doi:10.20944/preprints202009.0355.v1

Suitable Habitat Modeling of Prehistoric Antelope-like Bovid *Duboisia Santeng* in Java Island in The Early Pleistocene

Andriwibowo*

Keywords:
Bovid, forest, habitat, model, Pleistocene

*Email:
paleobio2020@gmail.com
*Address:
U. o. Indonesia,
West Java, Indonesia

Abstract

The migration routes have facilitated the distribution of mammals from south east Asian mainland to the Sundaland including Java island in the early Pleistocene. One of species that has migrated through that route is antelope-like bovid *Duboisia santeng*. In the present study, the potential distribution areas and the suitable habitats of *D. santeng* have been projected and modeled. The modeled habitat was a forest river basin sizing 302.91 Ha in the central of Java island. The model has classified and reconstructed the habitat suitability ranged from low to high back to Pleistocene. The surrounding areas of forest were mostly classified as medium and low related to the limited tree covers. Most suitable habitats were identified in the middle of forest river basin where the tree covers were presented.

Introduction

The adaptation and distribution of prehistoric mammals were favoured by migration routes. Presences of large mammal fossil from Indochinese and Sundaic provinces, which are distinct climatically, floristically, and faunistically support the hypothesis of a continental migration route during the middle and late Pleistocene periods. During the glacial periods, the faunal exchanges were favored by the emersion of a huge continental shelf known as Sundaland. This emerged land connected the South East Asian mainland to Borneo and other Indonesia islands including Java island. During that time, the land bridges were formed when the sea level was low. This condition characterized the mainland faunas with their displayed modern character and Javanese faunas with their endemic forms (Tougard 2001).

The migration routes of mammals during Pleistocene have resulted in the presence of mammal biodiversity in Java island. Several ecoregions in Java islands were having prehistoric mammals include Satir, Ci Saat, Trinil, Kedung Brubus, Ngangdong, Punung, and Wajak (Leinders et al. 1985, Theunissen et al. 1990, van den Bergh et al. 2001). The oldest mammals in those of Satir and Ci Saat, have been dated to 1.5 and 1.2 Ma of early Pleistocene (de Vos et al. 1994, de Vos and Long 2001). The numbers of species inhabited Satir, Ci Saat, Trinil, Kedung Brubus, Ngangdong, and Punung were 2, 6, 7, 12, 7, and 7 respectively. Considering Java island has been inhabited by Pleistocene mammals, this study aims to model the suitable habitats for those mammals. Prehistoric antelope-like bovid *Duboisia santeng* was selected in this study.

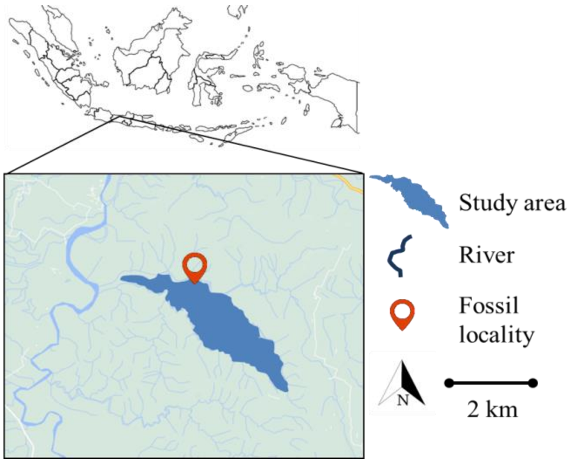

Figure 1. The study area and fossil locality in Maribaya forest river basin, central Java island.

Methods

The study area was a Maribaya forest basin with area of 302.91 Ha (Figure 1). The basin was bordered by 2 rivers in the north and south. The rivers were tributaries of 180.47 m width Pemali river on the west. At the current time, Maribaya landscape was consisting of grassy areas fragmented by plantations and pastoral areas. The pastoral areas were dominated by several grass, shrub, and leguminous tree species (Umami et al. 2018).

The fossil was found on the northern part of river basin near the river bank. The habitat model development was based on the historical record of forest cover remains in the form of orthophoto. The photo then classified into vegetation covers included trees, shrubs, and grass. The habitat suitability was developed based on vegetation covers and denoted as scale ranged from least to most suitable (Figure 2).

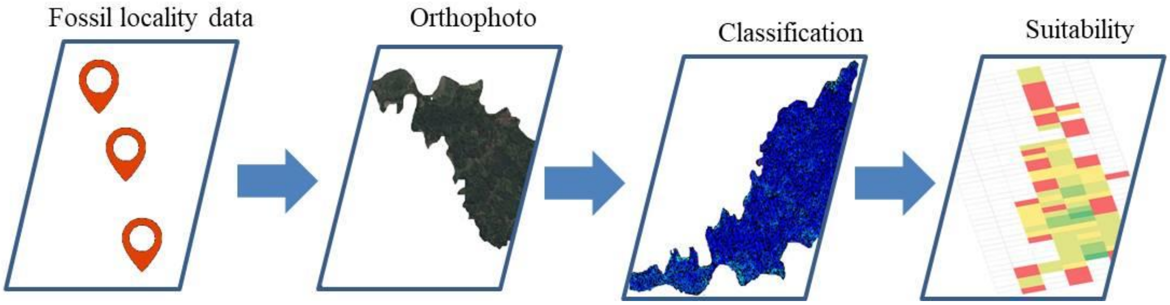

Figure 2. The methods for suitable habitat model development of *Duboisia santeng* in Java island in the early Pleistocene.

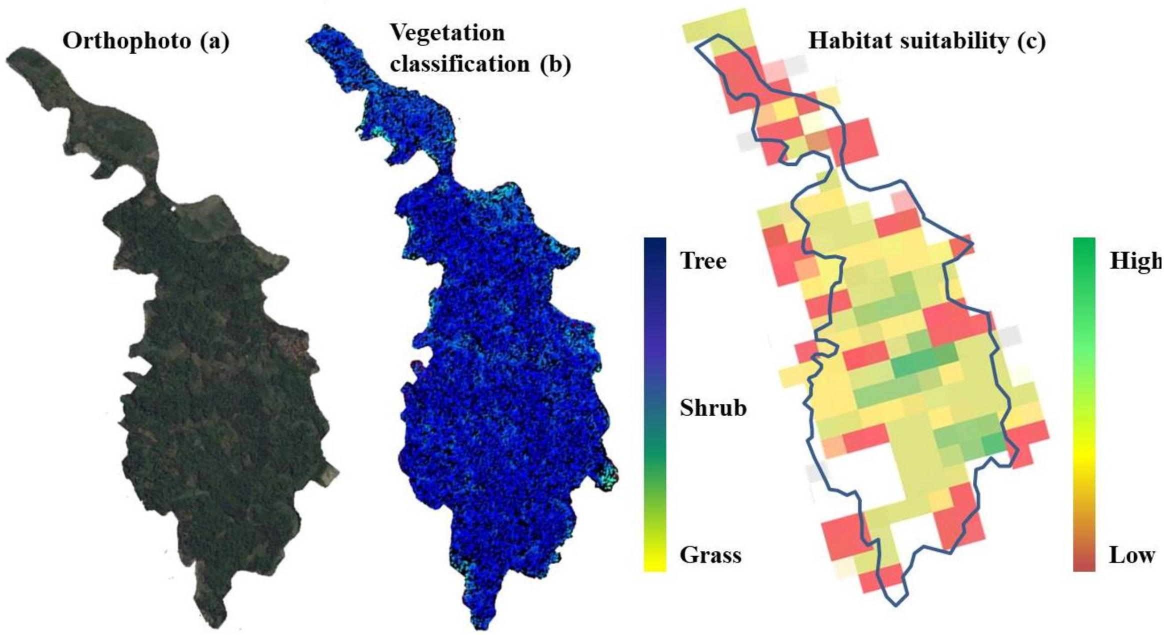

Figure 3. Orthophoto (a), vegetation cover classifications (b), and suitable habitat model (c) for *Duboisia santeng* in Maribaya forest river basin of Java island in the early Pleistocene.

Results

Historical forest covers presented by orthophoto (Figure 3.a) show the vegetation covers in Maribaya forest river basin. The covers were showing fragmentation especially in the areas near the river in the north and south. The cover classification shows clearly the trees, shrubs, and grass. North parts of the forest were fragmented by shrubs and grass and these patchiness were also observed in the east parts. Patches of shrubs and grass were also observed in the middle and inner parts of the forest. However, most of middle and south parts of the forests were dominated by tree covers (Figure 3.b).

Model of habitat suitability of *Duboisia santeng* can be seen in the Figure 3.c. The model has classified and reconstructed the habitat suitability ranged from low to high back to Pleistocene. The surrounding areas of forest were mostly classified as medium and low related to the limited tree covers. Most suitable habitats were identified in the middle of Maribaya river basin where the tree covers were presented.

Discussion

The distribution of *Duboisia* species on the south east Asia continental region have been reported in many literatures (Hooijer 1962, Moigne et al. 2016). Results in this study were compared to the findings of *Duboisia* species in other parts in Asia continent. Nishioka et al. (2018b) have reported the presence of calvarium of *Duboisia* from an indeterminate horizon at Bagan, central Myanmar. While Nishioka & Vidthayanon (2018) have confirmed *Duboisia* presence in Thailand in conjunction with the fossil record from Myanmar. *Duboisia* occurrence on south east Asia continent was estimated on the beginning of the early Pleistocene. This estimation was based on the basic cranial characteristics of the genus *Duboisia* including squared brain case, weak temporal crests, and antero-posteriorly compressed horn cores with medial and lateral keels. In fact, the Pleistocene fauna share many mammalian species between south east Asia continent and archipelago as well (Tougard 2001, Louys et al. 2007, Zin-Maung-Maung-Thein et al. 2010, Suraprasit et al. 2016).

The *D. santeng* records in Java have been made since ’30. The oldest fossil records were from Kedung Brubus and Trinil made by Hooijer (1958). Von Koenigswald (1935) and Tougard (2001) theorized that *D. santeng* presumably arrived on the Java island via the Siva-Malayan route in the middle and late Pleistocene . *D. santeng* in Java island may have experienced evolution related to adaptation to its habitat. Rozzi (2018) confirmed that *D. santeng* had been downsized and acquired unique characteristics in postcranial bones as a result of insular processes. This morphological evolution is related to the adaptation shift to inhabit the dense forest that has made *D. santeng* to become a forest dweller species. The past vegetation covers as documented by orthophoto have shown a tree covers (Figure 3.a). Considering the presence of tree covers, Maribaya landscape might support *D. santeng* population during Pleistocene. This condition is also supported with the fact that the present landscapes were used as grazing areas (Umami et al. 2018). Then Maribaya forest basin is suitable for bovid species including prehistoric *D. santeng*.

Many literatures have modeled the ecology of prehistoric species using pollen records (Meadows 2007, Qiu et al. 2020), climate, and ecological niche modeling (Machado et al. 2019). One of successful attempts can be seen from works by Ulker et al. (2018) on pedunculate oak (*Quercus robur*) during Pleistocene. Based on the model the *Q. robur* was having much broader distribution range from 6000 to 130000 years ago. While the comprehensive 22 palaeofauna modeling has been studied by Polly & Eronen (2011).

Developing the paleo habitat model can be achieved by fitting mathematical functions to the multivariate relationship including occurrence data and environmental factors. The result of mathematical functions is a geographically explicit suitability scores that predict where abiotic conditions are suitable and which are not suitable for a given species. This method has been applied to model *Ectenocrinus simplex*, an immobile shallow marine filter feeder living during the late Ordovician (Brame & Stigall 2014, Myers et al. 2015). The required environmental factors included distribution of occurrence data and interpolated environmental layer for percent mudstone. The results were habitat suitability ranged from low to high. In this study, the modeled habitat of *D. santeng* was also developed by considering several factors as recommended by previous literatures. First factor is the presence of species which was based on the fossil locality. The locality data then compared to the historical forest covers. The classification of forest cover was applied to divide forest covers into grass, shrubs, and trees. Furthermore, the suitability scores were given to the cover classifications and the scores were interpolated to determine and model which parts of Maribaya forest basin were inhabited by *D. santeng* during Pleistocene.

The modeled habitat in Maribaya forest river basin is remained stable and comparable to the condition during Pleistocene. In Taihu lake basin, Qiu et al, (2020) observed that after 23000 years, the vegetation landscape was comparatively stable as it remains today. The study in east Java was also confirming that Pleistocene landscape was similar to modern day landscape. The east Java landscape was different to the central Java since this landscape was dominated by grass and savannah. Lelono (2017) found that that Pleistocene of east Java is characterized by abundant grass pollen of *Monoporites annulatus* which may correspond to the period of expansion of savanna vegetation coinciding with glacial period. The landscape was also indicated by abundant charred Gramineae cuticles.

The remain bovid species in current time of Java island is only 1 species. The only *Bos Javanicus* species were found in Ujung Kulon forest in west of Java island and another population is inhabited Meru Betiri savannah in east of Java island. Even though modern bovids have larger body size and more adapted to the open forest, *B. javanicus* was observed foraging on trees. Garsetiasih & Heriyanto (2014) reported that *B. javanicus* has preference on habitats dominated by trees with height > 20 m. Pleistocene *D. santeng* was belonged to the same group with the modern *B. javanicus*. Respectively, *D. santeng* habitat preference was comparable to modern bovid. Hence, Maribaya forest basin is projected as habitat of *D. santeng*. From the model, it is clear that in those times the projected wider distribution ranges and areas of *D. santeng* that are now part of unsuitable habitat. Nowadays, the Maribaya forest basin has been fragmented and converted into plantation and pastoral areas. Besides land use conversion, better climatic and monsoon rainfall were also important factors affecting habitat suitability modeling and absence of a certain species (Karamiani et al. 2018).

Conclusions

The habitat modeling has confirmed that the Maribaya forest river basin once has supported bovid species during Pleistocene. It indicates that Maribaya has potential and important to support and provide habitat for bovids. Hence the study of habitat using Pleistocene species as model can provides heuristic methods for the management and conservation of important habitat especially in particular current time.

References

Brame HM, Stigall AL. 2014. Controls on niche stability in geologic time: congruent responses to biotic and abiotic environmental changes among Cincinnatian (Late Ordovician) marine invertebrates. *Paleobiology*. 40:70–90.

de Vos J, Long VT, 2001. First settlements: relations betweencontinental and insular Southeast Asia. In: Sémah, F, Falguères, C, Grimaud-Hervé, D, Sémah, A (Eds.), Origine des peuplements et chronologie des cultures Paléolithiques dans le Sud-est Asiatique. Semenanjung, Paris. pp. 225–249.

de Vos J, Sondaar PY, van den Bergh GD, Aziz F. 1994. The Homo bearing deposits of Java and its ecological context. Courier Forschungsinstitut Senckenberg. 171: 129–140.

Garsetiasih R, Heriyanto NM. 2014. Karakteristik Vegetasi Habitat Banteng (*Bos Javanicus* D'alton 1832) Di Taman Nasional Meru Betiri, Jawa Timur. *Jurnal Penelitian Hutan dan Konservasi Alam*. 11(1).

Hooijer DA. 1958 Fossil Bovidae from the Malay Archipelago and the Punjab. Zoologische Verhandelingen, Leiden 38: 1–112.

Hooijer DA. 1962. Report upon a collection of Pleistocene mammals from Tin-bearing deposits in a limestone cave near Ipoh, Kinta Valley, Perak. *Federation Museum Journal*. 7: 1–5.

Karamiani R, Rastegar-Pouyani N, Rastegar-Pouyani E. 2018. Modeling the Past and Current Distribution and Habitat Suitability for Two Snake-eyed Skinks, *Ablepharus grayanus* and *A. pannonicus* (Sauria: Scincidae).

Leinders JJ, Aziz MF, Sondaar PY, de Vos J, 1985. The age of the hominid-bearing deposits of Java: state of the art. Geologie en Mijnbouw 64: 167–173.

Lelono EB. 2017. Pleistocene climate of Indonesia. *J Earth Sci Clim Change*. 8:8.

Louys J, Curnoe D, Tong H. 2007. Characteristics of Pleistocene megafauna extinctions in Southeast Asia. *Palaeogeogr. Palaeocl*. 243: 152–173.

Machado AF, Nunes MS, Silva CR. 2019. Integrating phylogeography and ecological niche modelling to test diversification hypotheses using a Neotropical rodent. *Evol Ecol*. 33: 111–148.

Meadows M, Chase Brian. 2007. Pollen Records, Late Pleistocene.

Myers C, Stigall A, Lieberman B. 2015. PaleoENM: Applying ecological niche modeling to the fossil record. *Paleobiology*. 41(2): 226-244.

Nishioka Y, Vidthayanon C. 2018. First occurrence of Duboisia (Bovidae, Artiodactyla, Mammalia) from Thailand. *Foss. Rec*. 21, 291–299

Qiu Z, Jiang H, Ding L. 2020. Late Pleistocene-Holocene vegetation history and anthropogenic activities deduced from pollen spectra and archaeological data at Guxu Lake, eastern China. *Sci Rep*. 10.

Polly PD, Eronen JT. 2011. Mammal Associations in the Pleistocene of Britain: Implications of Ecological Niche Modelling and a Method for Reconstructing Palaeoclimate, Editor(s): Nick Ashton, Simon G. Lewis, Chris Stringer, Developments in Quaternary Sciences,

Rozzi R. 2018. Space–time patterns of body size variation in islandbovids: The key role of predatory release, *J. Biogeogr*. 45: 1196–1207.

Suraprasit K, Jaeger JJ, Chaimanee Y, Chavasseau O, Yamee C, Tian P, Panha S. 2016. The middle

Pleistocene vertebrate fauna from Khok Sung (Nakhon Ratchasima, Thailand): biochronological and paleobiogeographical implications. *ZooKeys*. 613: 1–157.

Theunissen B, de Vos J, Sondaar PY, Aziz F. 1990. The establishment of a chronological framework for the hominidbearing deposits of Java; a historical survey. *Geological Survey of America Special Paper*. 242: 39–54.

Tougard C. 2001. Biogeography and migration routes of large mammal faunas in South-East Asia during the Late Middle Pleistocene: focus on the fossil and extant faunas from Thailand. *Palaeogeography, Palaeoclimatology, Palaeoecology.* 168: 337–358

Umami N, Ngadiyono N, Panjono, Agus F, Shirothul H, Budisatria IGS, Hendrawati Y, Subroto I. 2018. Development of Botanical Composition in Maribaya Pasture, Brebes, Central Java. *IOP Conference Series: Earth and Environmental Science*.

Ülker ED, Tavşanoğlu C, Perktaş U. 2018. Ecological niche modelling of pedunculate oak (*Quercus robur*) supports the 'expansion–contraction' model of Pleistocene biogeography. *Biological Journal of the Linnean Society*. 123(2): 338–347,

van den Bergh G, de Vos J, Sondaar P. 2001. The Late Quaternary palaeogeography of mammal evolution in the Indonesian Archipelago. *Palaeogeography, Palaeoclimatology, Palaeoecology*. 171: 385–408.

von Koenigswald GHR. 1935. Die fossilen Saugertier Fauna Javas. Proceeding Koninklijke Nederlandsche Akademie van Wetenschappen 38: 188–198.

Zin-Maung-Maung-Thein, Takai M, Tsubamoto T, Egi N, Thaung-Htike, Nishimura T, Maung-Maung, Zaw-Win. 2010. A review of fossil rhinoceroses from the Neogene of Myanmar with description of new specimens from the Irrawaddy Sediments, *J. Asian Eath. Sci.* 37: 154–165.