AGONISTIC BEHAVIOUR IN CAPTIVE ADULT SALTWATER CROCODILE, *CROCODYLUS POROSUS*

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ABSTRACT

The most aggressive reptile is *Crocodylus porosus* (CPO), the saltwater crocodile. CPO can tolerate saline environments and typically found in brackish water around coastal areas. The study from Charles Darwin University states the agonistic behaviour is actually hard-wired since the age of juveniles until adult and CPO shows the most agony compared to the other crocodilian. However, past studies are only conducted to determine the aggression of juveniles. Therefore, observation on the behaviour of captive CPO specifically for adults is needed and in Malaysia, the ethology of CPO is still lacking. This study determined: the characteristics of captive CPO and their housing environment in Tuaran Crocodile Farm; the value of stock density related to aggression of CPO through observation at daylight, night, during feeding, and non-feeding time; and, the courtship and egg-laying behaviour, with the preferred nesting site of CPO during their mating season. The agonistic behaviour of CPO was determined in past studies, as dawn and dusk is when the species shows most aggression with tail-wagging and side-head strike (TWSHS) as its common behaviour. By interviews towards farm crews in Tuaran Crocodile Farm, structure details of the housing environment were determined, and, the parameters of the water from the housing and the surrounding temperature were also obtained. A thorough observation, comprising daylight and night with feeding and non-feeding time, were also conducted. The courtship and egg-laying behaviours were observed with the preferences of CPO's nesting site were also profoundly explained. The behaviour observations were recorded in the data quantification according to the behaviour stated from past studies. The data obtained from the observations were then analysed using Morpurgo *et al.* method (1993) with rectification on data reliability using IBM SPSS Statistics 22. Findings of the study regarding the housing environment stated that it met the requirement for sustainable captivity system of CPO with 20 ppt salinity and proper housing structure. The results revealed that captive CPO in Tuaran Crocodile Farm was most aggressive at daylight and specifically during feeding time with stock density related to aggression value equalled to 8.06 events/min observed in a density 0.3 crocodiles/m^2. Its most exhibited behaviour which was TWSHS and the additional of courtship and egg-laying behaviours were scientifically stated in the study. The findings here can be used for further explanation while studying the ethology of CPO specifically on students who are interested in marine reptiles as to conduct the real study in the wild is very difficult, time-consuming, and extremely dangerous.

ABSTRAK

Reptilia yang paling agresif adalah *Crocodylus porosus* (CPO), iaitu buaya katak. Habitat CPO ialah di kawasan air masin dan kebiasaannya CPO mendiami air payau berdekatan dengan persisiran pantai. Kajian telah dijalankan di Universiti Charles Darwin dan tingkah laku agonistik CPO sebenarnya daripada usia juvenil lagi. Jika dibandingkan dengan spesis lain, CPO adalah paling ganas. Sebelum ini, kajian hanya merangkumi tingkah laku CPO juvenil. Oleh itu, pemerhatian tingkah laku CPO dewasa dalam kaptiviti amat diperlukan. Lagi pula, di Malaysia, kajian terhadap tingkah laku CPO masih kurang. Kajian ini mengenal pasti: ciri-ciri CPO yang tinggal di kaptiviti dan ciri-ciri persekitaran kaptiviti di Taman Buaya Tuaran; tingkah laku CPO pada waktu siang, malam, waktu diberi makan dan waktu tidak diberi makan; dan, tingkah laku seksual dan ketika bertelur pada musim mengawan serta tapak sarang pilihan CPO. Kajian sebelum ini menyatakan CPO menjadi agresif pada waktu subuh dan senja, dengan menunjukkan tingkah laku melibas ekor dan serangan pada bahagian kepala (TWSHS). Butiran struktur kaptiviti CPO dan parameter air serta suhu persekitaran didapati melalui sesi temubual bersama pekerja di Taman Buaya Tuaran. Pemerhatian teliti, merangkumi waktu siang, malam, waktu diberi makan, dan tidak diberi makan, telah dijalankan dalam kawasan kaptiviti di Taman Buaya Tuaran. Pemerhatian terhadap tingkah laku seksual dan ketika bertelur dijelaskan secara terperinci sekaligus bersama penjelasan mengenai sarang tempat CPO bertelur. Pemerhatian tingkah laku yang telah dijalankan dimasukkan dalam kuantifikasi data. Data yang dimasukkan dalam kuantifikasi tadi kemudiannya dianalisis menggunakan kaedah Morpurgo *et al.* (1993) setelah data diperiksa menggunakan IBM SPSS Statistics 22. Hasil kajian menunjukkan struktur kaptiviti CPO di Taman Buaya Tuaran sesuai dengan habitatnya dengan saliniti air kolam yang optimum, 20 ppt. Hasil kajian menyatakan tahap agresif yang ditunjukkan oleh CPO di Taman Buaya Tuaran adalah ketika waktu siang khususnya semasa diberi makan. Nilai kepadatan stok yang berhubungkait sifat agresif adalah bersamaan dengan 8.06 pergerakan/min diperhati dalam densiti 0.3 buaya/m^2. Tingkah laku yang sering ditunjukkan oleh CPO ialah TWSHS dan huraian mengenai tingkah laku pada musim mengawan serta ketika bertelur juga dijelaskan secara saintifik. Dapatan kajian ini boleh digunakan untuk menjelaskan tingkah laku CPO khususnya kepada pelajar yang berminat untuk mempelajari lebih mendalam bidang reptilia marin, kerana untuk menjalankan kajian di kawasan liar adalah amat sukar, memakan banyak masa, dan juga berbahaya.

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LIST OF SYMBOLS

h	hour
kg	kilogram
m	meter
m^2	meter square
min	minute
pH	power of Hydrogen
p	significant difference
ppt	parts per thousand
s	second
′	minute (coordinate)
o	degree
^oC	degree Celsius
~	tilde symbol
%	percentage

LIST OF FORMULA

Formula	Page
$\text{Mean Duration of Interactions (min)} = \frac{\text{Total Duration (s)}}{\text{Number of Behaviours Exhibited}} \div 60$	19
$\text{Aggression (events/min)} = \frac{\text{Number of Behaviours Exhibited}}{\text{Number of Individuals} \div 100} \div \text{Mean Duration of Interactions}$	19
$\text{Stock Density (crocodiles/m}^2\text{)} = \frac{\text{Number of Individuals}}{\text{Total Area of the Housing}}$	20

LIST OF ABBREVIATIONS

B	Bite
CPO	*Crocodylus porosus*
Dr.	Doctor
E	East
et al.	*et alia* (and others)
HTR	Head and tail raised
HP	Head push
HRH	Head raised high
IP	Inflated posture
ITS	Inflated tail sweep
LIW	Low in water
LJC	Light jaw-clap
MA	Mouth agape
Mr.	Mister
N	North
PD	Push down
RF	Rapid flight
SF	Slow flight
SHS	Side head-strike
TW	Tail-wag
TWB	Tail-wag bite
TWSHS	Tail-wag side head-strike
UMS	Universiti Malaysia Sabah
V	Vocalization

CHAPTER 1

INTRODUCTION

1.1 Overview Saltwater Crocodile

Crocodylus porosus (CPO) is the largest living reptile in the world. No other reptile matches its size, strength, or hunting abilities in the wild. Due to its ability to travel long distances, the saltwater crocodile has a wide distribution where it is mostly found on the coasts of Northern Australia, New Guinea, and Borneo Island (Kawamoto, 2006). The saltwater crocodile can tolerate saline environments very well, which is why the saltwater crocodile typically found in brackish water around coastal areas.

CPO has a very large head and extremely strong, powerful jaws, comprised of the codont teeth (Figure 1.1). An adult male crocodile can apply up to about one tonne of jaw pressure with a single bite. Short limbs, a thick, laterally compressed tail, and webbed feet enable it to swim at high speeds during short bursts or at a leisurely pace. To swim, the crocodile folds its limbs against its body and laterally undulates, using its tail and body to move through the water.

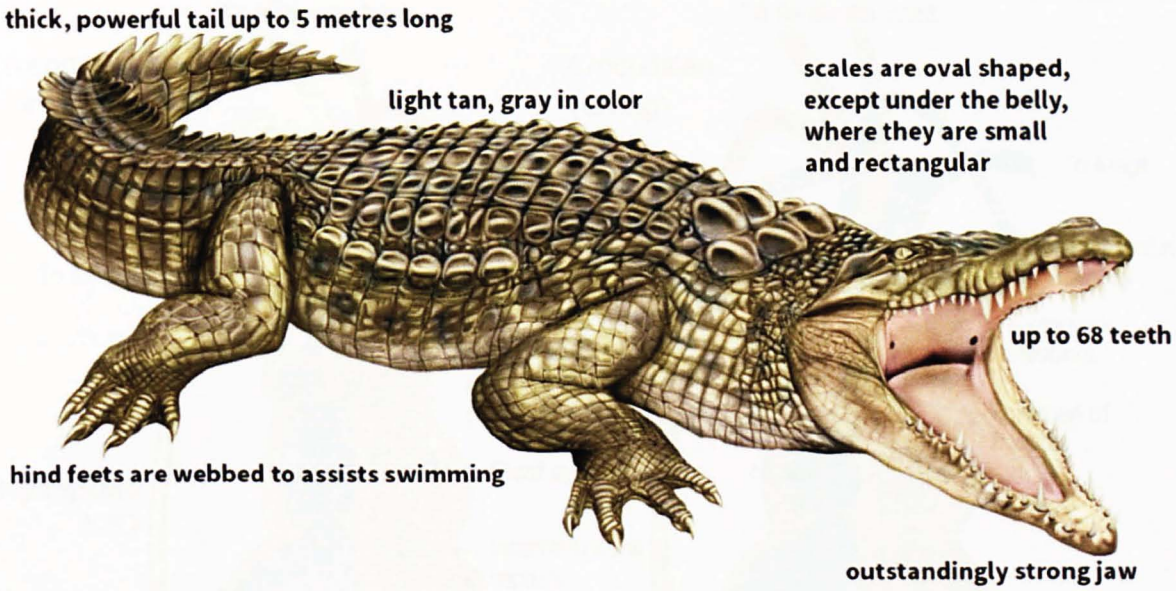

Figure 1.1 General anatomy of saltwater crocodile (James, 2010).

Like birds and mammals, crocodiles also have a four-chambered heart (Figure 1.2). A valve in the crocodilian heart shuts off the pulmonary system when it dives into the water. The heart is located under the lung and close to the liver (Figure 1.3). Saltwater crocodile also has salt-secreting glands called lingual glands located at the back of their throat for maintaining osmolarity. Saltwater crocodiles can conserve water by excreting excess sodium ions through their glands instead of the kidneys. The acidity of the crocodilians' stomach allows them to digest almost anything, including bones and shells of prey animals.

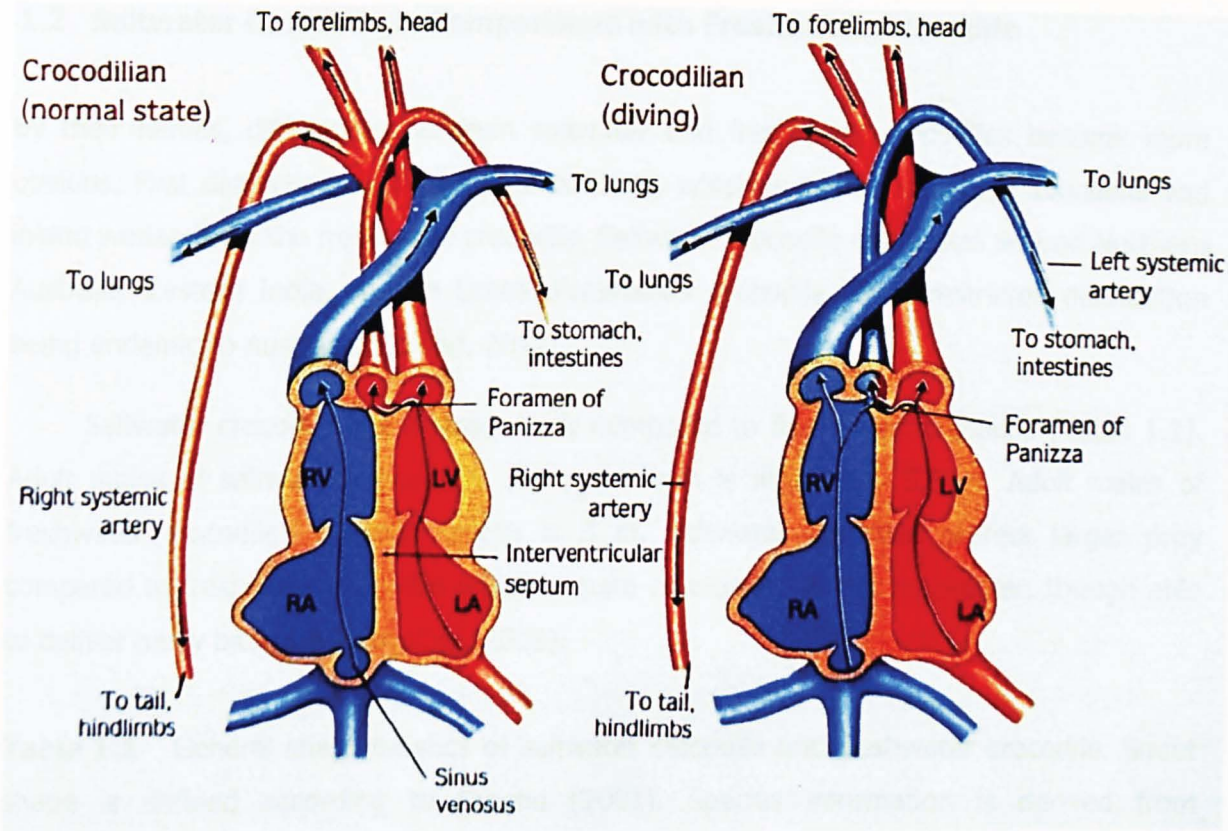

Figure 1.2 Crocodilian's four-chambered heart which is different than any other reptile (Richardson, 2000).

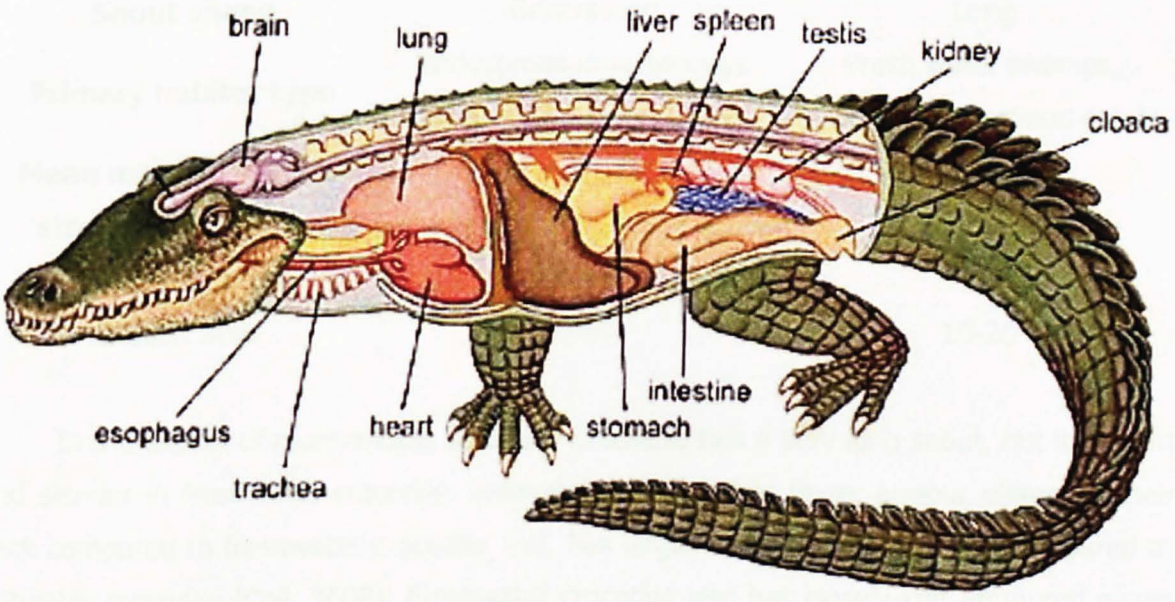

Figure 1.3 Internal organs of Saltwater Crocodile (Mozley, 2004).

1.2 Saltwater Crocodile in Comparisons with Freshwater Crocodile

By their names, differences between saltwater and freshwater crocodiles become more obvious. First distinction would be their habitats, which is sea for saltwater crocodile and inland wetlands for the freshwater crocodile. Saltwater crocodile distributes around Northern Australia, Eastern India, and Sri Lanka. Freshwater crocodile has a restricted distribution being endemic to Australia (Edlund, 2012).

Saltwater crocodile has a larger body compared to freshwater crocodile (Table 1.1). Adult males of saltwater crocodile's average length is about 4 – 5.5 m. Adult males of freshwater crocodile's average length is 3 m. Saltwater crocodile prefers larger prey compared to freshwater crocodile which is quite considered as not man-eater, though able to deliver nasty bite to human (Coil, 2008).

Table 1.1 General characteristics of saltwater crocodile and freshwater crocodile. Snout shape is defined according to Brochu (2001). Species information is derived from Groombridge (1987) & Thorbjarnarson (1992).

Species		*C. porosus*	*C. johnstoni*
Geographical location		South East Asia	Northern Australia
Snout shape		Generalised	Long
Primary habitat type		Widespread in waterways from coastal to far inland	Fresh water swamps, billabongs, rivers and creeks
Mean max. size (m)	**Male**	5	3
	Female	3	2
Nesting strategy		Mound	Hole
Clutch Size		30-60	10-20

In the aspect of morphology, saltwater crocodile has a very long snout, but it is short and slender in freshwater crocodile. Saltwater crocodile has fewer armour plates on their neck compared to freshwater crocodile, but, has larger and wider body scales compared to saltwater crocodile (Coil, 2008). Freshwater crocodile also has closely-knit armoured plates on its neck, which saltwater crocodile does not.

1.3 Captive Crocodile in Comparisons with Wild Crocodile

In term of number of hatchlings, obviously the survival rate of hatchling captive crocodile is higher than the survival rate of hatchling wild crocodile. The main reason to keep the crocodile in captivity is to preserve its species biodiversity. Other than that, keeping the crocodile in captivity also encourages research in the similar field, as educational purposes such as science observation for outdoor classes, and obviously as one of the most popular tourist attraction. The habitat of crocodile is categorized as threatened (Mabuwaya Foundation, 2003) therefore keeping the crocodile in captivity will help the hatchling to survive with higher rate compared to the wild ones.

The diet of crocodile in captivity is also well-prepared. There are various types of diet for crocodile according to their age. In captivity, the feeding is sufficient compared to the wild crocodile which it will feed on animals only if it hunts. Fortunately for wild crocodile, it is adapted to prey-predator environment where hunting skill is learned since the age of juvenile and the captive species has nothing of the hunting skills, at all (Mayer *et al.*, 1998).

Combative interactions of crocodile are usual. Two individuals which get involved will be led to severe injuries from one side or both. Wild crocodile will never have any medical treatment if they get injured like what captive crocodile will get. Thorough observations and treatments will get most attention in captive crocodile. According to the farm crews in Tuaran Crocodile Farm, once any individual get injured, medical treatment will straight be given to avoid loss of life. In similar points, the death rate of captive crocodile is lower than the crocodile which is growing in the wild.

There is a wider area for crocodiles' habitat in the wild which is greatly different to the housing area in captivity that is smaller. Open area for animals' habitat will affect the interactions between individuals (Lang, 1989).

1.4 Agonistic Behaviour

Agonistic behaviour plays an important role in determining access to resources such as food, shelter, courtship mates, and in establishing dominance status in a wide range of reptiles (Barker & Murphy, 1979). Among reptiles, crocodilian's behaviour is largely considered 'hard wired' from birth. However, detailed information on agonistic behaviour among adults of crocodilian is limited, especially in Malaysia, due to the limited access into the Crocodile Farm

itself. According to the study of Lang (1987) and Brien *et al.* (2013), males of saltwater crocodile are quite fearsome during the mating season as it is described as the males get in an agitated state then wind themselves up and swing their heads into other crocodiles.

1.5 Objectives

The objectives of this study are:

1. To study the characteristics of captive adult saltwater crocodile and the housing environment of the captivity area in Tuaran Crocodile Farm.
2. To determine the value of stock density related to aggression of saltwater crocodile in captivity through observations at daylight and night.
3. To determine the value of stock density related to aggression of saltwater crocodile in captivity specifically during feeding time and non-feeding time at daylight.
4. To study the courtship behaviour, nesting site, and egg-laying behaviour of captive saltwater crocodile during mating season.

1.6 Hypotheses

The hypotheses of this study are:

1. The housing environment in Tuaran Crocodile Farm meets the optimum requirement for captive saltwater crocodile's habitat (20 ppt salinity and proper housings structure).
2. The value of stock density related to aggression of saltwater crocodile is higher at daylight compared to night.
3. The saltwater crocodile is more aggressive during feeding time than non-feeding time as the value of stock density related to aggression during feeding time is higher than feeding time.
4. Captive saltwater crocodile undergoes courtship underwater before the female lays eggs in the preferred nesting site and goes into trance-like state during egg-laying but when the egg-laying is completed, it becomes very highly protective near its mound nest.

1.7 Significance of Study

The study of crocodilian social behaviour in the wild has been generally a difficult or nearly impossible task because most of its activity is performed below the surface of the water. However, progress has been made through studies in captivity, benefited by the large number of captive breeding programs which have been established during the last four decades. These studies allow the examination, at close range, of certain behaviours exhibited by animals accustomed to the presence of humans, which could hardly be documented in the wild. Despite high animal densities in captivity lead to an increase of social encounters, many of the observed interactions are usually specific and peculiar to the social behaviour of a particular species (Lang, 1989).

The study is carried out to gain information regarding the agonistic behaviours of saltwater crocodile, where the study takes place at Tuaran Crocodile Farm. There is no such previous study at this farm. Through personnel communications, the farm crews are keeping the adults of the species under a thorough supervision and secured equipment in captivity where the aim of the project to study the agonistic behaviours of the crocodilian is significant.

As agonistic behaviour in saltwater crocodile plays an important role in determining access to resources such as food, shelter, courtship mates, and in establishing dominance status, this study is essential to describe the behaviour as further studies regarding similar field are able to relate between the agonistic behaviour and the explanation why saltwater crocodile is hard-wired with this behaviour since they were born.

CHAPTER 2

LITERATURE REVIEW

2.1 Behaviour and Interactions

For most species, interactions appeared to occur accidentally when individuals lying together disturb each other when moving off, or if one swims into another. However, interactions are also initiated by one individual moving deliberately toward another in either a single movement or in a series of short, rapid advance movements. In response to an approach, an animal displayed a series of other agonistic behaviours. Below are the agonistic interactions that were studied by Brien *et al.* (2013), a wildlife biologist in Charles Darwin University.

Table 2.1 Description of various postures, non-contact and contact movements displayed by crocodilians during agonistic interactions.

	Abbreviation	Definition
Initiation		
Rapid advances	RA	Series of short rapid advance movements towards another individual while low in water.
Termination		
Slow flight	SF	Slow movement away from another individual in a low in water posture.
Rapid flight	RF	Rapid movement away from another individual in a low in water posture.

Posture		
Low in water	LIW	Immobile with only the top of the head and back above the water surface.
Inflated posture	IP	Immobile with upward extension of either the front two or all four limbs, with neck and back arched high and head and tail angled downward.
Head and tail raised	HTR	Immobile with head and tail raised out of water while back remains low. Head is usually parallel to the water but can also be angled upwards.
Head raised high	HRH	Immobile with upward extension of the front two limbs pushing the head and chest high out of the water on a ~45° angle while tail remains low.
Mouth agape	MA	Immobile with mouth opened wide (all postures)
Non-contact movement		
Light jaw-clap	LJC	Rapid opening and closing of the jaws at the water surface, often repeated several times while low in the water or inflated.
Tail-wagging	TW	Undulation of the tail from side to side in either a gentle sweeping motion or rapid twitching, often repeated several times (all postures).
Inflated tail sweep	ITS	In an inflated posture, the whole tail is swept side to side in a slow deliberate fashion as the individual approaches another. This becomes more rapid and the tail is trashed from side to side.
Vocalization	V	Vocalization observed and confirmed from body movement.

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