

In search of Makara, an extirpated freshwater crocodile *Crocodylus siamensis* (Schneider, 1801) of Java island, using temple reliefs, Ψ AIC and habitat modeling

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Abstract. Ancient reliefs in temple can provide information of past ecosystem along with biodiversity including Makara relief representing crocodile figure. In here, this study aims to identify and model the population of freshwater *Crocodylus siamensis* as portrayed in reliefs in 6 temples. The result shows that the crocodile reliefs in temples were having similar pattern to the freshwater *Crocodylus siamensis* fossils in term of locality. The temples and the fossils were located in the inland and near the rivers. While the temple locality patterns were in contrast to the locations where extant saltwater *Crocodylus porosus* has occurred. These contradictions strengthen the possibility that the crocodile portrayed in reliefs was made based on the *C. siamensis* occurrences. Based on the analysis, it is estimated that the *C. siamensis* once has occupied river and wetland in Java and its presence has been recorded in the reliefs. This occurrence at least happened from 1280 to 700 BC. From assessments of habitats near the temples using Ψ AIC, most surrounding habitats have high detection probability and occupancy for *C. siamensis* from Ψ 0.500 (95%CI:0.058-0.941). to Ψ 1.000 (95%CI:0.000-1.000).

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Introduction

One of important features in temple is its relief or known as carving on temple walls. It is not only functioned as decoration nonetheless it provides details information about what has happened in past. Relief is the way the ancestor perceived the world and environment in the pasts and it means a medium to tell a variety of stories. In Egypt, where the vast archaeological temples were found the reliefs were telling more about the king or pharaoh (Choukry 2008. Hawass 2001, Robins 1997). Engraved nine people bows under the feet of Ramesses II represented how the pharaoh has conquered his enemy. Beside human object, the temples were representing reliefs with animal object that relevant and representing the Egypt environment in the past. In the Great Temple of Abu Simbel, 22 seated baboons were engraved to symbolize sun worshipping. Besides that there were many arid desert ecosystem faunas were represented in the temple reliefs covering small scarab, dung-beetle, grasshopper, cobra, crocodile, buzzard, ibis, owl, jackal, and hippopotamus. The great Nile river near those temples was the natural habitats of those animals appearing in reliefs.

The representations of species and ecosystems were also appeared in temples in tropical and forest environment. Deep in south America forest, there were Aztec, Inca, and Maya civilizations known with their temples along with tropical forest faunal representations. This can be seen in endemic south America jaguar *Panthera onca* (Maffei et al. 2011) and puma *Felis concolor* (Busatta 2007). This species has been worshipped and has significant role for every ancient culture in Mesoamerican sites. In Lamanai, Belize, Mayan has built a Jaguar temple. In Teotihuacan, there was a palace yields series of murals and frescoes depicting jaguars (Saunders 2010). In far Asia, representations of endemic species within culture and reliefs were also significant. There was a symbolic creature of 1 species that become common in temples in Asian. This symbolic deity was known as Makara and its appearance in temples ranges from Tibet in north, Sri Lanka, Nepal in central Asia, far to Thailand and Indonesia in south east Asia. Makara itself is a representation close to the crocodile species that common in Asia. The connection of symbolic Makara to real species has been studied by Patil et al. (2012). In Sanskrit, a Makara is depicted as a crocodile like creature living in river. Among crocodile species there are 3 species living in Asia subcontinent and only 1 species that inhabits freshwater ecosystem include lake and river. This crocodile species is classified as *Crocodylus palustris*. By looking how the Makara is portrayed with its medium body length, broad-snouted and the most important is its habitats in the freshwater, Makara is resembled to *C. palustris*. Later on Makara in Sanskrit has been pronounced in english word and this refers to mugger crocodile *C. palustris*.

Java island alone is one of locations in south east Asia known for its vast cultures with its Borobudur temples and other magnificent temples. Those temples have been reported have reliefs representing animals species including the presence of Makara. Recently, flora and fauna presented in temple reliefs have been assessed since it can provide and document important information regarding the past biodiversity. In here, this study aimed to assess the animal relief in temples across the Java island and to construct the presence and distribution of past animal as depicted in the temple reliefs. The chosen object for this study was the crocodile reliefs.

Methods

Study area

The study area was the Java island. The objects assessed in the Java island during the study period were all temples observed in west, central and east Java. During observation in temple, observation on environment condition that might be suitable for the presence of crocodile was recorded.

Relief observation

Relief observation in temples was following Metusala et al. (2020). The observation was focusing on Makara installement and crocodile like creature depicted in the reliefs in the temple wall. The other

organisms or living creatures appeared in the relief with crocodile were also recorded. The geo coordinates of the temples that have the reliefs with crocodile were recorded to be mapped.

Freshwater crocodile presence

The freshwater crocodile presences were estimated based on the data comprise of crocodile records in temple combined with habitat variables (presence of river, wetland, valley). Those data with their geocoordinates then were mapped using GIS. The freshwater crocodile presences were estimated by overlaying those variables and weighed to determine the presence possibilities.

Since the presence of freshwater species was based on the relief records, a comparison with the presence of saltwater species was performed. With the same method, current saltwater crocodile presences or sightings with their geocoordinates were mapped. Likewise, presence of freshwater crocodile in the form of fossil finding was also recorded and mapped. The freshwater crocodile fossil record was obtained from literature studied.

Ψ AIC

Ψ AIC is abbreviation for psi and Akaike Information Criterion. This used to assess the level of habitat occupancy based on the absence and presence of the animals. It also measures the possibility of animal whether it can be detected in each assessed temple and nearby habitat (Mackenzie et al. 2002).



Figure 1. Location of temples with crocodile reliefs and river networks.

Table 1. Attributes of temples.

Temple	Elevation (m)	Distance to river (m)	Age (BC)
1	610	358	1280
2	353	166	1200
3	142	576	900
4	154	231	850
5	243	267	824
6	279	799	700



Figure 2. Makara figures in temple staircase.

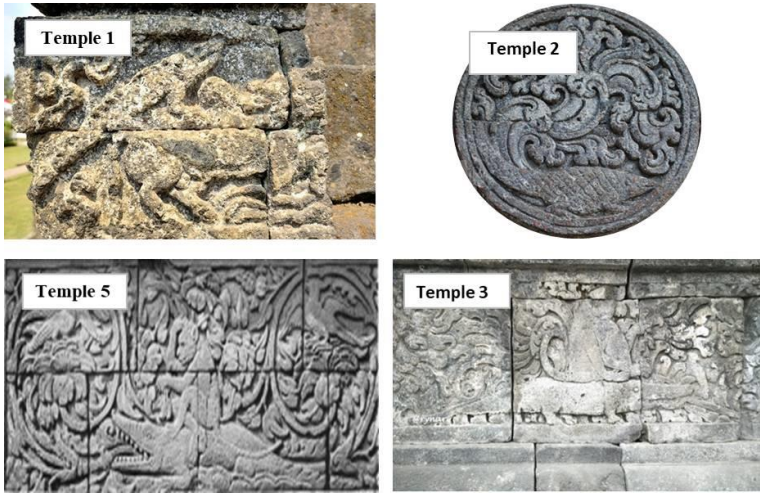


Figure 3. Crocodile reliefs in temple walls.



Figure 4. Sighting locations of extant saltwater *Crocodylus porosus* and fossil of freshwater *Crocodylus siamensis*.

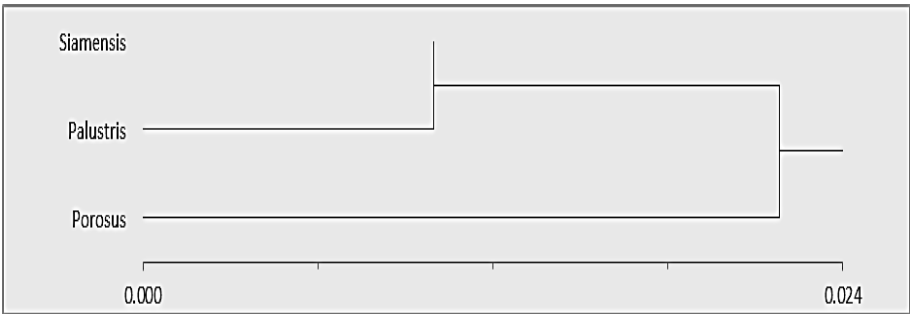


Figure 5. Bray Curtis similarity dendrogram of freshwater *C. siamensis*, *C. palustris* and saltwater *C. porosus*.

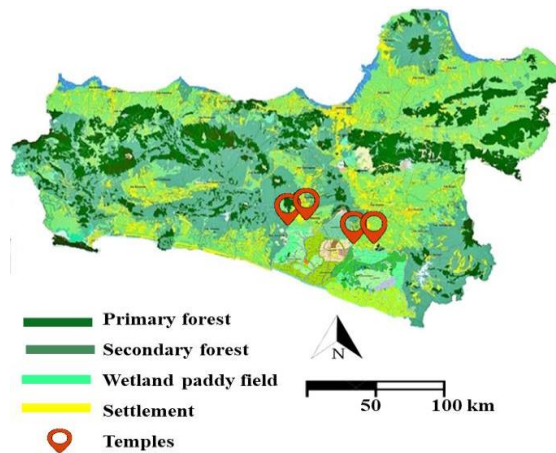


Figure 6. Temple locations with surrounding land uses.

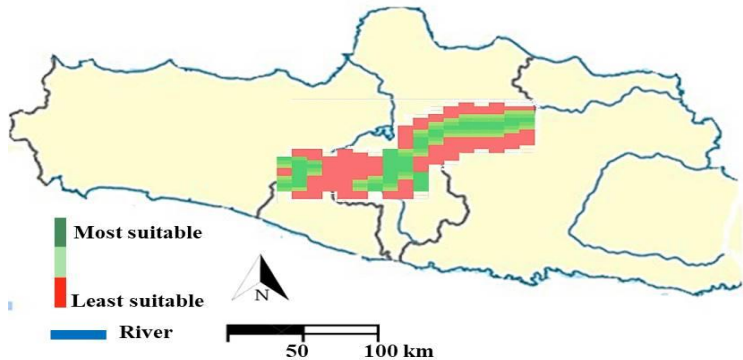


Figure 7. Estimated suitable habitat model of freshwater *Crocodylus siamensis*.

Table 2. Ψ AIC attributes of each temple and habitat nearby.

Temple	Ψ	AIC	SE	Low	Up
1	0.500	14.772	0.353	0.058	0.941
2	1.000	14.772	0.000	0.000	1.000
3	0.777	12.772	3465.6	0.000	1.000
4	1.000	14.772	0.000	0.000	1.000
5	1.000	14.772	0.000	1.000	1.000
6	0.777	12.770	2235.4	0.000	1.000

Results

The Makara and crocodile like creatures depicted in reliefs were found in 6 temples with 4 temples were located in central Java and 2 in east Java. The records from temples located in west Java were still limited (Figure 1). The temples were built located near rivers and has ages from 700 to the oldest 1280 BC (Table 1). Above sea level altitudes of temple within ranges of 142-610 m with temple located in east has the highest altitude and lower altitudes were in west. Makara in temples was in the form of engraved statue and put in the staircase in the gate of the temple (Figure 2). Besides Makara, there are several animal like figures in temple including turtle, bird, eagle, lion and snake. Makara figure is recognized through is opening long snout with sharp teeth. In temple relief, crocodile figure was depicted more realistic as a creature with long tail, snout, short leg and scales. In some reliefs, the crocodile was accompanied with other species including long tailed macaque and water buffalo. Those species were portrayed in lands and in aquatic habitats. In temple 1, crocodile was portrayed preying on a water buffalo. While species interactions can be seen in reliefs in temple 3 and 5 (Figure 3).

The location of extant saltwater crocodile *Crocodylus porosus* was presented in figure 4. It is apparent that most saltwater crocodile occurrences were in coastal areas rather than in inland. This pattern was common in west, central and east Java. In contrast to spatial occurrence patterns of saltwater crocodile, the fossils of freshwater crocodile *Crocodylus siamensis* were common in inland. Figure 5 informs the Bray Curtis similarity based on morphological characters of native saltwater species *C. porosus* compared to native freshwater *Crocodylus siamensis* and Asian freshwater *C. palustris*. The result show significant similarity between native and Asian freshwater species. Figure 6 presents the current land uses surrounding the temples. It is apparent that the temples were generally surrounded by combined wetland and paddy field. Whereas those wetlands were surrounded by growing settlement areas. Table 2 informs the Ψ AIC attributes of each temple. It is apparent that most temples have high detection probability values of Ψ more than 0.500 (95%CI: 0.058-0.941. Temple surrounded by wetland habitats was modeled more suitable and this covers a vast area (Figure 7).

Discussion

Figures in reliefs recently have received attentions and have been assessed to provide information of the environmental condition in the past. A comprehensive study on the relief assessments have been performed by Metusala et al. (2020). In their study, at least 63 plant species relevant to the local diversity have been identified. While in this study the crocodile like figures observed in the temples were represented in 2 forms, first as Makara and second was in more realistic forms in the relief. Makara itself in temples in Java is representation of aquatic animal in this case is crocodile (Murdiastomo 2018, Syafii & Supatmo 2019). Figures depicted in reliefs can represent actual environment and even biodiversity. In

the past, the carvers use their experience and observation to often illustrate the natural environment with scenery of various natural objects including plants and animals (Hattermann et al. 2018).

The crocodile figures portrayed in the temple reliefs may indicate several possibilities of relevant crocodile species including the native saltwater species, Asia continent originated freshwater species and native freshwater species. In our study all temples having crocodile figures were located in inland and near river. While in the present time, all crocodile sightings were located in the coastal areas far from inland. Based on the identification those crocodiles were belonging to saltwater species. Actual presence of saltwater species was far from the temple locations in freshwater induced ecosystem that is beyond the crocodile home range and physiology adaptations (Beauchamp et al. 2018, Campbell et al. 2013, Robertson et al. 2010). Makara itself originally represented the mugger crocodile *C. palustris*. Whereas this species distribution was limited to the subcontinent and the most possible species was lead to native freshwater species. In Asia subcontinent *C. palustris* was common species living in marsh habitat preferring high temperature with temperate climate of subtropical areas excluding tropical Java (Santiapillai & de Silva 2001, Chang et al. 2012). Crocodiles portrayed in temples were more resembled to the native Java freshwater species were supported by the fossil discoveries. The fossil of native freshwater species has been discovered in inland of Java island. Delfino and de Vos (2010) have reported the discovery of crocodile fossil in inland Java that identified and confirmed as *Crocodylus siamensis* (Delfino and de Vos (2014). Regarding the reliefs in temple, the crocodile species may represent either Asian *C. palustris* or Java *C. siamensis*. This similar representation is related to the following matters. First, these species both in Asia subcontinent and inland Java were inhabiting the similar habitats in marsh and wetland. Second, based on the Bray Curtis, those species exhibit significant similarity in term of morphological appearances. This leads to the possibility that *C. palustris* whether in Asia subcontinent or *C. siamensis* in Java was perceived as Makara.

The suitable habitats of *C. siamensis* were estimated based on the crocodile figure reliefs, environmental attributes, Ψ AIC and spatial modeling. The altitudes of the temples were within the range of crocodile altitude ranges. Some crocodile species were reported even can live in altitudes from 0 to 800 m. Sam et al. (2015) have reported a *C. siamensis* occurrence in the central Cardamom mountain at 600 metres above sea level. Spatial modeling of *C. siamensis* suitable habitat was based on the preferred habitat as has been reported from previous literatures. In this study, the presence of crocodile relief in temple reliefs was used as main principle references. The environment attributes to estimate habitat were the presence of water bodies and wetlands. Those temples were located in wetlands even can be closed as 100-200 m. Whereas there was a temple located quite far from the rivers. Wetlands as the most preferred habitat of *C. siamensis* have been reported by Behler et al. (2018). Ninety one percent of *C. siamensis* were occurred directly adjacent to or nearby (< 2 m distance) a floating grassy mat. Likewise, 92% of

occurrence was directly within floating vegetation, 8% were found in open water and a total of 8% of *C. siamensis* were seen in the flooded forest. Δ AIC values have also provided evidence that some habitats near the temples along with wetlands were having more detection probability and occupancy than other habitats.

Currently, *C. siamensis* species was disappearing. Once *C. siamensis* has occurred in Java (Ross 1990, 1992), whereas given the severe habitats loss there it is unlikely any populations remain (Simpson & Bezuijen 2010). This species disappearance was related to the land use changes. The river and wetland nearby have been converted into paddy field, plantation and settlements (Figure 8). This anthropogenic activities have reduced the *C. siamensis* freshwater habitat directly and the prey availability indirectly. Current land uses surrounding the temples may reflect the habitat loss threats that *C. siamensis* has encountered in the past.

Conclusions

Figures contained in temples in the form of reliefs can provide important information about past environment and biodiversity. Crocodiles like figures observed from temples in this study have indicated the possibility of freshwater crocodile existences. Their presences were also supported by the fossil of freshwater crocodiles found nearby. Combining the crocodile records from the temple and ecosystem characteristics, suitable habitat of freshwater crocodile has been modeled. From 1280 to 700 BC, *Crocodylus siamensis* was estimated has inhabited a vast area of river and wetland in Java.



Figure 8. Once a habitat of freshwater *Crocodylus siamensis* threatened by paddy field, plantation and settlements in Java island.

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