

Article

Habitat Suitability Model of Prehistoric Asian Hippo *Hippopotamus sivalensis* spp. From The Late Pleistocene of East Java

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Abstract: In the late Pleistocene, a prehistoric hippo species was distributed from Africa to the Asia including Pakistan, India, and Java Island. This study aims to model habitat suitability of Asian hippo known as a *Hippopotamus sivalensis* spp. in east Java. The measured parameters included the fossil locality, vegetation cover, elevation, and distance to the river in a forest river basin sizing 6652 Ha. Those parameters using GIS were weighted, overlaid, and interpolated to determine the most suitable habitats. The model projected that the suitable habitats of *H. sivalensis* spp. were in the central of the basin near the river. The largest suitable habitats were located in the eastern parts of basin which were dominated by forests.

Keywords: elevation; habitat; hippo; Pleistocene; river

Introduction

Currently in the modern era or also known as Anthropocene, there are only 2 species of hippos. The two species include the common hippopotamus (*Hippopotamus amphibius*) and the pygmy hippo (*Choeropsis liberiensis*). *H. amphibius* lives in East to South Africa, while *C. liberiensis* lives solitary in the rainforests of West Africa. In fact, mammals, including hippos, existed several millions of years ago. Mammals appeared 35 million years ago along with the existence of plants. The history of the existence of mammals on the island of Java began around 1.5 million years ago. The period of fauna existence itself consists of several periods which include Satir (1.5 million), Cisaat (1.2 million), Trinil (1 million), Kedungbrubus (800 thousand), Ngandong (400 thousand), and Punung (100 thousand). It was during the Punung period that modern mammals emerged, such as elephants, tigers, rhinos, gibbons, orang-utans, deer, and long-tailed monkeys.

The migration of fauna is thought to have come from Siwalik, Narbada, and Burma via the Siva-Malayan route (De Vos 1983, Sondaar 1984, Leinders et al. 1985, Sudijono 1986, Aziz 2000). The migration of fauna was supported by the existence of a route connecting the Asian continent and Java island along with the decline in sea level in the Sunda strait at the beginning of the Pleistocene 2.6 million years ago. The migration of fauna to Java island includes several types. In Cisaat and Trinil, inhabited by *Stegodon trigonocephalus* who came via the Siva-Malayan route from Siwalik, Narbada, and Burma. Meanwhile, *Elephas* and *Tapirus* make up the population of Kedung Brubus and Ngandong. Then in Cisaat and Ngandong, which were inhabited by prehistoric buffalo.

At the end of the Pleistocene, sea levels continued to decline and gave rise to a wider area of land between the Asian continent and Java island. As a result more species are migrating through this corridor. However, during the Holocene era, sea levels rose and fell again and submerged the land between the Asian Continent and the previously formed Java island. This happened about 12 thousand years ago.

In the late Pleistocene, the hippo *Hippopotamus sivalensis* spp. also includes fauna that migrate to Java. This species is thought to have lived from the oldest Satir to Ngandong periods (400 thousand years ago). Until recently, fossils of *Hippopotamus sivalensis* spp. have been found in

various locations in central to east Java. To complement existing data and body of knowledge, a study on habitat modeling of *Hippopotamus sivalensis* spp. on the island of Java is needed.

Methods

The study area for habitat suitability modeling was selected in the Kedung Brubus forest river basin located in east Java (Figure 1). The areas of basin were 6652 Ha. The elevation of this study area was ranging from 110 m to the 387 m especially in the hilly areas in the north. There was a 27.50 m width river in the middle parts of the forest. The *H. sivalensis* fossils were excavated in the 2 locations. First location was on the riverbank on the west side of the river. The second location was in the forest on the east side of the forest.

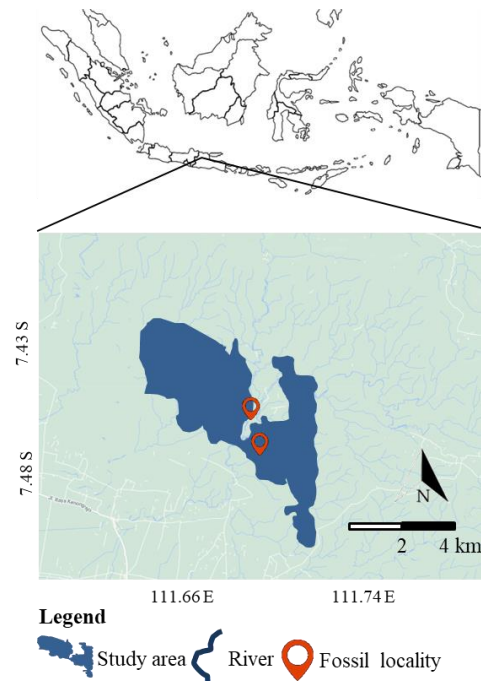


Figure 1. The study area and fossil localities in Kedung Brubus forest river basin, east Java.

Habitat modeling was following method by Wibowo (2020) with some modifications. Previous study was on forest dwelling species while hippos are known preferring aquatic habitat as well. In their habitat, hippos are having micro aquatic habitats including lakes and rivers (Dietz et al 2000, Kanga et al. 2011). According to Wibowo (2020), the habitat modeling was started from classification of vegetation covers from the orthophoto. The photo then classified into vegetation covers included trees, shrubs, and grass. For hippo's habitat suitability, several factors included elevation and distances to the river were also incorporated in to the model (Figure 2). Those determinant factors were weighed, given by scores, overlaid, and interpolated using Geographical Information System following Buruso (2018).

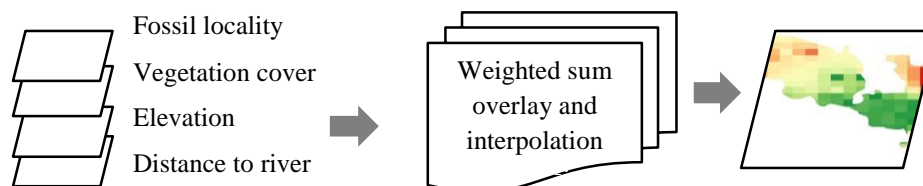


Figure 2. The methods for suitable habitat model development of *Hippopotamus sivalensis* spp. in Java island in the late Pleistocene.

Results

The measured environmental parameters in the Kedung Brubus basin were available in Figure 3. The basin has 2 types of river networks. First type was the small streams with width <2 m that were distributed widely across the basin. The western parts of basin have less streams than eastern parts. The large river with width equals to 27.50 m was located in the central of basin (Figure 3.a).

The elevations of Kedung Brubus were ranging from 110 to 387 m. Most hilly areas were located in the northern parts of basin. The landscape of eastern parts was higher than western parts (Figure 3.b). The vegetation covers in Kedung Brubus were dominated by the trees and bush. The hilly landscapes in north were dominated by bushes. While forests dominated the vegetation covers in southern parts of basin (Figure 3.c). The *H. sivalensis* spp. fossils were found in the river banks in west and in the forest in east. The elevations where the fossils found were 110 m for river banks and 150 m for forest.

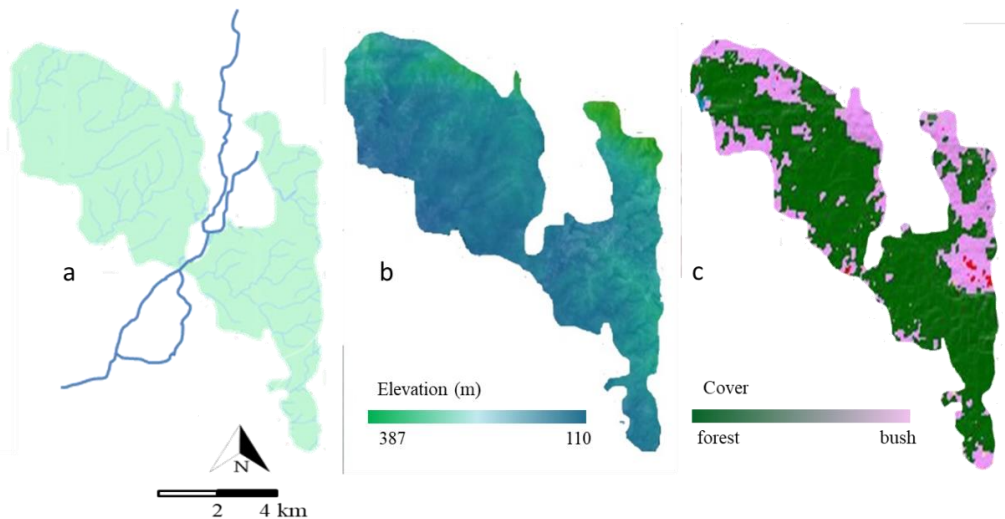


Figure 3. The river networks (a), elevation (b), and vegetation covers in Kedung Brubus forest river basin, east Java in the late Pleistocene.

The Figure 4 presents the habitat suitability of *Hippopotamus sivalensis* spp. in Kedung Brubus forest river basin, east Java. The suitability model was developed based on the fossil localities and environmental parameters. The model projected and divided the basin based on its suitability into 3 levels include most, moderate, and least suitable. As can be seen from Figure 4 that the most suitable habitats were estimated in the central of the basin near the river. The largest suitable habitats were also located in the eastern parts of basin. Most northern parts of the basin were less suitable in compared to the southern parts.

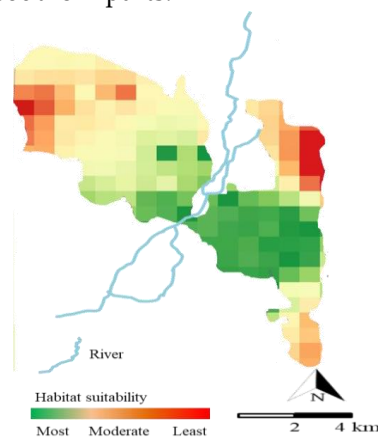


Figure 4. Habitat suitability of *Hippopotamus sivalensis* spp. in Kedung Brubus forest river basin, east Java in the late Pleistocene.

Discussions

The model developed in this study projected that the Pleistocene *H. sivalensis* spp. suitable habitats were centered near the river banks. This is in an agreement with the locations where most *H. sivalensis* spp. fossils have been found previously. *H. sivalensis* spp. in Java island was originated from the Asia continents with ranges from India to Africa under *Hexaprotodon* genus. Many literatures have reported the prehistoric hippos were found having proximity to the aquatic habitats. In east Africa, basin landscapes in the vicinity of Turkana were known having high abundance of prehistoric hippos (Arambour 1944, Arambour 1947, Coryndon 1977, Harris 1991). In Pakistan, 4 fossil localities of *Hexaprotodon* were found in Kas Chanatar basin that was surrounded by 2 rivers with width ranging from 50 to 100 m (Khan 2018). While in India, *Hexaprotodon* fossils were mostly found in rivers including Yamuna, Ravi, Narmada, and Godavari (Jukar 2019). The second explanations that can support the aquatic habitat proximity as presented in the model are related to the study by Brosserie (2005). *H. sivalensis* spp. was having eyes, ears, and nostrils placed high on the roof of the cranium which is this indicates *H. sivalensis* spp. already has proximity to the aquatic habitat (Zoric et al. 2018).

The habitat suitability model of Pleistocene *H. sivalensis* spp. was comparable to the Anthropocene hippos. Determinant factors that influence the habitat suitability of extant hippo species were incorporated in this model. Distance to the water body or in this study was a river, was one of the important factors determines the suitability of hippo habitats. Hippos are mammals that also have aquatic habitat besides their terrestrial habitat. A study by Buruso (2018) has shown comprehensively habitat suitability of hippos as in agreement with this study. Hippo prefers to live near the shallow water surrounded by grazing grass at the shore. This due to hippo's aquatic ecosystem requirement where hippos spend most of the time while forage pasture ashore (Eltringham 1999). Hippos were known aggregated on the vegetation covers near the river banks (Bogui et al. 2016). More hippo tracks per km² were found within 500 m from the water body and numbers of hippo tracks were declining in the distance from the water body >500 m (Eshuis 2011).

Elevation is another parameter should be considered in determine the suitable of hippo's habitats. The higher the elevation than the higher the abundances of hippo individuals. Hippo species was known climbing hills ranged 85-230 m to forage. In the Kedung Brubus, the elevation was ranging from 110 m to 387 m. While only the hilly areas in the eastern parts that suitable since these areas were dominated by forest.

The closest Anthropocene hippo species to *H. sivalensis* spp. is *Choeropsis liberiensis*. This species differs to the common hippos due to its habitats in the forest and body mass. Compared to the *C. liberiensis*, *H. sivalensis* spp. has comparable weight and also habitat preferences. Weight ranges of *C. liberiensis* and *H. sivalensis* spp. are 230-280 kg (Taylor et al. 2013) and 160-272 kg (Weston 2009) respectively. Regarding the habitat preferences, in Kedung Brubus, fossils of *H. sivalensis* spp. were found in the forests near the rivers. While *C. liberiensis*, the extant species which has similar body mass to *H. sivalensis* spp, also prefers rainforest. Extant *C. liberiensis* are known living in the dense vegetation of the rainforest. Despite forest dweller, this species hide in swamps, wallows, or hollows under trees next to rivers during the day (Eshuis 2011). Hence, related to the extant species, *H. sivalensis* spp. suitable habitats were mostly in forest.

The model in this study informs that the factors that limit the habitat suitable were the elevation, distance to the river, and forest. In fact, this model is different to the Anthropocene hippo's habitat model has been developed recently. Most model developed by Bogui et al. (2016), Buruso (2018), and Eshuis (2011) incorporated anthropogenic disturbance factors in their analysis. However this factor was not realistic for analyzing the habitat suitability of *H. sivalensis* spp. This species was living during Pleistocene areas where anthropogenic disturbance factors were not significant as can be seen in Anthropocene era currently.

Conclusions

H. sivalensis spp. is still having its closest relatives that still living during Anthropocene era nowadays. The habitat suitability model of extant hippo species then can be used and incorporated in developing suitable habitat of *H. sivalensis* spp. during Pleistocene.

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