Reproductive Biology of Great Cormorant (*Phalacrocorax carbo sinensis*) in the Qinghai-Tibet Plateau

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Abstract.—There have been no detailed studies on reproductive biology of the Great Cormorant (*Phalacrocorax carbo sinensis*) in Qinghai-Tibet Plateau. We conducted such investigations during the breeding seasons of 1999 and 2000 in Qinghai-Lake Bird Isle, China. Great Cormorants began to migrate to Qinghai-Lake for reproduction from the middle of March and left from early October at the end of reproduction. Nesting periods were from early April to mid June and took 50 days. Egg-laying occurred during the three weeks from the end of April to 20 May. Females typically laid an egg every 1-2 days until clutch completion. Mean clutch size in the study area over two years was 3.3 (SE ± 0.13, N = 68, range 1-5) and most (66.18%) fell within the range 3-4 eggs. Length of eggs averaged 61.01 mm and breadth averaged 34.13 mm. Fresh egg weight averaged 57.34 g (SE ± 0.36, range 46.0-73.7 g, N = 179). Hatching success was 48.7% and fledging success was 64.9% over two years. Decline of available fish resources in Qinghai-Lake might be one of main causes of lower reproductive success. The causes of chick loss were possibly high altitude, high winds and prolonged rain. *Received 24 December 2006, accepted 18 April 2007.*

Key words.—Reproductive success, *Phalacrocorax carbo sinensis*, eggs, clutch size.

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The Qinghai-Tibet Plateau is the highest and largest plateau in the world, with an average elevation of 4,000 m above sea level and an area of 2.5×10^6 km^2 (Zheng 1996). The unique geomorphological configuration, the complex land conditions and the diversified climate combine make the Qinghai-Tibet Plateau an area of world-wide importance for the evolution and adaptation of montane species in this area (Tang 1996), especially for those species distributed widely in both montane area and low land.

The world range of the Great Cormorant (*Phalacrocorax carbo*) extends discontinuously from north-east America (Labrador and Newfoundland) across Eurasia to Australia and New Zealand, as well as to South Africa. The distribution is far from continuous, especially in Europe and central Asia (Rand 1960). Cormorants that occur in Qinghai-Tibet Plateau are mainly *P. c. sinensis*, which is distributed mainly on the Qinghai Lake area. Few studies on the reproductive biology of the Great Cormorant (*P. c. sinensis*) have been conducted with the notable exception of the work on reproductive behaviors at northeast China by Liu *et al.* (1994, 1997) and some observation records on reproductive habits by Schjorring *et al.* (1999). However, no study on the reproduction of *P. c. sinensis* from the Qinghai-Tibet Plateau has been documented. Compared to those in low lands, *P. c. sinensis* distributed on the Qinghai-Tibet Plateau might have unique reproductive characteristics to adapt the generally harsh alpine conditions. We carried out studies on reproductive biology of Great Cormorants in this area with the objectives to provide basic information on breeding biology of this species (i.e., clutch size, proportion of eggs hatched, and proportion of chicks fledged), and to consider factors influencing reproductive success. Our study was aimed at providing insight into adaptations of cormorants in alpine environments.

METHODS

Study Area

Fieldwork was carried out at Bird Isle (99°44'-99°54'E, 36°57'-37°04'N, alt. 3194-3226 m) on Qinghai-Lake from March to November 1999 and 2000. Weather in this area has distinct plateau characteristics such as short cool summers and harsh winters. The annual average temperature is -2 - -1.0°C, and mean monthly temperature of April, May and June is 0-5°C, 5-10°C and 10-15°C respectively. The maximal wind power is 9-10 class in summer and annual precipitation is 372 mm (>90%

occurring from June to September). The study area is characterized by alpine meadow and the dominant plant species were *Achnatherum splendens, Amattfeldii pamp, Artemisia acoparia, Chenopodium album, Poaross bergiana, Oxytropis falcate, Potentilla anserine* and *Thexmopsis lanceolata.*

Data Collection

During each breeding season in 1999 and 2000, we systematically searched for the Great Cormorant nests throughout the island and selected and numbered some nests for research. We monitored nests closely to obtain data on nest-building, egg-laying, clutch size, hatching and caring nestling by telescope or visiting the colony repeatedly. Earliest egg-laying date, egg-laying interval, time of hatching were derived directly from observations. We also marked the eggs on both ends with pencil, measured their length and breadth to the nearest 0.1 mm with vernier calipers and weighed them using a 100-g spring scale to 1 g during regular nest-site visits. Eggs were weighed between 10.00-12.00 h every two days until hatching. We examined components of reproductive performance of the Great Cormorant at Qinghai-Lake Bird Isle, using mean clutch size, mean hatching success, and mean fledging success. Hatching success was calculated as the proportion of eggs hatched; fledging success equaled the proportion of chicks hatched that eventually fledged.

Statistics

All statistical analyses were performed using Microsoft Excel 2003 or the SPSS12.0 for Windows. One-way ANOVA used to analyze mean differences of different groups. Simple linear correlation analysis was used to obtain a measure of the strength of relationships between the variables. Statistical tests are two-tailed and values given are mean (± SE).

RESULTS

Arrival and Nest Building

Great Cormorants migrated to Qinghai-Lake area to breed in mid-March every year and left in early October after the end of reproduction, when environment became unfavorable. Therefore, Great Cormorants settled this region for about 180-210 days. Nests were built from early April to mid-June. Nest sites were selected at the tops of sea-cliffs and on the slopes or crags or extrusive rock on cliffs of nearby hills. Most nests persist for many years and accumulate growths of moss and algae. Nest bowls averaged 54.4 cm (SE ± 1.08, range 43.2-65.3 cm, N = 35) in outside diameter, 31.0 cm (SE ± 0.44, range 25.7-36.5 cm) in inner diameter, 23.4 cm (SE ± 1.59, range 9.7-45.2 cm) in height and 9.2 cm (SE ± 0.24, range 7.3-13.8 cm) in inner depth. *Saussurea salsa, Achnatherum splendens, Amattfeldii pamp* were common materials used for constructing nests with other grasses found on Bird Isle used occasionally. Great Cormorants completed constructing a nest in about 3-4 d.

Egg Laying

Great Cormorants did not lay eggs immediately after nests were completed and there was a delay of eight to ten d or more before laying. The earliest egg-laying date in 1999 was 7 April and the latest was 14 June, and 8 April and 18 June, respectively in 2000. Laying dates are shown in Fig. 1. In the three weeks from the end of April to 20 May, 82.2% (N = 90 nests) and 81.4% (N = 102 nests) of all eggs were laid for 1999 and 2000, respectively. Females typically laid one egg every one or two d until completing the clutch, but a few laying events happened irregularly: five eggs from normal-sized clutches were laid on successive days, three in a three-day and one in a six-day interval.

Egg and Clutch Size

There were no significant differences in egg length and breadth (One-way ANOVA, length: F = 0.081, P = 0.776; breadth: F = 0.031, P = 0.861) between 1999 and 2000,

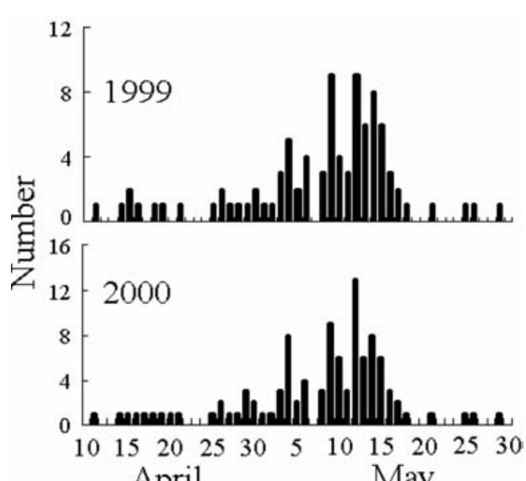

Figure 1. Dates of laying of Great Cormorant on Qinghai-Lake Bird Isle in 1999 and 2000. In 1999, surveys began on 1 April and ended on 20 June; in 2000, 5 April to 20 June.

Table 1. A statistic comparison of the egg length, width and weight on Great Cormorants (*Phalacrocorax carbo sinensis*) between 1999 and 2000 in Qinghai-Lake Bird Isle.

		Length (mm)		Width (mm)		Weight (g)	
Year	N	Range	Mean ± SE	Range	Mean ± SE	Range	Mean ± SE
1999	84	54.00-70.00	60.94 ± 0.36	29.80-38.25	34.15 ± 0.18	46.2-73.7	57.03 ± 0.53
2000	95	56.20-68.25	61.07 ± 0.29	30.15-38.35	34.11 ± 0.14	46.0-72.4	57.61 ± 0.50
Mean	179	54.00-70.00	61.01 ± 0.23	29.80-38.35	34.13 ± 0.11	46.0-73.7	57.34 ± 0.36

and egg weight has not significant differences (One-way ANOVA, F = 0.639, P = 0.425) (Table 1, Fig. 2). Mean clutch size over two years was 3.3 (SE ± 0.13, N = 68), ranging from 1-5 and most (66.18%) fell within the range 3-4 eggs (Fig. 3). There were no significant differences between the mean clutch size in 1999 (3.4 ± 0.17, N = 42) and 2000 (3.2 ± 0.21, N = 26; One-way ANOVA, F = 0.211, P = 0.648).

Incubation

Great Cormorants began to incubate immediately after laying. Both sexes incubated and change-overs were infrequent, sometimes only once in the course of the day. Incubating cormorants tolerated a very close approach (<2.0 m). In most cases (30 out of 36), we had to force them out of the nests to check incubation progress. During our examination, adults stayed silently 2-30 m away. The incubation period, i.e., the interval between the laying of the last egg in the clutch and the hatching of the last nestling (Moreau 1946) averaged 28.0days (SE ± 0.11, range 26-30 days, N = 72) in 1999 and 2000.

Reproductive Success

Of 126 eggs produced by birds in 1999 and 84 in 2000, 114 (90.5%) and 79 (94.1%), respectively, were fertilized, and out of these fertilized eggs, 58 (50.9%) and 36 (45.6%) hatched successfully. Mean hatching success was 48.7% over the two years. Fledging rate averaged 64.9% over the two years (67.2% in 1999 and 61.1% in 2000). The nest loss of the bird was the highest on the early three days of incubation period and average loss rate was 21.84% during this periods in 1999

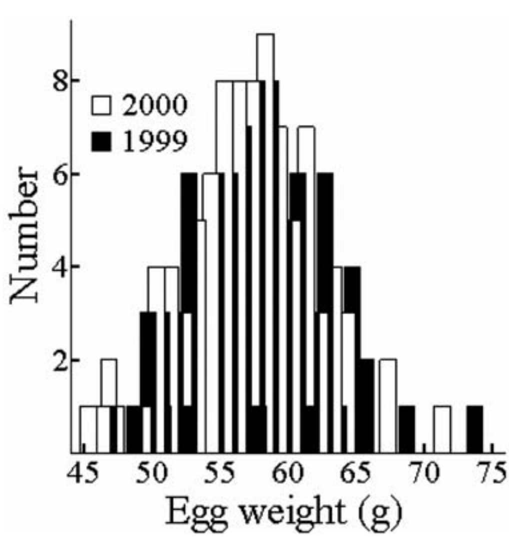

Figure 2. Egg weights distribution of Great Cormorant on Qinghai-Lake Bird Isle in 1999 (N = 84) and 2000 (N = 95).

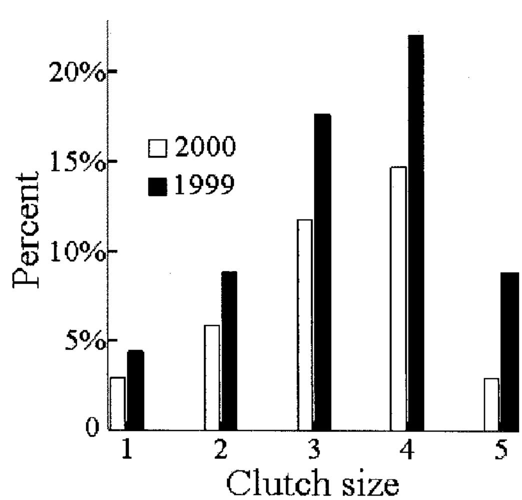

Figure 3. The distribution of clutch size of Great Cormorant on Qinghai- Lake Bird Isle in 1999 (N = 42) and 2000 (N = 26).

and 2000, evermore the nest loss descended (Fig. 4). Most chick mortality occurred during the first ten days of parental care, and averaged 23.7% for the two years, representing and was 66.4% of all chick mortality.

DISCUSSION

Laying dates of Great Cormorants on Qinghai-Lake Bird Isle were 5-7 d earlier than those reported in northern China (Liu *et al.* 1994). This could be caused by climatic differences. However, the incubation period in this study was the same as that found for Zhalong National Nature Reserve of northern China (Liu *et al.* 1994).

Predation is the principal cause of nesting mortality in many species (Ghalambor and Martin 2000; Mezquida and Marone 2002; Amo *et al.* 2004). In our study boar (*Sus scrofa*) and weasel (*Mustela sibirica Pallas*) predation was an important cause of Cormorant nest mortality. Microclimates at nest-sites often affect nesting success (Wagner and Seymour 2001; Lu *et al.* 2003). In our study area, winds were strong (Maximal is 9-10 class) and hail occurred frequently (more than 5) during the peak nesting period, contributing to nest loss.

The Great Cormorant was the only fish-eating bird species in Qignhai-Lake and fish populations have declined here. The highest commercial fish landings reached about twelve thousand tons at Qinghai-Lake in the early 1960s and declined to about one thousand tons in 1994 (Shi and Wang 1995). We suspect that reproductive success of Great Cormorants is limited by fish availability at Qinghai-Lake. Clearly, long-term data on cormorant population, their diets and some measures of fish availability are required to evaluate this hypothesis.

It is possible that in Qinghai-Lake Bird Isle higher mortality during the first ten days following hatch was related to high altitude, high winds, prolonged rain and low temperatures at this site. Even in summer, conditions on the exposed rocks used by Great Cormorants can be extraordinarily harsh.

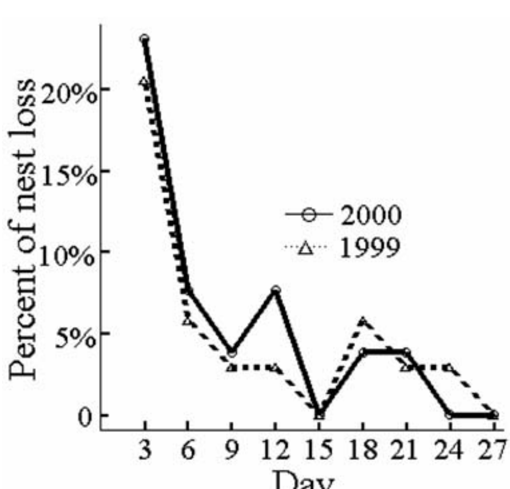

Figure 4. Loss rate of Great Cormorant nests in incubation periods in 1999 and 2000.

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