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Socio-ecological factors shape the distribution of a cultural keystone species in Malaysian Borneo

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Biophysical and socio-cultural factors have jointly shaped the distribution of global biodiversity, yet relatively few studies have quantitatively assessed the influence of social and ecological landscapes on wildlife distributions. We sought to determine whether social and ecological covariates shape the distribution of a cultural keystone species, the bearded pig (*Sus barbatus*). Drawing on a dataset of 295 total camera trap locations and 25,755 trap days across 18 field sites and three years in Sabah and Sarawak, Malaysian Borneo, we fitted occupancy models that incorporated socio-cultural covariates and ecological covariates hypothesized to influence bearded pig occupancy. We found that all competitive occupancy models included both socio-cultural and ecological covariates. Moreover, we found quantitative evidence supporting Indigenous pig hunting rights: predicted pig occupancy was positively associated with predicted high levels of Indigenous pig-hunting groups in low-accessibility areas, and predicted pig occupancy was positively associated with predicted medium and low levels of Indigenous pig-hunting groups in high-accessibility areas. These results suggest that bearded pig populations in Malaysian Borneo should be managed with context-specific strategies, promoting Indigenous pig hunting rights. We also provide important baseline information on bearded pig occupancy levels prior to the 2020–2021 outbreak of African Swine Fever (ASF), which caused social and ecological concerns after mass dieoffs of bearded pigs in Borneo. The abstract provided in Malay is in the Supplementary file.

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INTRODUCTION

Socio-cultural and biophysical landscapes are fundamentally connected. However, our empirical understanding of the links between them is still limited. While researchers often quantitatively examine links between biophysical factors and wildlife, far less quantitative work has been carried out on the influence of socio-cultural factors on wildlife distributions. Yet socio-cultural factors—such as ethnic identity, culturally-distinctive hunting practices, armed conflict, recreation, feasts, traditions, and value systems—have been shown to have far-reaching implications for animal behavior, wildlife distributions, and conservation efforts^{1–6}. As such, social and cultural practices, tolerances, affinities, and other socio-cultural factors require more attention as important predictor variables, alongside ecological variables, for determining occurrence patterns of wildlife species⁷.

A primary challenge has been integrating nuanced quantitative measures of socio-cultural factors into wildlife distribution modeling. Recently, socio-cultural covariates have begun to move

beyond broader indices of human disturbance or footprint to include culturally-shaped metrics, such as hunting accessibility, social carrying capacity for development, or religious practices^{8–10}. These more recently adopted metrics reflect an emerging understanding of the conceptual complexity of human-wildlife interactions, which take place within nested social and ecological systems¹¹. While the number of socio-ecological studies has increased dramatically in recent years¹², greater attention is needed to the integration of social and ecological variables in wildlife modeling¹³. However, relatively few robust case studies have leveraged the social and environmental data needed to quantify their joint influence on species distributions.

The bearded pig, *Sus barbatus*, is an ideal species for assessing the relative contribution of socio-cultural and ecological variables to wildlife distributions. Bearded pigs are sensitive to social factors, such as hunting practices, which can influence their local distribution and behavior^{6,14}. The bearded pig is also the most favored terrestrial game species for many non-Muslim Indigenous communities in Sabah and Sarawak, accounting for up to 54–97%

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