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Original Article

Density and management of estuarine crocodile in Samarahan river basin, Sarawak, Malaysian Borneo♣

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Abstract

Estuarine crocodile, *Crocodylus porosus* is the most common crocodile found in Sarawak, Malaysia. Despite its importance in ecological services, socio-economy and cultural belief, crocodiles are still considered pests due to frequent human crocodile conflicts (HCC) resulting in either injuries or death. This study determined the density of crocodiles in three selected rivers within Samarahan River Basin (SRB) of Sarawak, using a standard night spotting technique over a three-year period (2019-2021). The average density of crocodiles in SRB is showing an increasing trend, although there is active removal of the animals from the rivers either by commercial hunting or by relocation of certain individuals as immediate response to HCC. This paper also describes conservation initiatives carried out in SRB aiming to use crocodile as a resource in bioeconomy, which supports the United Nations Sustainable Development Goals.

Keywords: biodiversity, density, crocodile, resource utilization

1. Introduction

Estuarine crocodile, *Crocodylus porosus*, is widely distributed in the Indo-Pacific region including Bangladesh, Northern Australia, Brunei, Philippines, Sri Lanka, Indonesia and Malaysia (Webb, Manolis, & Brien, 2010). This species can live in different types of aquatic habitats; it regularly moves between rivers around the coasts and could also be found in offshore islands (Webb *et al.*, 2010). Estuarine crocodile has a large triangular head, broad snout and round eyes located on top of the head (Grigg, & Gans, 1993). Its body colour is typically green or pale tan and eventually fades becoming less colourful after some years, due to the presence of mud, algae and grime.

Crocodile is an apex predator; it plays a major role in maintaining nature's balance in the riverine ecosystem (Webb *et al.*, 2010). In terms of socio-economy, trade of crocodile leathers is a lucrative business. In addition, other body parts of the animal are also in high demand as they are used in Traditional Chinese Medicine practice (Hassan, Md Adzhar, Abdul-Gani, & Ahmad, 2018). Farming, ranching and crocodile-based tourism activities promote the growth of economy and human capital in the society (Webb *et al.*, 2010). Other than that, crocodiles play important roles in local people's beliefs and culture, as well as influence everyday life for example in local communities living along the rivers in coastal area of Sarawak Malaysia (Abdul-Gani, Hassan, Tisen, & Ahmad, 2022).

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Estuarine crocodile is listed as a Least Concern animal in IUCN Red List of Threatened Species, whereas in the *Convention on International Trade in Endangered Species* of Wild Fauna and Flora (CITES), it is under Appendix I in majority of range countries except for Papua New Guinea, Australia, Indonesia and Malaysia (wild harvest restricted to the state of Sarawak and Zero quota for wild specimens for the other states of Malaysia). In line with its new status in the Appendix II, Sarawak Crocodile Management Plan 2016-2020 had been established and now the state has begun its second Sarawak Crocodile Management Plan.

Studies on density, distribution and ecology of estuarine crocodile had been carried out in the Indo-Pacific region, for example by Saragih, Kayat, Hidayatullahand Hadi (2020) in Timor Island, East Nusa Tenggara; Sideleau (2015) in Indonesia; Santiapillai, and de Silva, (2001) in Sri Lanka; Tarun, Guerrero, Rodriguez, and Telan (2004) in the Philippines; and Webb *et al.* (2010) in Australia. For Malaysia, studies were mainly carried out by researchers in Malaysian Borneo, for example by Stuebing, Ismail, and Ching, (1994) in Sabah as well as Zaini, Ripot, Ubang, Francis, and Simon, (2014) in Sarawak. The local agencies such as Sarawak Forestry Corporation (SFC) and Forest Department of Sarawak (FDS) have been conducting crocodile surveys on several major rivers in Sarawak since 1994, but those data are kept as records for management purposes only.

Sarawak is the largest state in Malaysia, located in Borneo, with Sabah, Brunei and Kalimantan Indonesia as its neighbours. It has 22 large river basins and one of them is Samarahan River Basin (SRB). Batang Samarahan is the largest and longest river in SRB (approximately 70 km in length) with a complex network of rivers and tributaries. Batang Samarahan drains into the South China Sea where the river mouth is full of mangrove plants and *Nypa*, while towards the inland part, riverine forest and peat swamp can be found (Hassan, Ahmad, Md Adzhar, Abdul-Gani, Ayob, & Zainudin, 2016). SRB is one of the areas that recorded high numbers of human crocodile conflict (HCC) where the incidents of attacks on humans resulted in various degrees of injuries, and deaths (Abdul-Gani *et al.* 2022). Nonetheless, the river systems provide livelihoods for the local people, as they are used on a daily basis for irrigation of agricultural plots, water transportation, and freshwater fisheries.

Despite the presence of crocodiles and long history of HCC, limited scientific data related to crocodiles is available for SRB. Thus, the Sarawak state is still finding ways to optimize the usage of this resource. Research studies on the crocodiles are still on-going, and it is hoped that the data collected would be useful for sustainable utilization of crocodiles living in SRB, in the near future. This paper describes the density of crocodiles in three selected rivers within SRB, over a three-year period (2019 – 2021), with a brief insights into commercial crocodile hunting activities that are currently carried out, HCC in the area, development programs of public awareness towards crocodiles, and future crocodile-based ecotourism.

2. Materials and Methods

Methodology of this project involved two parts, namely (i) field surveys, and (ii) collection of secondary data related to estuarine crocodile.

Field surveys were conducted yearly in three selected rivers in SRB (Table 1, Figure 1). The surveys employed a night spotting technique adapted from Cox and Gombex (1985). All crocodiles were then classified according to their size class (hatchling, yearling, sub-adult and adult) as suggested by Abdul-Gani (2019).

Secondary data were obtained from Sarawak Forestry Corporation (SFC), a state agency entrusted to safeguard and sustainably manage the biodiversity. The data include**:** (i) information on permits given to the public to harvest crocodiles from the wild, (ii) details of HCC in SRB, and (iii) crocodile conservation activities in Samarahan area.

3. Results and Discussion

A total of 1, 022 crocodiles were spotted in this three-year study, ranging from hatchling to adult (including 'eyes only') (Table 2). The highest number of crocodiles recorded was in 2021 with a total number of 586 individuals, followed by year 2020 (N = 277 individuals) and 2019 (N = 159 individuals). The number of crocodiles spotted in this study was higher compared to Abdul-Gani (2014) and Cox and Gombex (1985) with 112 and 1 individual, respectively.

There is an increasing trend in the density of crocodiles in SRB from year 2019 to 2021 (Table 2), from 0.98 individuals/km in 2019 to 6.49 individuals/km in 2021. Sungai Tuang showed the highest density with 3.53 individuals/km in 2019 and 6.16 individuals/km in 2020, then increasing to 13.02 individuals/km in 2021. Meanwhile, the least increment was for Sungai Belat, from 1.73 individuals/km to 2.80 individuals/km in 2020, then increasing to 5.60 individuals/km in 2021. Hatchlings were excluded from the density calculation, following a suggestion by Webb *et al.* (1983). They reported that greater stability will be the result of excluding hatchling size class from the calculation when determining rates of recovery or population growth for *C. porosus* due to the high variance between nest abundance and mortality of hatchlings within nest (Webb *et al.*, 1989).

During the surveys in Sungai Tuang and Sungai Sabang, there were sightings of young crocodiles (hatchlings and yearlings) in groups or in near proximity to one another. The presence of young crocodiles in a particular area could be a sign of nesting site and the cluster of young crocodiles probably comes from the same nest (Webb *et al.*, 1977; Fukuda & Saalfeld, 2014). Additionally, it is also possible that there is a crocodile nesting place particularly with the presence of at least one adult crocodile nearby the young ones (Webb, Messel, and Magnusson, 1977). Other surveys for example by Abdul-Gani (2019), and Zaini *et al.* (2014) have also recorded high numbers of hatchlings sighted in rivers all over Sarawak.

In the current study, a high number of EO was also recorded (Table 2). It is likely EO were adults or sub-adults (Webb *et al.* 2010). EO also suggests that crocodile population in the river has high wariness probably due to the past experience of hunting or extreme disturbances, which had been noted in the older report by Cox and Gombex (1985). The presence of adult crocodiles near human settlement had also been observed in this study, similar to Hassan *et al.*

Table 1. GPS coordinates of the three rivers involved in this study

River	GPS Coordinates	
	Starting Point	Ending Point
Sungai Sabang	1° 25’ 29.3"N, 110° 32’ 13.498"E	1° 23’ 42.1"N, 110° 31’ 44.799"E
Sungai Tuang	1° 22’ 50"N, 110° 26’ 53.9"E	1° 27’ 15.5"N, 110° 29’ 54.399"E
Sungai Belat	1° 27’ 18.23"N, 110° 30’ 7.423"E	1° 26’ 30.293"N, 110° 27’ 29.721"E

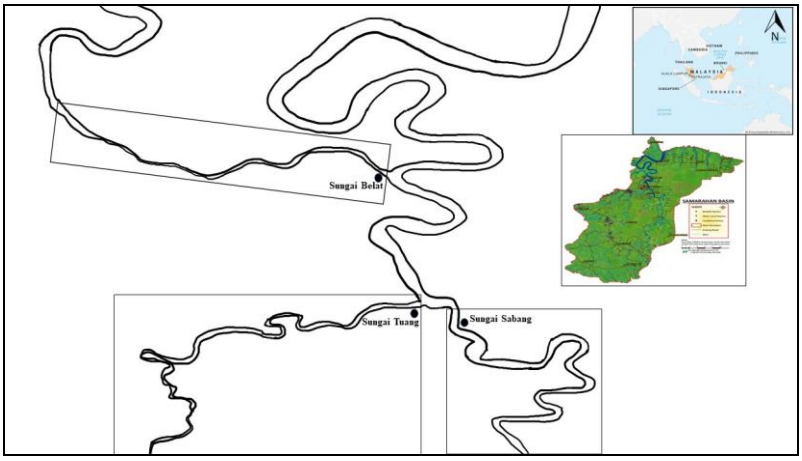

Figure 1. Map showing the three rivers involved in this study, namely Sungai Belat, Sungai Tuang and Sungai Sabang. Maps of SRB and Malaysia are included as inserts.

Table 2. Density of crocodiles by river in 2019 to 2021

Year	River	Number of crocodiles according to size class					Total number of individuals	Relative density (individuals/km)	Average density (non-hatchlings/km)
		Hatchling	Yearling	Sub-adult	Adult	EO			
2019	Sabang	25	6	3	0	9	43	2.87	
	Tuang	81	3	2	0	4	90	6.00	0.98
	Belat	9	5	2	1	9	26	1.73	
	Sabang	102	10	8	0	3	123	8.20	
2020	Tuang	88	16	6	2	0	112	7.47	`1.33
	Belat	27	4	3	0	8	42	2.80	
	Sabang	65	51	22	9	51	198	13.20	
2021	Tuang	208	29	5	40	22	304	20.27	6.49
	Belat	21	2	0	19	42	84	5.60	
	Total	626	126	51	71	148	1022		

*Size for Hatchling (less than 60 cm), Yearling (60 cm – 120 cm), Sub-adult (120 cm – 180 cm) and Adult (more than 180 cm)

(2018) probably because those adults were attracted to rubbish deposited in the rivers as easy food source.

Since 2018, local people are allowed to hunt wild crocodiles in Sarawak, provided that they obtain a permit from the Controller of Wild Life (Sarawak). From 2019 to 2021, a total of 16 licenses or permits were issued to local people for hunting estuarine crocodiles in SRB with a quota of 126 crocodiles given to the licence holders. For the period of three years, in total 34 adult crocodiles were caught and harvested from SRB by the licence holders, mainly for self-consumption or selling for around MYR10/kg (USD 2.1/kg) or higher to restaurants that serve exotic cuisine. However, records on the size and gender of the crocodiles taken out of the rivers were incomplete, thus a calculation on the biomass could not be done. In the future, more systematic data recording should be practiced so that an estimate of biomass could be carried out, and consequently better crocodile management plans can be produced.

Incidents of crocodile attacks on humans in Sarawak are considered high compared to other states in Malaysia, particularly those where the victims either suffered injuries or fatalities (Abdul-Gani *et al.* 2022). Table 3 displays information of HCC in SRB from years 2011 – 2021, where fatalities averaged one per year. Managing HCC is a challenging task for Sarawak, as sentiment is high after each incident or attack, thus improvement on the Standard Operation Procedure is needed to benefit both the animals and the local people living along the rivers. So far, after each incident of crocodile attack, a special task force from the SFC will catch the aggressive or any individual crocodile with

Table 3. Pooled HCC data in SRB for years 2011-2021

Results of HCC	Number of victims
Injury (non-fatal)	5
Fatal	10
Total	15

Data source: Sarawak Forestry Corporation

potential risk of attacks towards humans, using custom-made traps. Afterwards, those crocodiles are either: (i) relocated to conservation facilities such as Matang Wild Life Centre, sanctuaries and crocodile farms, or (ii) culled (if necessary). As for the victim, a police report must be made, which later becomes a supporting document for application of consolation money from the Welfare Department, Malaysia.

Fukuda, Manolis and Appel (2014) stated that the frequency of crocodile attacks is strongly related to the increasing human population in Australia. Similar claim was made by Abdul - Gani *et al.* (2022) when reviewing HCC incidents in Sarawak from 2020-2022. They both agree that as the human population grows, more areas are cleared for human settlement along with an increase in fishing pressure in the nearby rivers in order to meet local wet market demands on fish and other seafood, and consequently the availability of crocodile food is reduced. The more human and crocodile interactions happen, the more likely it is that conflicts arise.

Findings in this study revealed that the density of crocodiles in SRB is increasing although removal of the reptiles from the rivers is being carried out either by commercial hunting or as post-HCC immediate response. Abundance of crocodiles representing all cohorts in SRB shows that the population of crocodiles in the rivers is in a healthy state and not affected by the removal of several crocodiles. It is likely that new recruitments occur in the river and over time they will replace the crocodiles removed or captured by the hunting activities. It is also possible that crocodiles from other rivers migrate into these rivers due to an abundance of suitable habitats, and consequently a good chance to establish new territories (Webb *et al.* 2010). However, for long term sustainable management of the wild crocodile population, strict quota needs to be imposed on the hunting activities to avoid overexploitation. To mitigate HCC, it is important to educate the locals on how to safely co-exist with the crocodiles while lowering the risks of attacks rather than actively removing crocodiles in the river system. SFC had identified hotspots of HCC along the rivers leading to the development of public awareness program. Raising awareness among the younger generation on the importance of biodiversity and conservation is the top priority for Sarawak (Hassan, Azizi, Md Adzhar, Abdul- Gani, Ahmad and Leh, 2018). Other than that, SFC are organizing awareness program known as 3M, which is to get people to recognise, understand and conserve (3M – *Mengenali*, *Memahami dan Memulihara*) crocodiles. In the program, the public is taught about crocodiles in general, the importance of the animal to the ecosystem, and in socio-economic perspectives, the risks of HCC and tips on how to live with the crocodiles. The Resident Office of Kota Samarahan Sarawak has been initiating crocodile-based tourism program in 2019 with a series of Town Hall sessions involving local people living along the rivers. However, this activity was disrupted by the Movement Control Order during the *Covid -19* pandemic and this order is yet to be revoked. Research is on-going to support development of ranching and crocodile culture in small farms owned by local people. The state government is also being applauded for creating positive incentives for, for example, crocodile-based tourism activity in order to persuade local people to get involves in the conservation of crocodiles.

4. Conclusions

Density of crocodiles in Samarahan River Basin is showing an increasing trend, along with a high number of Human Crocodile Conflict (HCC) that has been recorded. To ensure that humans and crocodiles can co-exist within the same landscape, current conservation efforts emphasize awareness education as well as monetary benefits to the local people living along the rivers, in line with circular bioeconomy and eventually the United Nations Sustainable Development Goals.

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