A preliminary study on the population and habitat of saltwater crocodile (*Crocodylus porosus*) in Timor Island, East Nusa Tenggara

G S Saragih¹,², Kayat², M Hidayatullah³,² and D S Hadi²

¹ Center for Research and Development of Quality and Environmental Laboratory Gd. 210, Komplek Puspiptek, Serpong, South Tangerang, Indonesia
² Kupang Research and Development Institute for Environment and Forestry Jl. Alfons Nisnoni No.7, Kupang, East Nusa Tenggara, Indonesia
³ Research and Development Institute of Technology Non-Timber Forest Product Jl. Dharma Bakti No.7, Lombok Barat, West Nusa Tenggara, Indonesia

E-mail: graceserpin@menlhk.go.id

Abstract. The information on the population size and habitat condition of the Saltwater crocodile (*Crocodylus porosus*) in East Nusa Tenggara is unavailable. The present paper discusses preliminary data on population and habitat characteristics of the Saltwater crocodile in three conservation areas in Timor island, namely Teluk Kupang Marine Nature Tourism Park, Menipo Nature Tourism Park, and Maubesi Mangrove Forest Nature Reserve. Spotlight surveys and vegetation analyses were carried out in each location. The crocodile encounter rate was calculated as individuals detected per km surveyed. The encounter rates in Teluk Kupang, Menipo, and Maubesi were 0.3 crocodiles/km, 0.4 crocodiles/km, and 0.6 crocodiles/km, respectively. Hatchlings, juveniles, and adult saltwater crocodiles were found in Maubesi, and only hatchlings were found in Menipo. Hatchlings were found in paddy fields, and adults were found in mangroves, estuaries, and rivers. Mangrove densities in Teluk Kupang, Menipo, and Maubesi were 127 trees/ha, 124 trees/ha, and 186 trees/ha, respectively. These are the first systematic surveys in the areas studied, and additional work is needed to characterize the population and habitat of the saltwater crocodile in East Nusa Tenggara.

1. Introduction
Saltwater crocodile (*Crocodylus porosus* Schneider, 1801) is widely distributed in Indonesia [1]. It is listed in the Regulation of the Ministry of Environment and Forestry Number P.20/2018 of Protected Plant and Animal Species. The saltwater crocodile is considered as the largest reptile, which can grow up to 6.17 m [2]. Crocodiles are the top predator in the aquatic ecosystem that maintains ecosystem balance [3]. Research showed that the loss of apex predator would alter the ecosystem structure and function [4, 5]. The saltwater crocodile is a totem animal in East Nusa Tenggara (Nusa Tenggara Timur or NTT). There is a Timorese folktale telling that Timor Island was originated from a crocodile’s body. However, in recent years, human-crocodile conflicts arise in areas where saltwater crocodiles natural habitat and human settlements nearby.
East Kalimantan and East Nusa Tenggara were two provinces with the highest crocodile attacks rate in Indonesia [6]. In West Timor, East Nusa Tenggara, increasing rates of crocodile attacks were reported during 2009 – 2014 [7]. The International Union for Conservation of Nature (IUCN) – Species Survival Commission (SSC) Crocodile Specialist Group states that the increasing number of estuarine crocodile attacks raises the assumption that the saltwater crocodile populations in Indonesia are increasing. Still, there is no data to support this assumption [8]. The increase of the crocodiles’ population was often thought to be related to the increasing number of human-crocodile conflict as happened in Sarawak, Malaysia [9]. Some reasons for crocodile attacks on humans are maintaining habitat territory, protecting nests [10], misidentifying humans as prey, and establishing self-defense mechanisms [11].

An extensive crocodile survey program was conducted by FAO and the Directorate General of Forest Protection and Nature Conservation (PHKA) in the 1990s. Still, it did not produce information on population estimates or the distribution of estuarine crocodiles throughout Indonesia [12]. Reports of crocodile attacks on humans in East Nusa Tenggara province are most common in the island of Timor, especially in Kupang and Malaka Regencies. Likely, there are still many incidents of crocodile attacks that are unreported because they occur in remote areas. There are three conservation areas in Timor Island, which are natural habitats of estuarine crocodiles, namely the Teluk Kupang Marine Nature Tourism Park, Menipo Nature Tourism Park, and Maubesi Mangrove Forest Nature Reserve. To overcome human-crocodile conflict, a strategy that integrates human awareness and information about the crocodiles’ population and habitat in incident-prone areas is needed [13]. At present, the data on population and habitat of saltwater crocodiles in East Nusa Tenggara province is unavailable. This information is required to develop strategies on human-crocodiles conflict mitigation. Therefore, it is necessary to research the saltwater crocodile population and habitat in the Teluk Kupang Marine Nature Tourism Park, Menipo Nature Tourism Park, and Maubesi Mangrove Forest Nature Reserve.

2. Methods

2.1. Study location
Teluk Kupang Marine Nature Park is a conservation area designed for tourism and outdoor recreation activities. This area includes Kupang Regency, Kupang City, and surrounding waters covering an area of 50,000 hectares. This area was designated by the Minister of Forestry Decree Number 18/Kpts-II/1993 dated January 28th, 1993. Menipo Nature Tourism Park covered an area of 2,499.50 ha located in Kupang Regency. It was designated as a conservation area, according to the Minister of Forestry Decree No. 1134/Kpts-II/1992, December 28th 1992. Maubesi mangrove area is located in Belu Regency. It was designated as Maubesi Mangrove Nature Reserve with an area of 3,246 ha by the Minister of Forestry Decree Number SK.687/MENHUT-II/2009 dated October 16th 2009. This area is representative of mangrove forests and lowland forests. The map of the study locations is presented in Figure 1.

2.2. Population and habitat survey
The saltwater crocodile survey in the Teluk Kupang Marine Nature Park was conducted in 2015. Afterward, the studies in the Menipo Nature Park and Maubesi Mangrove Forest Nature Reserve were held in 2016. The survey was conducted using a combination of daylight and night counts/spotlighting method [14]. Spotlight surveys were carried out using a medium-size motorized fiberglass boat with an average speed of 10 km/h. A battery-powered spotlight was used to locate the crocodiles. The spotlight was covered by transparent red plastic to prevent the light from disturbing the crocodiles. Potential routes survey was conducted during the day to search for basking crocodiles, track, or slides on riverbanks, while the spotlight surveys were conducted in riverbanks, estuaries, and coastlines during the low tide, adjusted with dark phases of the lunar cycle.
When the observers located a crocodile, the boat approached slowly, and the observers would determine the crocodile’s size class, estimation of crocodile size classes as based on total length (TL). Thus, crocodiles with TL < 0.5 m were classified as hatchlings. Crocodiles between 0.5 and 1.5 m were as juveniles, and crocodiles with TL > 1.5 m were as adults [15]. When the TL was unable to be determined, it was recorded as “eyes only” or EO. The time, location, and size class of crocodile encounters were recorded in a tally sheet.

![Map of Study Area](image)

**Figure 1.** Map of study locations.

Habitat survey was performed by boat and on foot to identify the core habitats (mangrove, riverbanks, and coastline) and possible nesting sites of *C. porosus*. The basic information of potential crocodile habitat was gained from interviews with the local people such as fishermen and fishpond owners. They were asked to identify locations of saltwater crocodile’s sightings and nests.

2.3. Data analysis

The total number of crocodiles and the encounter rate (number crocodiles/km) were calculated for each location surveyed, as described by Messel and Bayliss [14, 16]. Single counts provide an index of relative density and not absolute density. Absolute density can be obtained by the mark-recapture method.

Mangrove species diversity and density in each location were determined using the vegetation analysis method described by Kusmana [17]. Sample plots to measure mangrove density were placed in areas of crocodiles encountered. The plot sizes were 10x10 m to record tree stage, 5x5 m for a sapling, and 2x2 m for seedlings. The mangrove species were determined using the field guide manual [18].
3. Results and discussion

3.1. C. porosus population

The length of the surveys varies in all three locations due to differences in area, the width of the rivers, and the number of rivers or estuaries. Several rivers are emptying into Teluk Kupang. Nunkurus, Oel'o, and Uwel rivers were chosen as the location of spotlight surveys because these rivers were navigable by boat. Besides, the survey site selection was also based on information about crocodile sightings from the local people. Observations were also conducted on the coastlines where residents saw C. porosus sunbathing, and people rarely visited those beaches. However, there was no encounter at the time of the survey at the coastline from Lasiana to Kelapa Tinggi and from Noelbaki to Tanjung Batu Putih.

Menipo Nature Park area covers Menipo Island and a small area in the mainland. The spotlight survey track in Menipo was the mangrove-lined estuary that separates Menipo Island and the mainland. C. porosus hatchlings were found in the paddy field near the village. Similar to Teluk Kupang, Maubesi also covers a vast area. There are eight inlets in the south and north parts of the area, namely Muara Weto, Muara Tahak, Muara Kotun, Muara Kletek, Muara We Hali, Muara Kali Buak, and Muara Uarat. Adult individuals were found in Itu Wain and Kali Wedik creek. The summary of C. porosus spotlight surveys is presented in Table 1.

There were ten crocodiles observed in the 31.93 km surveyed in Teluk Kupang. It means the observed density is 0.3 crocodiles/km. There were four hatchlings and three adults recorded, while three were sighted as Eye Only (EO). In Menipo, there were 6 EO sightings and three hatchlings were found within 22.9 km survey distance (Figure 2). The C. porosus density in Menipo is 0.4 crocodiles/km, which is similar to the density in Teluk Kupang. The highest density of 0.6 crocodiles/km was observed in Maubesi. A total of 24 C. porosus were observed in 38.9 km of accumulated distance survey. In Maubesi, there were 13 hatchlings, four juvenile and seven adults of C. porosus observed. The relative density of C. porosus in this study is similar to the relative density in the East Coast Plains, Australia ranging from 0.3 – 0.6 crocodiles/km [19]. Habitat quality is suggested as the most crucial factor in influencing crocodiles’ density [20].

![Figure 2. C. porosus hatchlings in a paddy field in Menipo.](image-url)
In spotlight surveys, crocodiles observed were only 35-66% of the total population [14, 16]. Therefore, the abundance estimations of C. porosus in Teluk Kupang, Menipo, and Maubesi were approximately 15 – 29, 14 – 26, and 36 – 69 crocodiles, respectively. This estimation is considered to be an underestimate of the actual population size. Spotlight surveys require a considerable time and limited to areas that can be accessed by boat. Besides, several factors affect the outcome of the spotlight surveys, such as 1) the thickness of the vegetation on the riverbank, 2) the width of the river, and 3) the sensitivity of the crocodile to noise or disturbance [15]. However, this data is essential to provide the basis for long term monitoring of the saltwater crocodile population.

3.2. Habitat of C. porosus

Teluk Kupang ecosystem consists of mangrove forests, coasts, coral reefs, and seagrass beds. Teluk Kupang Marine Nature Tourism Park is bordered by thirty-eight coastal villages. Teluk Kupang is conveniently accessible from Kupang city center, the capital of East Nusa Tenggara. Tourist sites, fish markets, restaurants, and hotels can be found along the coast in Teluk Kupang. Besides, there are activities such as fishing, sand mining, salt ponds, and fish ponds. In recent years, there has been an increase in sand mining activities, bomb fishing, wood extraction from mangrove forests, and the development of salt ponds in Teluk Kupang [21]. Firewood collection from mangroves can reduce the
density of mangroves, as well as fish and salt ponds development that converts mangrove forests. Besides, damage to the coral reef ecosystem in Teluk Kupang has reached 30.6% due to destructive fishing activities [22]. The high level of human activities in Teluk Kupang increases the chances of a human-crocodile conflict.

Potential nest location in Teluk Kupang was surveyed using information from the local people. A clump of “Harpos” grass (Typha angustifolia) is identified as a crocodile nest (Figure 3). It is located in the floodplain between the Nunkurus and Uwel rivers. According to residents, although this plain is located quite far from the river, it will be inundated in the rainy season and difficult to access. It is located outside the Teluk Kupang Marine Nature Park area and approximately 1 km from paddy fields. C. porosus hatchlings in Menipo and Maubesi were found in the freshwater submerged paddy field. In Australia, saltwater crocodile nests can be found in floodplains and swamps [23]. C. porosus uses Typha sp. and Thoracostachyum sumatranum for nesting [24].

![Figure 3. Harpos grass (Typha angustifolia). Local people identified the clump of T. angustifolia as C. porosus nest in Teluk Kupang.](image)

Of the three locations, Menipo Nature Tourism Park is the area with the lowest level of human activity. Menipo borders with six villages, namely Enoraen, Pakubaun, Oebesi, Pathau, and Oemolo [25]. In Menipo, there are fishing activities but not as extensive as in Teluk Kupang and Maubesi. Human-crocodile conflicts are often associated with overfishing [26], but it is suggested that fish is only made up of 33% of crocodiles’ feed. Saltwater crocodiles prey on 6 - 10 % fishes caught by fishers and most of the fish species are non-economically valuable fish [27]. However, the activity that threatens the crocodile habitat in Menipo is the expansion of paddy fields that are approaching the mangrove area.

Moreover, some villagers reported that crocodiles prey on their livestock. Crocodiles are opportunistic predators that will prey on animals in any size [28]. Crocodiles’ prey includes dog, cow, goat, reptile, sea turtle and bird [11]. C. porosus inhabits marine habitats, mangroves, coastal, swamps, and river courses [29] [30]. The average tree diameter of mangroves in Menipo and Maubesi was higher than Teluk Kupang. Mangrove densities in Teluk Kupang, Menipo, and Maubesi were 127 trees/ha, 124 trees/ha, and 186 trees/ha, respectively. Mangrove density had a strong correlation to fish diversity [31]. Mangrove also provides habitat for resting and hiding [29]. There were nine mangrove species identified in Teluk Kupang, namely Sesuvium portulacastrum, Avicennia alba, Rhizophora mucronata, Xylocarpus granatum, Aegialitis annulata, Bruguiera gymnorrhiza, Bruguiera parviflora Roxb, Sonneratia alba, and Avicennia officinalis. In Menipo area, crocodiles reside in the mangrove forests in the middle and eastern parts of the island, which are dominated by Rhizophora mucronata, Bruguiera parviflora, and Sonneratia alba. Mangrove forest on the open area in the estuary is dominated by Avicennia sp. In Maubesi, the most dominant mangrove species were Rhizophora apiculata and Bruguiera gymnorrhiza. While other mangrove species identified were Ceriops tagal.
and *Aegiceras floridum*, *Sonneratia* sp. and *Avicennia* sp dominated mangroves in the riverbanks (Figure 4).

![Mangrove in Teluk Kupang, Menipo and Maubesi](image)

**Figure 4.** Mangrove in Teluk Kupang, Menipo and Maubesi.

Juvenile and adult saltwater crocodiles were found in mangroves and estuaries of Maubesi. There are eight inlets in the north and south part, namely Muara Weto, Muara Tahak, Muara Kotun, Muara Kletek, Muara We Hali, Muara Kali Buak, and Muara Uarat. Meanwhile, hatchlings were found in the Kali Wedik creek and paddy field in Itu Wain. Some activities that could threaten the saltwater crocodile habitat include conversion of mangrove to salt ponds and fish ponds and firewood collection from mangrove forests in Itu Wain and Kletek. On the other hand, the development of ponds in Itu Wain, Lakekun village indirectly provides a new source of food for crocodiles. Some fish farmers reported that crocodiles prey on fishes in the ponds.

Moreover, crocodile sightings in creeks near Betun have increased. The cause to be suspected is trash disposal to creeks which can attract crocodiles. Such a situation has been observed in Sri Lanka, where crocodiles are often seen at the waste disposal site in urban areas [32]. In general, several factors influence the use of habitats by crocodiles, namely human activities, environment factors, and availability of nesting habitats [33]. Further studies on the home range, feed availability, and population structure are needed. An understanding of the habitat requirements, activity patterns, and spatial distribution of a species are critical for the management of the saltwater crocodile population and habitat management.

4. Conclusion
This study provides relative indices of the saltwater crocodile abundance in three conservation areas. Maubesi Mangrove Forest Nature Reserve had the highest density of 0.6 crocodiles/km. In Teluk Kupang Marine Nature Tourism Park and Menipo Nature Tourism Park, the densities of *C. porosus* were 0.3 crocodiles/km and 0.4 crocodiles/km, respectively. *C. porosus* were found in river banks, mangroves, paddy fields, and estuaries. Mangrove densities in Teluk Kupang, Menipo, and Maubesi were 127 trees/ha, 124 trees/ha, and 186 trees/ha, respectively. Expansion of fish ponds, salt ponds, and firewood collection are some threats to the saltwater crocodile habitat.
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