chronology

The study was conducted at Notch Island (38°56'S, 146°40'E), approximately 19 km east of Wilsons Promontory, northern Bass Strait (Fig. 1). The Black-faced Cormorant colony is situated on the eastern side of the island on a steep granite cliff (10–20 m asl) that has been used for at least 25 years (P. Dann pers. obs.).

The breeding chronology of Black-faced Cormorants on Notch Island was determined during six visits to the colony between June and December 2006. The number of apparently occupied nests (AON), defined here as substantial, well-constructed nests capable of holding eggs and occupied by at least one adult bird, within the entire colony was determined from suitable viewpoints using field binoculars (7 × 50). Counts were conducted between 12h00 and 13h00, as preliminary investigations indicated this was when the lowest number of breeding partners and/or non-breeding individuals were present, allowing a better estimate of breeding birds.

In addition to recording the number of occupied nests, 152 nests selected at random were mapped within the colony from various viewpoints to assess breeding chronology. Nests were monitored every two days during extended visits to the island and their contents noted (i.e. numbers of eggs, chicks or adults present).

Due to adverse weather conditions, access to the study colony was limited and, as a result, data for individual nests were incomplete.

Consequently, published information on the length of the incubation period, stages of plumage, and age at creching and fledging were used in conjunction with the observations of the study nests to estimate the chronology of breeding events. Laying dates were calculated by subtracting an incubation period of 30 d (mean reported for 28 other *Phalacrocoracidae* species: Marchant & Higgins 1990b, del Hoyo *et al.* 1992, Johnsgard 1993) from estimated hatching dates.

Due to limited access to the study site, all estimated hatching dates had margins of error (i.e. period of time in which chicks may have hatched) associated with them.

Diet

Diet was assessed by analysis of hard prey remains from fresh regurgitated pellets (i.e. still moist and intact, ≤ 7 d old) collected opportunistically around the periphery of the colony to reduce the levels of disturbance to birds breeding within the colony. During each visit to the colony, all visible pellets were removed so that all subsequent samples were within a known period of time. Given the extreme wariness of this species and the location of the colony on a steep cliff, this resulted in pellet losses and restricted the overall sample size. The pellets may have come from both breeding and non-breeding birds at the colony. Samples were stored dry in paper bags until laboratory analysis. In the laboratory, samples that were still moist were dried in an oven at 60 °C for 24 h. Dry samples were then soaked in warm water with detergent (to facilitate separation) and sorted through a series of nested sieves (0.2–1.0 mm mesh size). All diagnostic remains (i.e. sagittal otoliths, fish mouthparts, spines, eye lenses, cephalopod beaks) were removed and collected.

With the exception of cephalopod beaks, which were stored in 70% alcohol, all prey remains were stored dry in plastic vials until further analysis.

Identification of otoliths was made by comparison with reference collections held at Phillip Island Nature Parks. Otolith quality was measured using the erosion scale of Adams *et al.* (1999) with least eroded (Level 1) to most eroded (Level 5). Counts of the number of left and right otoliths were used to calculate the minimum number of fish present for each taxon within each sample. The frequency of occurrence (FOO) is the number of times a given prey taxon is identified within regurgitate samples. The spines of leatherjacket spp. (Monacanthidae) and mouthparts of wrasse spp. (Labridae) were used to indicate the number of fish present for these taxa.

Cephalopod beaks were identified by comparing upper and lower beaks to the reference collection (Lu & Ickeringill 2002). The number of identified upper and lower cephalopod beaks were recorded to provide the minimum number of cephalopods in each sample.

Data were tested for normality using a Kolmogorov-Smirnov test, and *t*-tests were used to compare means. Comparisons of diet between the sampling periods were made using Analysis of Similarity (ANOSIM) and SIMPER in PRIMER (v.6. PRIMER-E, Ivybridge, UK). Unless otherwise stated, the data are presented as mean \pm SE and statistical results were considered significant at $P < 0.05$.

RESULTS

Timing of breeding

The number of AON increased rapidly from late June, peaked in the first week of August, then decreased throughout September

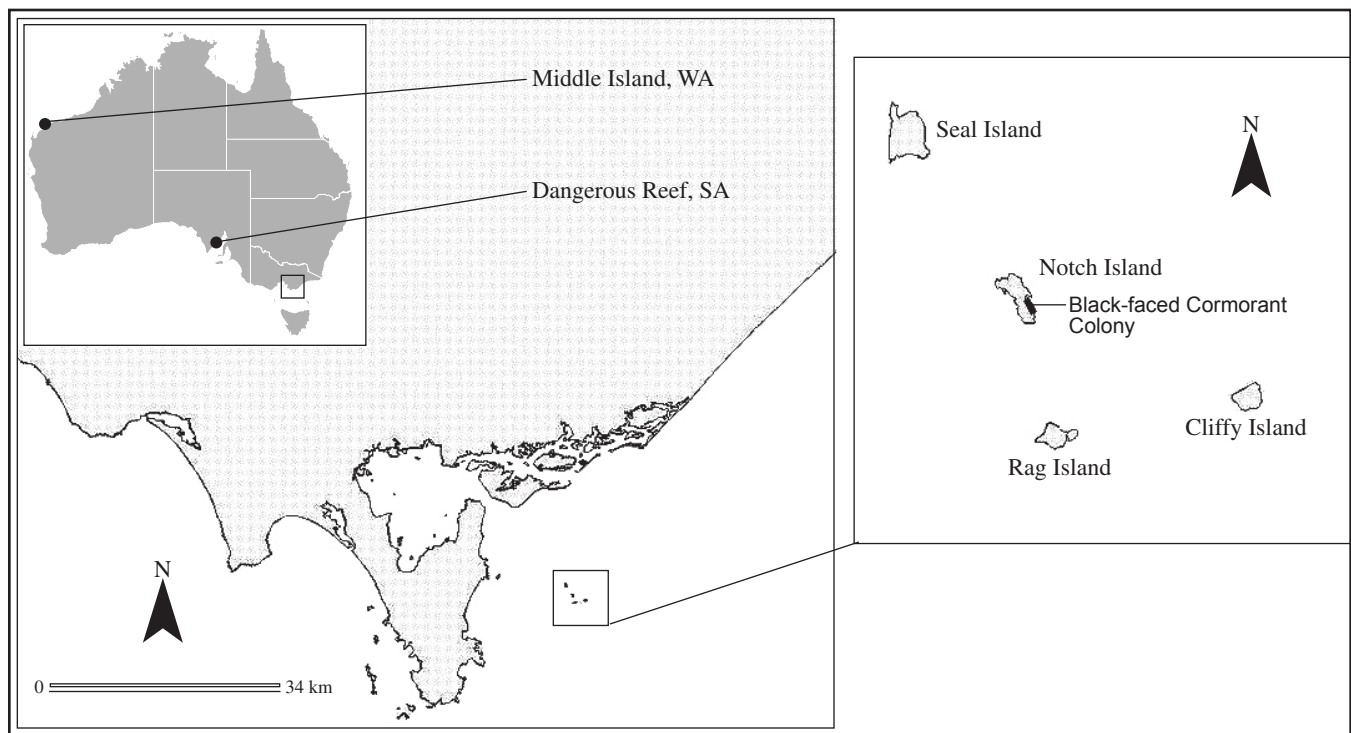


Fig. 1. Location of the Black-faced Cormorant *Phalacrocorax fuscescens* colony on Notch Island, northern Bass Strait.

(Fig. 2). We estimated that the colony occupied close to 950 nests at its peak. Most nests became inactive and were destroyed during harsh environmental conditions and/or by nearby cormorants by late

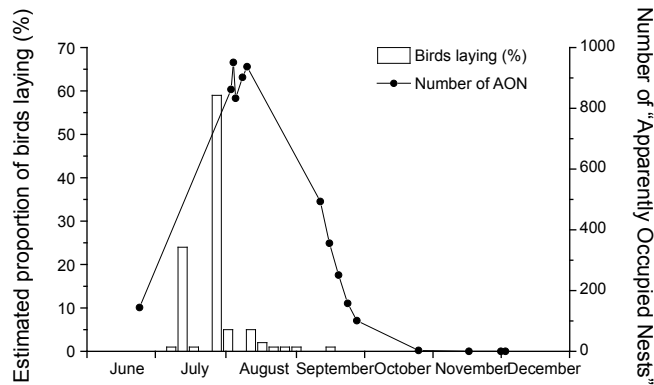


Fig. 2. Estimated percentage of birds laying (± 2 days of error on average) across 152 mapped nests within the colony, and total number of apparently occupied nests. Data are grouped in five-day intervals.

October. There were no signs of re-nesting during visits throughout November and December. Peak egg-laying coincided with peak counts of occupied nests (Fig. 2), occurring from early July until mid-August. Some nests were occupied when the study began in late June, and we estimate that a small proportion of birds (<5%) initiated breeding attempts earlier in June (Fig. 2). Overall, the median laying date was 26 July ± 2 days. There was some variation in laying dates within the colony, with birds in the lower, steeper regions of the colony breeding earlier (18 July ± 1 day) compared with birds in the highest regions with less steep slopes (12 August ± 4 days).

Diet

Totals of 30 and 36 pellets were collected during late winter/early spring (August–September) and spring/early summer (October–December), respectively. Of these samples, 98% contained diagnostic prey remains, with fish constituting 97% and cephalopods 3% (Table 1). No crustacean remains were found in any of the samples. A total of 917 otoliths were recovered, of which 287 (31%) were too eroded to be identified and were removed from further analyses.

TABLE 1
Frequency of occurrence and numerical abundance of fish and cephalopod prey remains identified in regurgitate samples from Black-faced Cormorants at Notch Island, northern Bass Strait, during the breeding and post-breeding periods

	Season; frequency of occurrence (%)		Season; numerical abundance (%)	
	Breeding N = 30	Post-breeding N = 36	Breeding N = 30	Post-breeding N = 36
Fish prey				
Wrasse sp. (Labridae sp.)	12 (40.0)	15 (41.7)	12 (9.7)	15 (5.8)
Silver trevally (<i>Pseudocarynx dentex</i>)	12 (40.0)	6 (16.7)	23 (18.5)	10 (3.8)
Silverbelly (<i>Parequula melbournensis</i>)	8 (26.7)	24 (66.7)	14 (11.3)	93 (35.8)
Red cod (<i>Pseudophysis bachus</i>)	5 (16.7)	6 (16.7)	6 (4.8)	6 (2.3)
Flathead (Platycephalidae spp.)	4 (13.3)	4 (11.1)	5 (4.0)	6 (2.3)
Redfish (<i>Centroberyx</i> sp.)	4 (13.3)	2 (5.6)	19 (15.3)	8 (3.1)
Whiting (<i>Sillago</i> spp.)	3 (10.0)	11 (30.6)	4 (3.2)	17 (6.5)
Common Bullseye (<i>Pempheris multiradiata</i>)	3 (10.0)	0 (0)	4 (3.2)	0 (0)
Species 1 (Carangidae)	2 (6.6)	4 (11.1)	12 (9.7)	13 (5.0)
Gurnard (Triglidae sp.)	2 (6.6)	3 (8.3)	3 (2.4)	3 (1.2)
Hardyheads (Atherinidae spp.)	1 (3.3)	16 (44.4)	18 (14.5)	84 (32.3)
Ocean perch (<i>Helicolenus percoides</i>)	1 (3.3)	0 (0)	4 (3.2)	0 (0)
Scorpionfish (Scorpaenidae spp.)	0 (0)	2 (5.6)	0 (0)	3 (1.2)
Leatherjacket (Monacanthidae spp.)	0 (0)	2 (5.6)	0 (0)	2 (0.8)
Total	57	95	124	260
Cephalopod prey				
Sepidae	4 (13.3)	1 (2.7)	5 (3.8)	2 (0.4)
Unidentified cephalopods	2 (6.7)	0 (0)	2 (1.5)	0 (0)
Species 1 (Octopoda)	1 (3.3)	0 (0)	1 (0.8)	0 (0)
<i>Octopus berrima</i>	0 (0.0)	1 (2.7)	0 (0)	1 (0.4)
Total	7	2	8	3

The remaining otoliths accounted for 384 fish prey items. Squid beaks accounted for a total of 11 cephalopod prey items. Only one species of cephalopod was identified, the Southern Keeled Octopus *Octopus berrima*; the remaining beaks being classified to family (Sepidae) or as unidentifiable.

While wrasse (Labridae sp.) and Silver Trevally *Pseudocaranx dentex* had the highest frequency of occurrence (FOO) during late winter/early spring (*ca* 40%), the latter was substantially lower (17%) in the spring/early summer sample (Table 1). At this time Silverbelly *Parequula melbournensis* increased in prominence to the highest FOO (67%). The greatest dissimilarities (8%, SIMPER) between the two groups in FOO, however, was the rise in Hardyheads (Atherinidae) and Silverbelly in the post-breeding period (44% and 67%, respectively). Similarly, there were significant differences in the numerical abundance (NA) of prey between the two sampling periods (ANOSIM, $R = 0.095$, $P < 0.008$), with Silverbelly and Hardyheads rising substantially in the post-breeding sample and making the largest contribution to the differences.

DISCUSSION

Timing of breeding

Egg-laying peaked in late July and had ceased by mid-September (Fig. 2) confirming previous anecdotal reports by Littler (1910) of winter breeding by Black-faced Cormorants within Bass Strait. In contrast, preliminary anecdotal data from Western Australia (Middle Island) and South Australia (Dangerous Reef), where other major colonies are located, suggest this species breeds during spring and summer (Serventy *et al.* 1971; Marchant & Higgins 1990b).

Peak egg-laying in Black-faced Cormorants occurs when minimum and maximum air temperatures are at their annual lowest. While the thermo-neutral zone (TNZ) of Black-faced Cormorants is not known, by using the methods of Ellis and Gabrielson (2002), a lower critical temperature (LCT), below which metabolism rises, can be estimated as ~ 12 °C. Ambient temperatures during winter were within the lower limits of the Black-faced Cormorants' estimated TNZ (i.e. daily temperatures averaged ~ 12 °C during winter months). Similarly, sea temperatures surrounding Wilsons Promontory at this time (~ 13 °C) are also within this range and may not lead to substantially increased metabolic rates as observed in other cormorant species diving in colder water of < 5 °C (Enstipp *et al.* 2005; Gremillet *et al.* 2005). Furthermore, data for other temperate cormorant species in the Northern Hemisphere suggest they have low upper critical temperatures (above which they must expend energy to lose heat). For example, similar-sized cormorants such as European Shags *P. aristotelis* in Norway (lat $\sim 62^\circ\text{N}$) have upper critical temperatures of ~ 19 °C (Enstipp *et al.* 2005). Assuming similar upper critical temperatures for Black-faced Cormorants, winter may be the most thermoregulatory suitable period for breeding. Indeed, in the present study, it was noticed that Black-faced Cormorants were panting under direct sunlight, a method of evaporative heat loss, during even mild temperatures (~ 15 – 20 °C). It is possible, therefore, that the available breeding habitat of Black-faced Cormorants (i.e. large boulders or open granite cliff faces) could become too warm to breed and rear chicks during summer months. As mortality of nestlings from overheating has been documented in other cormorant species (Lasiewski & Snyder 1969), it is possible that Black-faced Cormorants minimise chick mortality by breeding during winter when ambient temperatures are lower.

Diet

Cormorants generally feed on demersal and benthic fish (Lilliendahl & Solmundsson 2006). Previously, Black-faced Cormorants have been reported eating only fish in Victorian coastal waters, predominantly Hardyheads, Pipefish *Stigmataphora* spp., Cobbler *Gymnapistes marmoratus*, Flathead and Dragonets *Callionymus* spp. (McNally 1957).

In the present study, Black-faced Cormorants consumed a total of 14 different fish species, with four having a FOO of $\geq 5\%$ during the winter/early spring and six during spring/early summer (Table 1). This level of prey diversity is similar to that observed in other cormorant species in temperate regions throughout the world (*see* Gremillet *et al.* 2004; Santoul *et al.* 2004; Lilliendahl & Solmundsson 2006). However, we need to recognise that pellets may not be fully representative of whole diets and that our sample size was small.

ACKNOWLEDGEMENTS

This study was assisted by funding and resources from the Phillip Island Nature Parks and Deakin University. The assistance of Fiona Hume with the dietary analysis, of the numerous field workers and of Geoff Boyd for transport to the island is much appreciated. The manuscript has benefited from the comments of two referees, and we wish to thank them. The research was conducted under Deakin University AWC permits A30/2006 and A31/2006 and Department of Sustainability and Environment Wildlife Research Permit 10003785.

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