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Two introduced crocodile species had changed reproductive characteristics in China

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ABSTRACT

The purpose of this study was to study the reproductive characteristics of the Nile crocodile and Siamese crocodiles after introduction into China since the time this occurred near the end of the last century. The data for the eggs and young crocodiles (recently hatched crocodiles) of two introduced species were collected at a Sanya crocodile breeding farm in Hainan. The characteristic variables of crocodile eggs were statistically analyzed, and the results indicated that: egg mass of the Nile and Siamese crocodile was significantly correlated with the egg length and width. Regression analyses were used to develop the linear equation between the egg length, egg width and egg mass. There was a strong positive correlation between the egg mass and initial weight of young crocodiles. The linear equation for assessing egg mass and initial weight of young crocodile was developed for regression analyses. There was no significant linear relationship between clutch size and egg characteristics. Mating time of the Nile crocodile in Hainan (November-April) and the spawning season (March-May) are significantly earlier than in the Zimbabwe region of origin. The average of clutch size and the mean size of eggs for Nile crocodiles in their native habitat is greater than the introduced region as indicated by analyzing data using a two-sample t-test. The Siamese crocodile spawning time was similar in the Hainan and Zimbabwe regions, but the size of clutches and the mean size of eggs in the introduced region were greater than in their native region as indicated by results using a two-sample t-test.

1. Introduction

The Nile crocodile is one of the largest reptiles which belong to the order of Crocodiles (Pooley and Gans, 1976), and is widely distributed in tropical areas of about 47 African countries (Hekkala et al., 2010). Crocodile farming has a positive effect on wild animal protection and has a certain economic value (Revol, 1995). In 1995, for the first time, 72 Nile crocodiles were introduced from South Africa and cultivated in Sanya City, Hainan Province. The southern part of Hainan Province of China has climatic characteristics similar to the regions where Nile crocodiles such as South Africa the natural habitat for this species The ecological requirement, habitat uses and preferences often are of key importance in wildlife conservation and management (Aramde et al., 2011; Adugna et al., 2017).

The Siamese crocodile is considered one of the least studied and most critically endangered crocodilians in the world (Bezuijen

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et al., 2013; Han et al., 2015). The regions in which Siamese crocodiles have their natural habitat is mainly in Kampuchea, Indonesia, Laos, Thailand, Vietnam and other places (Simpson and Bezuijen, 2010). In June 2001, Siamese crocodiles were brought into China from Cambodia for artificial breeding. Artificial breeding populations of these crocodiles are an important and necessary Conservation Strategy to protect the wild population (Lapbenjakul et al., 2017).

Because of the breeding habits and embryonic development of crocodiles vary in regions of the world that crocodiles have their natural habitats; there are differences in reproductive patterns such as nest site selection and nesting habits of crocodiles in different regions (Greer, 1970; Platt and Van Tri, 2000; Combrink et al., 2017). The local climate results contributes to specific temperature conditions that affect the growth and development of the embryo, the hatching rate, and the time it takes for the young crocodile to develop (Ferguson and Joanen, 1982; Kanui et al., 1991; Chantakru et al., 2004). In China, there are newly developed reproductive characteristics of the Chinese alligator after artificial reproduction (Meng et al., 2008) which may be related to the multi-parental reproductive pattern of the Chinese alligator (Wang et al., 2017). This pattern of reproduction may result in certain changes in the breeding characteristics when artificial breeding of crocodiles occur in this new environment.

Little research has been done on the reproductive characteristics of the Nile and Siamese crocodiles in their new habitat. This article mainly analyses the new reproductive characteristics of the Nile and Siamese crocodiles reared at the Hainan Sanya Crocodile Farm Factory (Sanya Yufeng Agricultural Development Co., Ltd.), to understand the normal range of the basic morphological variables of crocodile eggs and young crocodiles and the relationship between these.

2. Materials and methods

2.1. Research approaches and measurement methods

Eggs were collected from female crocodiles that were greater than 10 years of age. The Nile crocodile eggs (39 clutches, 1574 eggs), and Siamese crocodile eggs (56 clutches, 2205 eggs) were collected at the Sanya Crocodile Breeding Farm of Hainan between 16 March and 19 April 2017; 20 June 20 and 30 June 2017. The Nile crocodile (22 clutches, 644 hatchling), Siamese crocodile (31 clutches, 588 hatchling) was hatched, and the hatching rate was determined. Crocodile eggs were collected after being laid and were immediately marked. In the incubation room, a caliper was used to measure the egg length, egg width (precision 0.1 mm), and an electronic balance (precision 0.1 g) was used to weigh the egg mass and weight of the young crocodiles (newly hatched crocodiles). The clutch size, clutch mass and average clutch mass were recorded.

2.2. Statistical analysis

Using Origin8.0, a frequency distribution map, distribution of characteristic values for variables such as egg length, egg width, egg mass, clutch size, clutch mass, average clutch mass and weight of the young crocodile (newly hatched crocodiles) were statistically analyzed, and the distribution was consistent with the normal distribution ($P > 0.05$). The single factor variance analysis ($P < 0.05$) of the egg variables of Nile and Siamese crocodiles was analyzed using SPSS19.0. A partial correlation analysis ($P < 0.05$) and regression analysis ($P < 0.05$) was conducted for egg mass, egg length, egg width and weight of the young crocodiles were conducted using SPSS19.0 and a partial correlation analysis ($P > 0.05$) was used to assess the clutch size and characteristic variables of eggs.

3. Results

3.1. Analysis of characteristic variables of eggs

The data for reproductive characteristic variable values for crocodile eggs are shown in Table 1 and the frequency distribution of reproductive characteristic variables are depicted in Figs. 1 and 2. The egg mass, egg length, egg width, clutch size, clutch mass, average clutch mass and weight distribution for the young juvenile crocodiles were consistent with a normal distribution ($P > 0.05$). Through the scatter plot depiction, it was observed that there was a mean of each variable (Figs. 3 and 4. From Table 1 and Fig. 1, it can be ascertained that the ranges for the variables of egg length of Nile crocodiles was from 7.10 to about ~ 8.00 cm; egg width from 4.38 to ~ 4.62 cm; egg mass from 84.0 to ~ 107.0 g; clutch mass from 2676.0 to ~ 5031.0 g; clutch size from 31 to ~ 51 eggs; average clutch mass from 84.1 to ~ 105.2 g; egg length of Siamese crocodiles from 7.60 to ~ 8.31 cm; egg width from 4.84 to ~

Table 1
Descriptive statistics of egg characteristics of crocodile.

Nile crocodiles/ Siamese crocodiles	n	Maximum	Minimum	Mean ± SD	*P*
Egg length (cm)	1574/ 2205	8.80/ 9.60	6.10/ 6.20	7.57 ± 0.41/ 8.01 ± 0.29	$P < 0.01$
Egg width (cm)	1574/ 2205	5.00/ 6.10	3.90/ 4.30	4.52 ± 0.18/ 5.01 ± 0.17	$P < 0.01$
Egg mass (g)	1574/ 2205	128.3/ 204.1	58.8/ 77.4	95.49 ± 11.51/ 119.04 ± 25.79	$P < 0.01$
Clutch size	39/ 56	60/ 52	18/ 26	40.36 ± 10.00/ 39.38 ± 7.18	$P > 0.05$
Clutch mass (g)	39/ 56	7279.2/ 6409.5	1240.5/ 3058.1	3853.8 ± 1177.86/ 4665.2 ± 928.2	$P < 0.01$
Average clutch mass (g)	39/ 56	121.3/ 132.08	68.8/ 87.37	94.66 ± 10.65/ 118.47 ± 8.23	$P < 0.01$