POPULATION ECOLOGY AND POTENTIAL FOOD SOURCES OF THE SALTWATER CROCODILES IN KAWANG RIVER, SABAH

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ABSTRACT. *Kawang River is one of the remaining habitats for Crocodylusporosus (saltwater crocodile) on the west coast of Sabah. The objectives of this study are to find the current abundance of C. porosus, to obtain their historical background, list fish and invertebrates that could be their food sources, and potential human-crocodile conflict (HCC) issues in the Kawang River. Spotlight surveys to search for crocodiles and interview surveys were conducted to obtain more information on their historical background and HCC issues. Two fishing trips were also made to investigate the potential food sources (fish and invertebrates) of C. porosus in the river. Results from three spotlight surveys showed 36 C. porosus were recorded. The average calculated density of C. porosus was 2.73 crocodiles km^{-1}andthe value has appeared to increase marginally from 2.11 crocodiles km^{-1} but statistical analysis showed that there was no significant mean difference of density of the C. porosus between the past and current study. From the 18 local people interviewed, 15 claimed that they have seen crocodiles in the Kawang River with high proportion (50% of different crocodile sizes estimated by the interviewees) of immature crocodiles. The results from fishing trips identified seven species of fish and two species of invertebrates as potential food sources. Interview results showed that the awareness of the local people towards HCC was low in the Kawang River, altogether with poor livestock management and human encroachment into crocodile habitats, these factors can trigger HCC in the future.*

KEYWORDS. Abundance, human-crocodile conflict, interview surveys

INTRODUCTION

The saltwater crocodile, *Crocodylusporosus* which is also known as the estuarine crocodile was discovered by a German naturalist Johann Gottlob Schneider in 1801. *C. porosus* has been listed as a 'Protected Species' since 1982, and remains on Schedule 2 of the Sabah Wildlife Conservation Enactment 1997. It is also listed as 'Endangered' under CITES Appendix I (Sabah Wildlife Department, 2002).

In Sabah, the saltwater crocodiles inhabit rivers, freshwater swamps and mangrove habitats in several protected areas, such as the Kinabatangan Wildlife Sanctuary and the Kulamba Wildlife Sanctuary (Sabah Wildlife Department, 2002). According to the department, estuarine crocodiles probably exist in the tidal sections of most of Sabah's rivers.

The first crocodile study in Sabah was done by Whitaker (1984) on *C. porosus* abundance in a six-week assessment. A total of 1,146km of riverine habitat was and 56 *C. porosus*werefound. This gives a minimum density of 0.05 crocodiles km^{-1} with the value of corrected density 0.21 crocodiles km^{-1}. After about twenty years later, Sabah Wildlife Department (2002) did a thorough population census on the *C. porosus*status. The results obtained were a minimum density of 1.1 individuals km^{-1} and corrected density of 2.27 individuals km^{-1}. Based on corrected average densities, crocodile numbers have increased in

some rivers by about ten-fold during the last twenty years.

Norazmi (2008) conducted the only crocodile survey in the Kawang River. The result showed that an average density of 2.4 crocodiles km^{-1} and corrected density of 4.52 crocodiles km^{-1}in the 5 kilometers of the Kawang River main channel surveyed. The aims of this study are to find the current abundance of *C. porosus* in the Kawang River and to obtain the historical background of *C. porosus*.

This study also represents a first attempt to obtain a list of abundant species of fish and invertebrates that could be essential food items for *C. porosus* in the river and to identify potential HCC issues that are happening in the Kawang River.

MATERIALS AND METHODS

Study Area

Kawang River is located on the West Coast of Sabah, between latitude 5° 46' N to 5° 48' N and longitude 116° 00' E to 116 ° 01' E, with an approximation of 30km from the Kota Kinabalu City. The location of Kawang River is shown on the Figure 1. The majority areas of the river are dominated by mangrove vegetation, *Rizhoporaapiculata* and in the upper stream co-dominated with *Nypafruticans*.

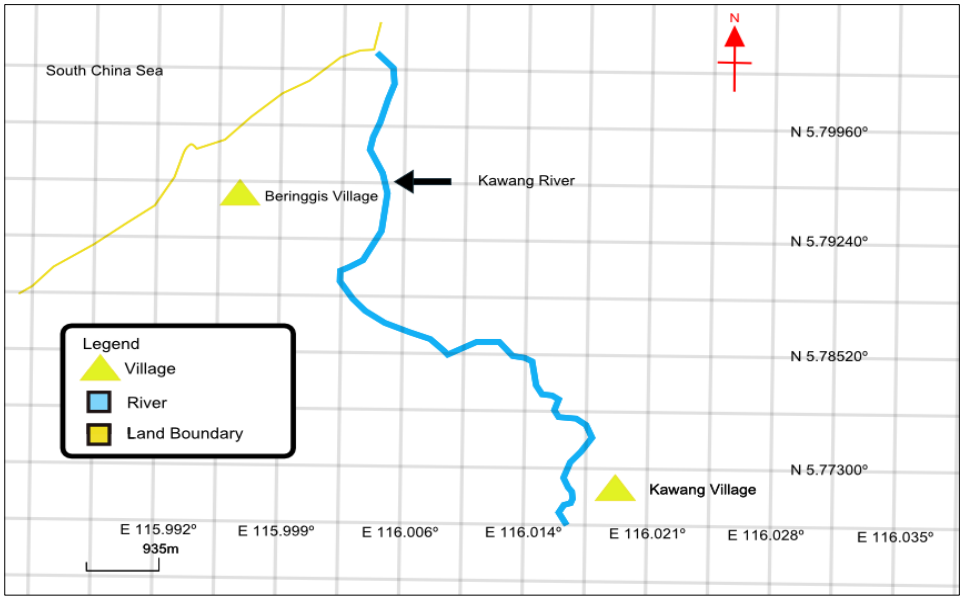

Figure 1.The map of the Kawang River on the West Coast of Sabah.

Data Collection

Spotlight surveys were used to estimate the abundance of the *C. porosus* in the Kawang River. It was conducted once every two monthsfrom October 2010 until February 2011.Each survey covered a distance of 4.4 kilometers of the main channel ofKawang River.

Spotlight surveys are crocodile surveys which use a powerful spotlight to count crocodile numbers from boat and have their sizes estimated by approaching the animals to within 6 m (Messel&Vorlicek, 1989). Surveys were conducted during ebb tide as more crocodiles are visible with an increase in the amount of exposed mud bank (Bayliss, 1987). When a light source was shined at a crocodile under low light conditions, the eye shine was distinctive red or white colour (depending on the angle and intensity of the light), due to the reflection of the light off the retinal tapetum and it could be seen from beyond a hundred metres away under ideal conditions (Department of Environment and Resource Management

of the state Queensland, 2011). Once an individual crocodile was sighted and with its size estimated, it was assigned into standard size class following standard classification of saltwater crocodile using the Bayliss's method (1987).

Global Positioning System (GPS) device with mapping software was used to record all routes and locations. The position of crocodiles in the waterways and along riverbanks was recorded using a GPS once crocodileswere sighted.

A list of questions was asked in the interview surveys to obtain the historical background of the *C. porosus* and to assess into the HCC issues in the Kawang River. Target group of the interview surveys were those local people who live near the river.

In order to assess the potential food sources of *C. porosus* in the Kawang River. Two fishing trips were conducted. Gill nets, trammel nets and a cast net were used in this study.

Data Analysis

During spotlight surveys, crocodile individuals were classified into standard size class adapted from Bayliss (1987) where 7 classes of crocodiles were introduced (see Table 1).

Table 1. The classification of saltwater crocodiles adapted from Baylis (1987).

Class	Size (Total body length, m)
Hatchling	<0.5
1	0.5 ≤ 1.0
2	> 1.0 ≤1.5
3	>1.5 ≤2.0
4	>2.0 ≤3.0
5	>3.0
6	EO (Eyes only)

'Class 6' implies that only the eye shines of the crocodileswere able to be detected but the body size was unable to be estimated.

The density of the crocodiles sighted was estimated by using the following equation adapted by Bayliss (1987) as follow:

Density = Total number of crocodiles sighted / Total distance of survey length (km)

Correction factors adapted from Bayliss (1987) were introduced to correct the relative density to absolute density for better estimation of the total crocodile population size. The corrected population density was estimated by using the following equation:

$$\text{Corrected population density} = \frac{\sum (\text{Number of individual per class} \times \text{Correction factor per class})}{\text{Total distance of survey area (km)}}$$

The following table gives the correction factor adapted from Bayliss (1987).

Table 2.The correction factor according to different classes of saltwater crocodiles (Baylis, 1987).

Class	Size (Total body length, m)	Correction factor
Hatchling	< 0.5	1.44
1	0.5 ≤ 1.0	1.34
2	>1.0 ≤ 1.5	1.30
3	>1.5 ≤ 2.0	1.34
4	>2.0 ≤ 3.0	1.78
5	>3.0	3.08
6	EO (Eyes Only)	6.54

Table 3.The DAFOR scale table.

Group	Sighting per unit effort
Dominant	> 20
Abundant	11 ≥ 20
Frequent	5 ≥ 10
Occasional	3 ≥ 4
Rare	1 ≥ 2
Absent	0

All specimens caught from the fishing trips to catch the potential food sources of the *C. porosus* in the Kawang River were kept into separate plastic bags and identified at the labarotary.

RESULTS AND DISCUSSIONS

Spotlight Surveys

A total of three spotlight surveys were carried out and 36*C. porosus* of different size classes were recorded. The results from all the spotlight surveys were summarized in Table 3.

Table 3.Summary of spotlight surveys done.

Spot-light survey	Date	Distance covered (km)	Number of crocodiles according to different size classes					Number of individuals
			Hatchling	1	2	3	6	
1	23 Octo-ber 2010	4.4	2	4	-	-	2	8
2	4 Decem-ber 2010	4.4	3	3	1	1	-	8
3	26 Febru-ary 2011	4.4	10	3	2	-	5	20
		Total	15	10	3	1	7	36

The Densities and Corrected Densities of the *C. porosus* in the Kawang River

A total of 36*C.porosus* were sighted from the three spotlight surveys thus giving density values ranging from 1.82 to 4.55 and an average density of 2.73 ± 1.58 crocodiles km^{-1} in the 4.4 kilometers of river water surveyed.

Results fromNorazmi (2008) study showedan average densityof 2.40 crocodiles km^{-1}in the 5 kilometers of river water he surveyed. If this figure is standardized into the 4.4 kilometers of survey length in the main channel of the Kawang River that is slightly different to present study, the average density was only 2.11 crocodiles km^{-1}. There was no significant mean difference of densities of the *C. porosus* between the past study (Norazmi, 2008) and current study ($\alpha \leq 0.05$, one sample t-test) although the average crocodile density has appeared to be increased marginally from 2.11 crocodiles km^{-1} to 2.73 crocodiles km^{-1}.

From the 36 *C. porosus* sighted, a high proportion of the sightings were categorized as 'Hatchling' (15 animals or 41.67%). The 21 non-hatchling *C. porosus* recorded, 13 crocodiles (36.1%) were estimated to be 0.5 m to 1.0 m in length, 3 crocodiles (8.3%) were 1.0 m to 1.5 m in length and 1 crocodile (2.7%) was 1.5 m to 2.0 m. There was no recorded observation of *C. porosus* greater than 2.0 m.Seven crocodiles (19.4%) were also categorized as 'Class 6' as their sizes could not be estimated by the observers. The population was strongly biased towards immature animals with 100 per cent of all *C. porosus* sighted (where total length was estimated) being equal or less than 2.0 m in length.There were no crocodile greater than 2.0 m in length sighted during the survey period. It was likely that some of the recorded eyes only or 'Class 6' observations could be indicative of large size class of crocodiles given that large crocodiles exhibit wariness to human activity (Bayliss, 1987).

The number of hatchlings recorded in the third spotlight survey (n_3=10) was higher than the previous two surveys (n_1=2 and n_2=3). The third survey was done in the February and according to Stuebing (pers comm.), the early month of January until the middle of March is the time when *C. porosus* usually hatch in the Klias River which also located at the west coast of Sabah. Although there is no information on *C. porosus* breeding status in the Kawang River, it may be inferred that crocodile hatchlings also hatch around that period. Thus, contributing to the higher number of hatchlings found during the third spotlight survey.

Due to visibility bias discussed earlier, the corrected density was applied. In this study, the corrected density values calculated were as follow: 3.94, 3.05 and 6.96 for the three spotlight surveys done. Table 4 summarizes the densities and corrected densities for *C. porosus* found in the Kawang River during the spotlight surveys.

Table 4. The densities and corrected densities of *C. porosus* found in the KawangRiver.

Spotlight survey	Distance covered (km)	Number of crocodiles according to different size classes					Number of individuals	Density (Number of crocodiles km^{-1})	Corrected density (Number of crocodiles km^{-1})
		Hatchling	1	2	3	6			
1	4.4	2	4	-	-	2	8	1.82	3.94
2	4.4	3	3	1	1	-	8	1.82	3.05
3	4.4	10	3	2	-	5	20	4.55	6.96

Interview Surveys

A total of 18 people from the Kawang and Beringgis villages were interviewed to obtain some historical background of *C. porosus* in the Kawang River. From all the 18 interviewees, 15 have seen *C. porosus* in the Kawang River. The highest number of crocodile belonged to a size class seen was the the 'Hatchling' (Total body length, < 0.5 m) (n=10) followed by 'Class 5' (Total body length, >3.0 m) (n=8) and 'Class 1' (Total body length, 0.5 ≤1.0 m) (n=7) crocodiles. 'Class 5' crocodiles are large adult crocodiles which have reached their maturity and according to some local people, during the early dawn, they could be spotted basking along the river banks. Figure 2 shows the categories of different crocodile sizes seen by the interviewees. Most of the interviewees (67%) also agreed that there have been more crocodiles recently compared to the past. Two interviewees said that crocodile numbers were decreasing and two claimed crocodile numbers to remainthe same. Only one interviewee was unsure about the crocodile population structure. Relating this to the crocodile abundance that

has been calculated, it is believed that crocodile number is increasing in theKawang River even though it may be at only a marginal value.

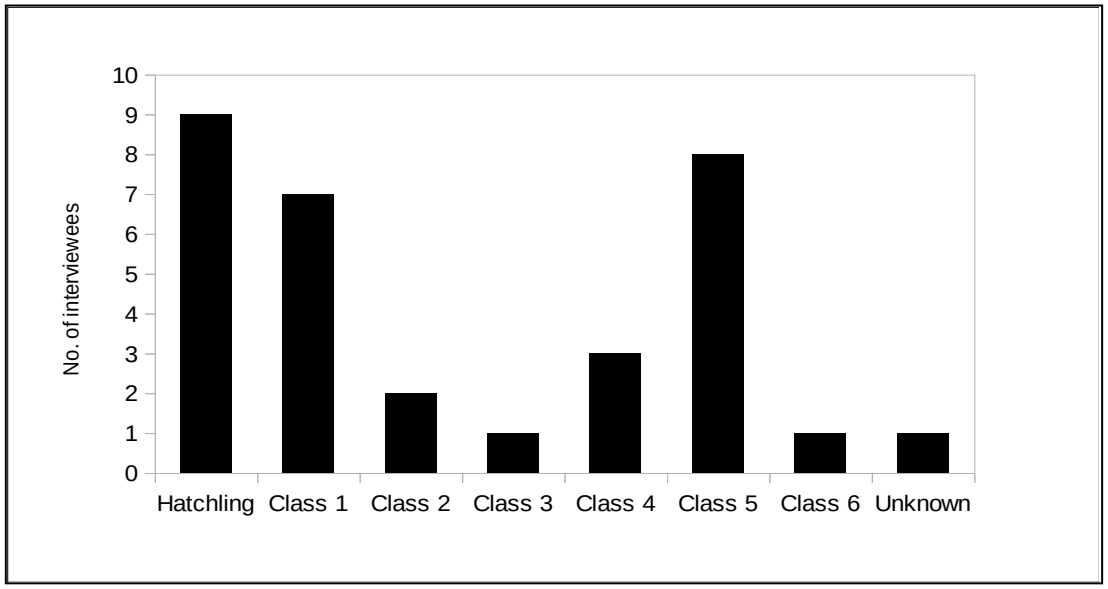

Figure 2. The total crocodile sightings according to different size class distribution.

Sighting per Unit Effort of the Interviewees

Based on the DAFOR scale (Table 3), all 15 interviewees who have seen crocodiles in the Kawang River were categorized into different groups. The highest number of people was categorized as 'Rare', meaning only 1-2 sightings had been recorded for the past 5 years (2005-2010). Figure 3 shows the sighting per unit effort of interviewees that have seen crocodiles in the Kawang River. More than half of the interviewees (53.3%) which have seen crocodiles were categorized into the top 3 groups: 'Frequent', 'Abundant' and 'Dominant', for which crocodile sightings range from at least 5 sightings per year up to at least 20 sightings per year, this might indicate that crocodiles can be commonly sighted by the villagers around the Kawang River.

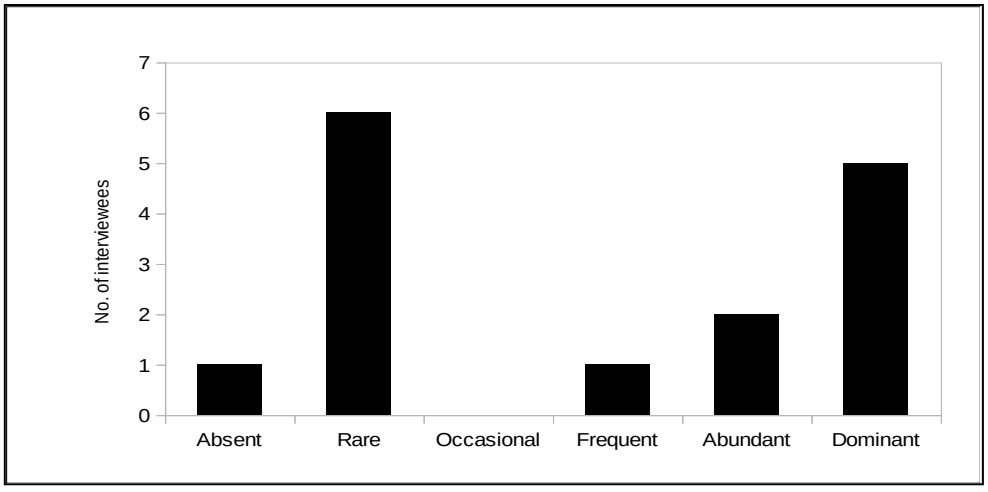

Figure 3.The sighting per unit effort of the interviewees.

The Species List of Fish and Invertebrates Caught

Based on the two fishing trips carried out on the 16 September and 21 October 2010, seven species of fish and two species of invertebrates were caught. Table 5 summarizes the species list of fish and invertebrates that might be the potential food sources of the *C. porosus* in the Kawang River.

Table 5. A species list of fish and invertebrates caught that may be the potential food source of the *C. porosus*intheKawang River.

Fish	Invertebrates
Catfish (Ikanduri), *Arius caelatus* (7)	Mud crabs (Ketambakau), *Scylla paramanosian*(4)
Toadfish (n.a.), *Allenbatrachusgrunniens*(2)	White prawn (Udangputih), *Penaeusindicus*(1)
Spotted scat (Kertang), *Scatophagusargus* (1)	
Orange spotted grouper (Ikankerapu), *Epinepheluscoiodes*(1)	
Archer fish (Ikansumpit), *Toxotesjaculatrix* (1)	
Indo-pacific tarpon (Ikanbulan), *Megalopscyprinoides*(1)	
(n.a.), *Neostethus* sp. (1)	

*The first brackets in each column indicates the local names of the fish or invertebrates in Sabah and the second brackets in each column indicates the number of individual/individuals caught.

The diet list did not include insects (suborder Coleoptera and Homoptera) which were a major component in the diet of juvenile crocodiles in the Klias River (Shahrul&Stuebing, 1996). Taylor's (1979) reporting on the main diet of subadult*C.porosus* in Northern Australia of mainly the subfamily Sesarminae was also not found in the list although they were abundant based on observation. In that study, Taylor (1979) also claimed that crustaceans are an important food of juvenile *C. porosus* in tidal habitats. *Scylla paramamosain*, a mangrove crab species which was found to be caught frequently, may be a major food source for the *C. porosus* in the Kawang River.

Shahrul and Stuebing (1996) reported that only atyid prawns of genus *Caridina* were regularly eaten by juvenile *C. porosus* in the Klias River although other prawns (eg. *Macrobrachium* and *Penaus*) occur in the Klias River. In this study, no *Caridina* prawn was found but generally this study believes that *C. porosus*will take on any prey suitable for their respective sizes due to their reputable status as the opportunistic feeders although insects can constitute the major food sources of the juveniles and adults take larger preys with an increasing proportion of prey size as their body sizes increase (Cooper-Preston & Jenkins, 1993).

Human-Crocodile Conflict (HCC)

Human-crocodile conflict was not a big issue in the Kawang River based on the interview surveys. Only 5 out of the 15 interviewees interviewed have seen or heard about HCC issues. No case has been reported yet regarding human fatalities or injuries sustained due to crocodile attacks in the Kawang River.

According to the interviewees who claimed to have seen or heard of HCC, crocodiles would sometimes wander into a small creek near the Beringgis Village to prey on the livestock (such as goats and chickens) that strayed into the river banks. Even though this danger still lurks until today, no action has yet been taken to curb this problem. From personal observation, despite the risks involved, poor livestock management has to be put into blame in response to the threat.

Another reason that could trigger HCC was the close proximity of human settlements near crocodile habitats. At the upstream region where the Kawang Village lies, some houses could be seen just a few meters away from the river's edge. It was evident that human settlement has lead to encroachment into crocodile habitats. Lamarque*et al.*(2009) claimed that conflict between crocodiles and local communities escalate because of loss of habitat as the crocodile range become more and more fragmented and crocodile is also confined into smaller pockets of habitat, leading to increasing contact between human and crocodiles and in conflict with each other.

Wallace (2010) reported that in the Chiawa Game Management Area of Zambia, although majority of household had a borehole closer than the river, yet many people still utilize river water. This is because either the borehole is broken or it is quicker to perform daily activities near the river, as it eliminates the queing system at the borehole. Villagers around the Kawang River did not have the problem above as from personal observation; there was tap water available for each household. People generally were not dependant on river water for daily chores.

There are reasons to believe that the villagers from either the Beriggis Village or Kawang Village should be aware of HCC and foresee the danger before any human fatality is involved. When the interviewees were asked whether if they do keep a distance when actually see a crocodile, 9 interviewees answered no and one even showed the evidence he caught crocodiles using bare hands. In addition, only 9 out of the 15 interviewees were aware of *C. porosus*as a protected species in Sabah. This reflected that the awareness of the local people towards HCC was low, altogether with poor livestock management and human encroachment into crocodile habitats, these factors can trigger HCC in the future.

The crocodile population in the Kawang River is believed to be increasing although statistical analysis showed that between the past and current study, there was no significant mean difference of *C. porosus* density. Evidence based on field trips and interview surveys have augmented the idea that *C. porosus* are breeding well in the river due to the high number of immature crocodiles spotted. In addition, even most of the interviewees interviewed claimed that crocodile numbers are increasing due to the emergence of more hatchlings lately. Although the species of potential food sources caught may or may not represent the actual diet of the *C. porosus* in the Kawang River, it is believed that the crocodiles in the river will prey on any suitable prey as long as it suitable for their respective sizes. The local people's awareness towards HCC was low in the Kawang River, with the factors such as poor livestock management and human encroachment into crocodile habitats, it is afraid that HCC can happen in the future.

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