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Distribution and habitat mapping of key fauna species in other land use for biodiversity offset

ENDANG HERNAWAN♥, MIA ROSMIATI, TIEN LASTINI, MAMAT KANDAR
School of Life Science and Technology, Institut Teknologi Bandung. Jl. Ganesa 10, Bandung 40132, West Java, Indonesia.
Tel.: +62-22-251-1575, Fax.: +62-22-253-4107, ♥email: endang.hermawan@itb.ac.id

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Abstract. *Hernawan E, Rosmiati M, Lastini T, Kandar M. 2024. Distribution and habitat mapping of key fauna species in other land use for biodiversity offset. Asian J For 9: 124-136.* Despite their status as non-forest and non-conservation areas, other land use areas (APL), especially those adjacent to forests, are still habitats for wildlife, including key animals or essential ecosystems that are ecologically important for biological conservation as animal boundaries or as protectors of conservation areas. The existence of key animal habitats or essential ecosystems underscores the urgent need for a comprehensive biodiversity action plan (BAP) for APLs. The APLs are geographically dispersed nationwide to address diverse external needs beyond forestry. Some APLs are situated on Mount Tenggamus in Lampung Province, Sumatra Island, and on Mount Latimojong in South Sulawesi Province, Sulawesi Island, Indonesia. This research aims to find out the distribution of key animals in other land uses as a basis for controlling land use for sustainability. The research method used is vegetation analysis based on elevation, presence of animals, and distribution mapping using Weighted Linear Combination (WLC). The results showed that degraded and deforested ecosystems dominated both APLs. Some key species are confined to APLs, where their habitats have been fragmented by agricultural land use. This results in limited home ranges and the possibility of inbreeding, which will reduce the survivability of offspring. In addition, due to human pressure, including hunting, key animals in OLs are at risk of extinction. Immediate protection measures are essential to prevent this.

Keywords: Degraded, distribution mapping, essential ecosystem, flora endemic, key animal habitat

INTRODUCTION

Lampung Province is located within the Ring of Fire of Sumatra Island in the South (Utama et al. 2021). In addition to its notable biodiversity, the region is home to numerous endangered species of flora and fauna. The International Union for Conservation of Nature (IUCN) has classified the Sumatran rhino (*Dicerorhinus sumatrensis* (G.Fischer, 1814), tiger (*Panthera tigris* subsp. *sumatrae* Pocock, 1929), and elephants (*Elephas maximus* subsp. *sumatranus* Temminck, 1847) as critically endangered species due to their dwindling populations (IUCN SSC Cat Specialist Group 2015; IUCN SSC Asian Rhino Specialist Group 2020; Williams et al. 2020; Winarno et al. 2024). In comparison, South Sulawesi Province is situated along the Wallace Line, which delineates the boundary between the Asian and Australian continents. Maps showing old water levels during the Pleistocene demonstrate that Sulawesi is just east of the old Sunda land shelf. This persistent water gap, even during the Pleistocene, has prevented many plant and animal groups from colonizing Sulawesi. The species that did get to Sulawesi have developed at least subspecies differences from the mainland population in most cases. Thus, diversity is less in Sulawesi, but endemic species and subspecies are much higher than in Sundaland (Metcalfe 2017).

The origins of APLs in Tenggamus Mountain and Latimojong Mountain are rooted in converting a protected forest into a site conducive to cultivation activities and human settlements, resulting in a diminution of suitable habitat for flora and fauna (Muhaimin et al. 2018). Road construction also hurts animals in Lampung Province. Highways can greatly impact where animals live and how they live, especially near the highways. The highways can make it hard for animals to move around, harming their health. More and more accidents occur when animals try to cross highways, which can mean more traffic. The noise from vehicles can also bother animals and force them to move to a smaller area. At the start of road construction, wildlife was monitored. This showed more threats to wildlife, especially tigers, Sumatran elephants, and Sumatran rhinos (Winarno et al. 2024). Operations of mining have significant effects on biodiversity over the level of spatial scales, from the local site to the larger landscape, regional, and even global levels, and have effects both from direct mining processes as well as indirect ones like occupancy to places rich in biodiversity (Shanmukha et al. 2024). In addition, mining activities and micro hydro development can accelerate habitat loss for flora and fauna. The biodiversity in Wallace's line of great interest in world science has declined, which was triggered by forest degradation and deforestation driven by Indonesian government policies. One of the policies of the government of Indonesia is to release state forest areas as the habitat of endemic species for other uses such as agricultural land, plantation land, transmigration, and mining concessions. In reducing the impact of these releases on decreasing biodiversity, the Government of Indonesia is also developing conservation

in an ex-situ manner, namely in essential ecosystems. It requires a BAP in the management of former forest areas to protect key animal habitats that are included in the IUCN red list criteria for species threatened with extinction. According to Iskandar (2021), for this work, as usual, we must be aware of the presence of plants and animals that meet the criteria of Indonesian Law, CITES, and IUCN. As a rule, the IUCN criterion is the highest, but traded species might meet the CITES regulation but not the IUCN criteria. For this reason, we must check every species observed and/or reported against all the three main regulations mentioned above. Then, to find out the distribution of the remains of unique species on the island of Sumatra and the island of Sulawesi, especially outside the conservation area, it is necessary to know their distribution. The objective of this paper is to map the distribution of key species in the Tenggamus Mountains of Lampung Province and the Latimojong Mountains of South Sulawesi Province, specifically in other land use areas.

MATERIALS AND METHODS

Study area

In Lampung Province, the research area is situated near the protected forest area of Mount Tenggamus, with a focus on identifying potential micro hydro development sites. Administratively, the research site is in Way Panas Village, Wonosobo Sub-district, Tanggamus District, Lampung, Indonesia (Figure 1). Way Panas village is situated in the northern portion of Wonosobo Sub-district, forming a border between Wonosobo Sub-district and Ulubelu Sub-district. Wonosobo Sub-district, the largest sub-district in Tanggamus District, is home to 28 pekon, or villages, making it the most pekon-rich sub-district. The administrative center of Wonosobo Sub-district is situated in Tanjung Kurung, 12.8 km southwest of Way Panas Village. The area of Way Panas Village encompasses 11.48 km^2, with a population of 2,926 inhabitants. Way Panas Village is the largest village in Wonosobo Sub-district, accounting for 5.05% of the total area of Wonosobo Sub-district.

In South Sulawesi, the research location was in Rante Balla Village and Boneposi Village, Latimojong Sub-district, Luwu District, South Sulawesi Province, Indonesia, where PT MDA's gold mining CoW is physically located. The Tana Toraja, Makassar, Bugis, and Javanese tribes, Rante Balla, Salubulo, Boneposi, Tolajuk, and Ulu Salu Villages are the nearest to the project site (mine) (Figure 1).

Procedures

The focus of the research was on APL areas that have the potential to be used for micro hydro and mining activities that have the potential to cause loss of flora and fauna. AOI has identified based on literature review, data and information land use for development planning of micro hydro or mining activities. Secondary and primary data were collected after the AOI (Area of Interest) was identified and delineated. Based on technical considerations in the field and differences in tree habitat based on height above sea level, the observation points for tree vegetation are based on altitude. Meanwhile, observation points for animals and animal habitats are carried out based on information from local communities and field workers. In addition, observation points are based on presence-absence. The research flow chart can be seen in Figure 2.

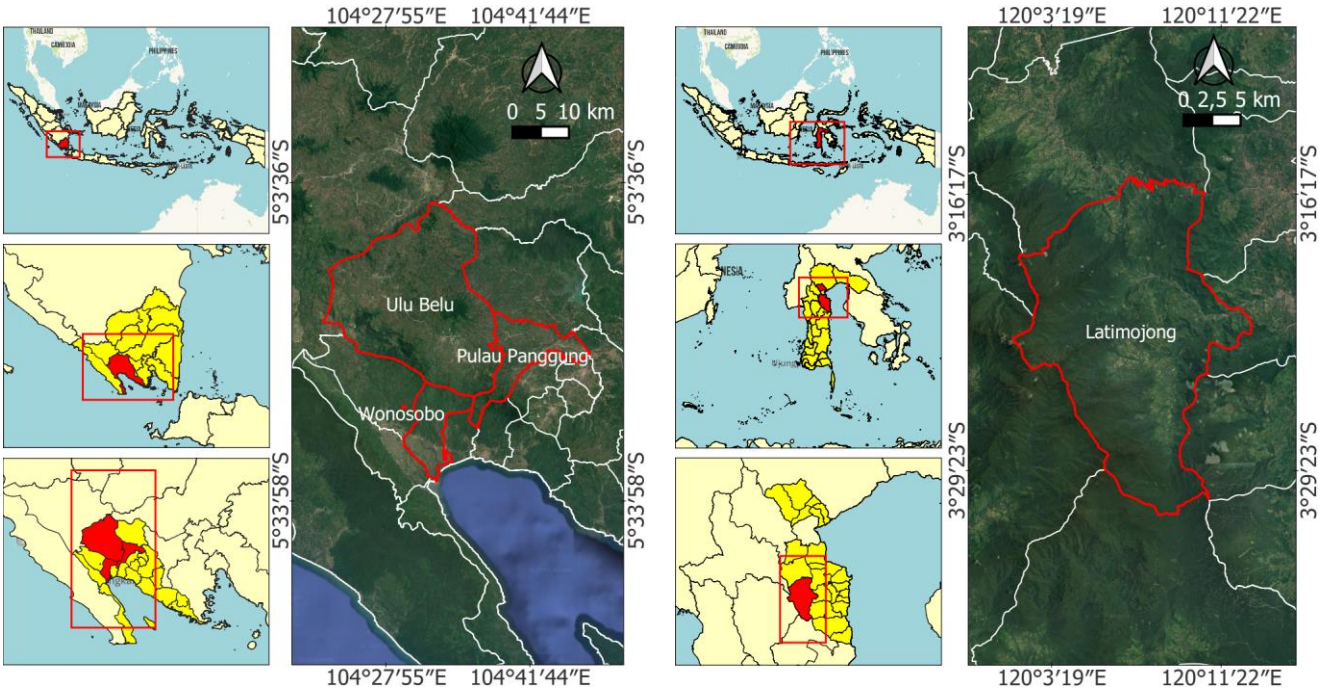

Figure 1. A. Research location in Wonosobo, Tanggamus, Lampung, Indonesia; B. Research location in Latimojong, Luwu, South Sulawesi, Indonesia

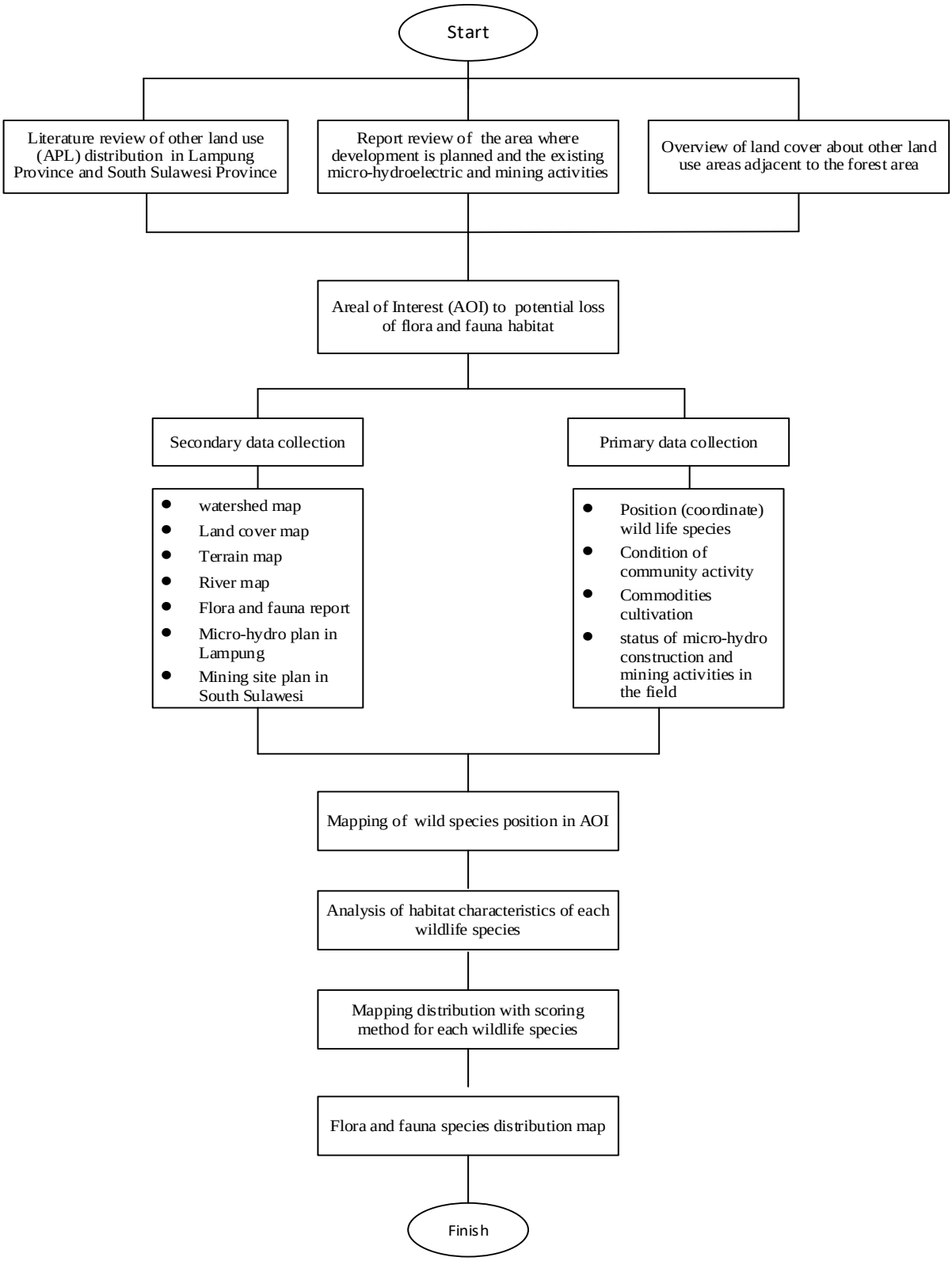

Figure 2. Flow chart diagram of research

Data analysis

The species mapping method used by using the scoring method, namely by using data on animal presence, land cover, and water presence, then scoring each variable. Scoring of potential animal presence is done by scoring a score for areas where animals are found, a score of 100, and for those where no animals are found, a score of 20. Scoring of land cover is divided into natural forest cover with a score of 100, secondary forest cover with a score of 60, and other land uses with a score of 20. While scoring

the availability of water is based on the proportion of animal presence. The weight for animal presence is 50, the weight for land cover is 30, and the weight for water availability is 20. The distribution value is the sum of the multiplication between the weight and score of each variable. To determine the distribution level, the low distribution value, if the value is < 40; the medium distribution value, if the value is between 40 - 60; and the high distribution value if the value is > 60.

RESULTS AND DISCUSSION

Mapping of key flora and fauna species habitat in Lampung

AOI determination

Referring to the results of the gap analysis by the Ministry of Forestry and the Ministry of Marine Affairs and Fisheries in 2010, there are still endangered wildlife habitats; it is estimated that around 80% are still outside the conservation area system (Chrismiawati et al. 2022), one of which is in the essential ecosystem as ex-situ conservation of wildlife. Essential ecosystem areas are regions with significant ecosystem values, not classified as nature conservation areas, nature reserves, or hunting parks. These areas are crucial for supporting ecological survival through biodiversity conservation efforts (Qomariah et al. 2021), while ex-situ conservation can have the function of providing an additional layer of protection for species that are critically endangered or whose habitats are severely threatened (Mahanayak 2024). In accordance with prevailing legislation and regulatory frameworks, designated essential ecosystem areas encompass parks, wildlife corridors, and high conservation value areas. However, areas with potential as essential ecosystems are not limited to those within forest or conservation areas (in-situ) but also include those outside these areas (ex-situ). These areas are vulnerable to human pressures, such as converting forest land into cultivation areas, including micro-hydro development. The range of electricity produced by micro hydro is 5kW-100 kW, usually providing power for a small community or rural industry in remote areas away from the grid. The basic concepts considered in the design of micro-hydropower plants are: topography and geomorphology of the site, evaluation of water resources and their generation potential, site selection and basic layout, hydraulic turbines and generators and their controls, environmental impact assessment and mitigation measures, economic evaluation of the project and financing potential, institutional framework and administrative procedures for obtaining necessary permits (Anaza et al. 2017). One possible impact is the reduction of land cover for the construction of micro-hydro facilities and equipment and changes in water temperature due to the generator process, leading to the loss of terrestrial flora and fauna and aquatic biota such as fish. It is, therefore, necessary to assess the state of biodiversity as a basis for mitigation. The area of interest research in Lampung Province is the area that has the potential for the development of micro hydro around Tenggamus Mountain (Figure 3).

Mapping of key flora and fauna species habitat in the Tenggamus Mountain, Lampung

The condition of the existing land cover in the AOI for micro hydro plant area shows that it is dominated by dry land mixed with shrubs is 84.27%, followed by 6.66% wetland agriculture land cover, 5% pure dryland agriculture, 3.12% settlements, and the rest are secondary dryland forest and open land; above this AOI is directly adjacent to the protected forest area. Thus, the function of this AOI is an area of spillover of flora and fauna from the protected forest areas (Figure 4; Table 1).

The data presented in the table above indicates the existence of two distinct flora and fauna habitats within the study site: natural habitats in primary dryland forest land cover and modified habitats in other land cover types. The natural habitats in this AOI are characterized by their location along riverbanks, where the steep slopes make the area unsuitable for agricultural use. These habitats within the study site have significant conservation value, providing essential food sources for fauna and flora. This is evidenced by notable conservation vegetation species such as *dao* (*Dracontomelon dao* (Blanco) Merr. & Rolfe) and figs (*Ficus* spp.) within the area. The urgency of preserving these habitats is underscored by the presence of endangered or threatened species such as *Anguilla bicolor* McClelland, 1844 or *pelus pita* (NT), *Spilornis cheela* (Latham, 1790) or Crested serpent eagle (LC), *Helarctos malayanus* (Raffles, 1822) or sun bear (VU), *Symphalangus syndactylus* (Raffles, 1821) or siamang (EN), and *Macaca nemestrina* (Linnaeus, 1766) or *beruk* (EN).

The proximity of agricultural areas to natural habitats often leads to human-wildlife conflicts (Rifaie et al. 2021). A survey of the modified habitat indicated the absence of protected tree species. The only three species identified were those with high economic value, including durian (*Durio zibethinus* Murray), *duku* (*Lansium domesticum* Corrêa), cacao (*Theobroma cacao* L.), and coffee (*Coffea arabica* L.). Based on observation interviews with the locals, we observe several moderate to high-risk IUCN status species; there are siamang (*S. syndactylus*), pig tailed monkey (*M. nemestrina*), and Malayan sun bear (*H. malayanus*).

Table 1. Land coverage in AOI in Lampung

Land coverage	Area (ha)	Percentage (%)
Secondary dryland forest	118.62	0.90
Settlement	411.91	3.12
Dryland agriculture	659.74	5.00
Dryland mixed agriculture	11129.08	84.27
Wetland farming	879.71	6.66
Open Land	6.91	0.05
Grand total	13205.97	100.00

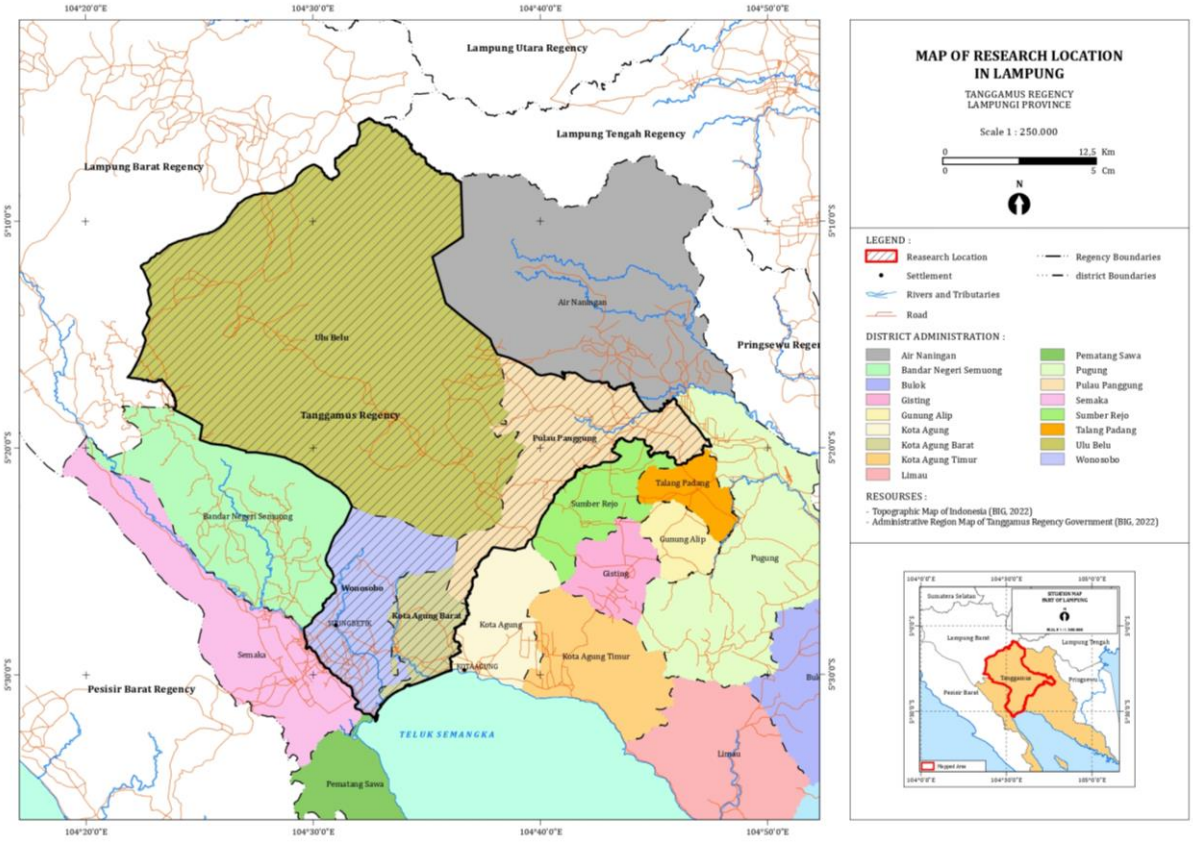

Figure 3. An area of interest for research is APL. There is the potential for micro-hydro development in Mt. Tenggamus, Indonesia

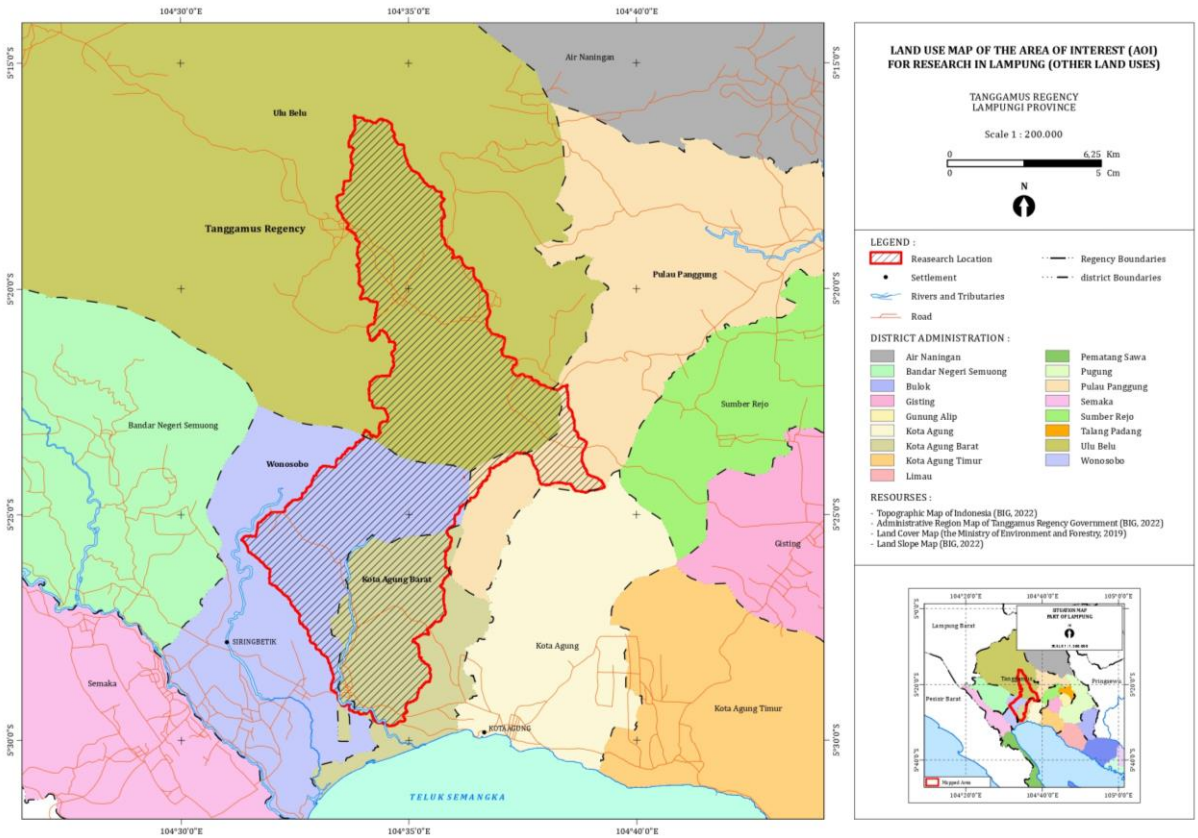

Figure 4. Map of land coverage in AOI in Lampung, Indonesia

Threatened species of birds can be spotted within modified habitats, with no sightings of Endangered (EN) species. Coffee plantations and mixed orchards sustain diverse species of birds. Thus, modified habitats have become important to many birds livelihoods. Notable species in modified habitat are the collared kingfisher (*Todiramphus chloris* (Boddaert, 1783)), ruby-throated bulbul (*Rubigula dispar*), and tailed drongo-cuckoo (*Surniculus lugubris* (Horsfield, 1821)). The results of the incidental observation nocturnal visual encounter survey indicated the presence of a few low-risk IUCN status species. These species included the Asian common toad (*Duttaphrynus melanostictus* (Schneider, 1799)), the Asian giant toad (*Phrynoidis asper* (Gravenhorst, 1829)), and the crab-eating frog (*Fejervarya cancrivora* (Gravenhorst, 1829)). No threatened species of amphibians were encountered within the modified habitat. The species observed demonstrated tolerance to pollution disturbance. Residents rarely observed or knew indicator species due to their cryptic morphology and low population size. The reptiles documented in modified habitats are classified as "Least Concern" (LC) by the IUCN. The lizards have been observed primarily in proximity to orchards. The Asian box turtle (*Cuora amboinensis* (Daudin, 1801)) is frequently encountered in the downstream area of the Way Belu River and has been introduced into local captivity. The Malayan softshell turtle (*Dogania subplana* (Geoffroy Saint-Hilaire, 1809)) is found near Way Panas Village, where the local populace consumes it. Based on the findings of flora species and animal encounters and overlaid with the land cover map, a distribution map of endemic flora distribution, bird distribution, amphibian distribution, and fish distribution was obtained as shown in Figure 5.

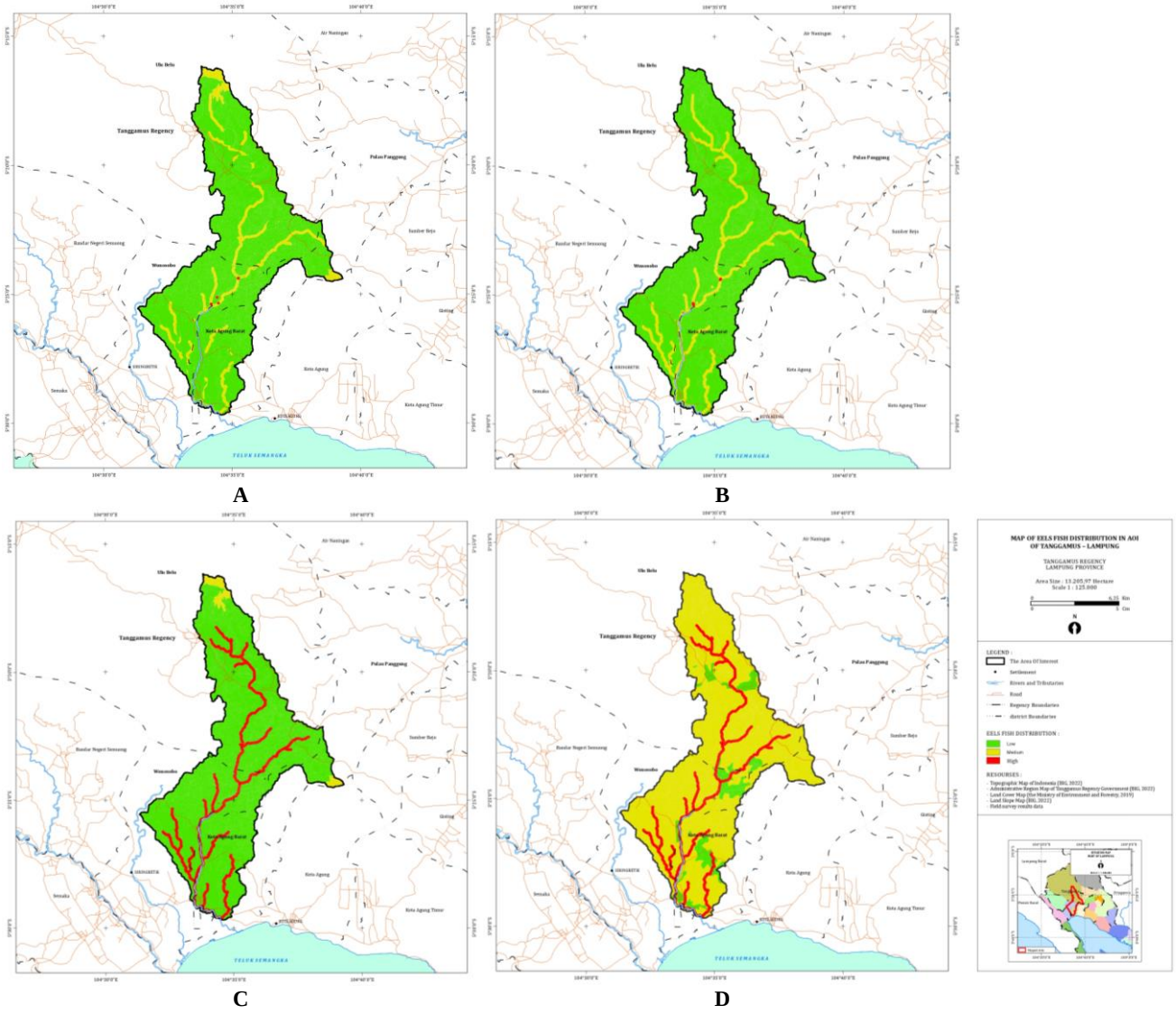

Figure 5. Distribution map of some plants and animals in Tenggamus Mountain, Lampung, Indonesia: A. Endemic vegetation; B. Birds; C. Amphibians; D. Fish

Mapping of key flora and fauna species habitat in South Sulawesi

APL of Latimojong Mountain, South Sulawesi

Conservation efforts at mining sites should focus on preserving biodiversity. This is because mining activities will disrupt vegetation establishment, and the basal area of shrubs and fragmented and open forests will be higher than before mining activities (Kpangui et al. 2021). Therefore, the APLs as the AOI that will be examined for flora and fauna distribution is the APL of Mount Latimojong, an area indicated to have the potential for mining material deposits (Figure 6). This is the main basis for assessing the impact of mining activities as the basis for mining mitigation strategies.

Despite the designation of this area as forest and its subsequent categorization as APL in the Latimojong Mountains of South Sulawesi, the ecosystem remains classified as a forest ecosystem that has undergone degradation due to land clearing, which was then followed by the cultivation of garden crops, including cloves, coffee, and cocoa. The condition of the existing land cover in the AOI for micro hydro plant area shows that it is dominated by most of the area is dry land mixed with shrubs (84.27%), followed by 6.66% wetland agriculture land cover, 5% pure dryland agriculture, 3.12% settlements, and the rest is secondary dryland forest and open land. Above this AOI is directly adjacent to the protected forest area. In contrast to the situation in Lampung AOI, the South Sulawesi AOI exhibits a distinguishing characteristic (Figure 7; Table 2). The presence of natural flora and plants in this region cannot be distinguished between natural and modified habitats. This is since some modified habitats, such as those found in mixed agricultural drylands, have been left by cultivators and have experienced natural succession. Consequently, these habitats already possess endemic flora resulting from the natural succession process and the results of planting (Figure 8). The presence of notable conservation vegetation species, such as (i) the banyan (*Ficus* sp.), which provides a nesting place for tarsiers and a food source for various birds and short-tailed monkeys; (ii) *dao* (*D. dao*), whose fruit is food for hornbills; (iii) kalopiso trees (local name, indeterminate), whose fruit for short-tailed macaques (tonkean); and (iv) *aren* (*Arenga pinnata*): the trunk is a nesting place for tarsiers; the fruit is food for tonkean monkeys, tarsiers, and cuscus. Wood from various types of trees is economically valuable to the community. These include various *bakan* trees (*Actinodaphne* sp.), *mara* (*Macaranga tanarius* (L.) Müll.Arg.), *dao* (*D. dao*), *rengas* (*Gluta renghas* L.), *kani* or *dadap* (*Erythrina fusca* Lour.), and *nyatoh* (*Palaquium* sp.). A notable tree, the *pulai* (*Alstonia scholaris* (L.) R.Br.), is used for its medicinal properties, with its bark and trunk used in traditional remedies. A comprehensive review of the existing literature reveals the diverse therapeutic applications of *pulai* wood and bark, including the treatment of prolonged fever, obesity, elevated cholesterol, dandruff and lice, toothaches, diarrhea, nausea, and malaria. At the same time, the fauna found in Mount Latimojong AOI is included in Table 3.

Based on the habitat characteristics of several species of animals found, they have been mapped as described in Figure 8.

Table 2. Land coverage in AOI in South Sulawesi

Land coverage	Area (ha)	Percentage (%)
Secondary dryland forest	551.11	30.57
Dryland agriculture	377.98	20.97
Dryland mixed agriculture	681.13	37.78
Shrubs	192.49	10.68
Grand total	1802.71	100.00

Table 3. Land coverage in AOI in Mt. Latimojong, South Sulawesi, Indonesia

Species	Family	2013	2017	2019	2022	IUCN	Note
Ailurops ursinus (Temminck, 1824)	Phalangeridae	1	1			VU	Endemic Sulawesi
Strigocuscus celebensis (Gray, 1858)	Phalangeridae	1	1			NT	Endemic Sulawesi
Macaca tonkeana (Meyer, 1899)	Cercopithecidae	1			1	VU	Endemic Sulawesi
Tarsius fuscus	Tarsiidae	1	1			VU	-
Sus celebensis Müller & Schlegel, 1843	Suidae	1	1		1	NT	Widespread
Babyrousa bolabatuensis Hoojer, 1950	Suidae	1				EN	-
Rusa timorensis (Blainville, 1822)	Cervidae	1	1			VU	Widespread
Bubalus depressicornis (C.H.Smith, 1827)	Bovidae	1				EN	Doubtful, see
Bubalus quarlesi (Ouwens, 1910)	Bovidae	1				EN	Burton et al. 2005
Macrogalidia musschenbroekii (Schlegel, 1877)	Viverridae	1	1			VU	Not yet recorded from S. Sulawesi
Acerodon celebensis (Peters, 1867)	Pteropodidae					VU	Endemic Sulawesi
Pteropus griseus (E.Geoffroy, 1810)	Pteropodidae					VU	Sulawesi & East Nusa Tenggara
Rousettus bidens (Jentink, 1879)	Pteropodidae	1				VU	Endemic Sulawesi
Accipiter nanus (W.Blasius, 1897)	Accipitridae	1				NT	Endemic
Ichthyophaga humilis (S.Muller & Schlegel, 1841)	Accipitridae	1				NT	Widespread SE Asia
Lophotriorchis kienerii (Sparre, 1835)	Accipitridae	1				NT	-
Macrocephalon maleo S.Müller, 1846	Megapodiidae					EN	Nesting ground not in this area
Megapodius cumingii Dillwyn, 1853	Megapodiidae	1				NT	Nesting ground not in this area
Ficedula rufigula (Wallace, 1865)	Muscicapidae	1				NT	Habitat loss
Rhyticeros cassidix (Temminck, 1823)	Bucerotidae	1	1		1	VU	Endemic
Penelopides exarhatus (Temminck, 1823)	Bucerotidae				1	VU	Endemic
Hydrosaurus microlophus (Bleeker, 1860)	Agamidae				1	DD	In CITES list
Malayopython reticulatus (Schneider, 1801)	Pythonidae	1	1		1	LC	In CITES list
Macaranga tanarius (L.) Müll.Arg.	Euphorbiaceae	1	1		1	LC	In CITES list
Erythrina fusca Lour.	Fabaceae	1	1		1	LC	In CITES list
Palaquium sp.	Sapotaceae	1	1		1	VU	In CITES list
Total		21	11	0	9		

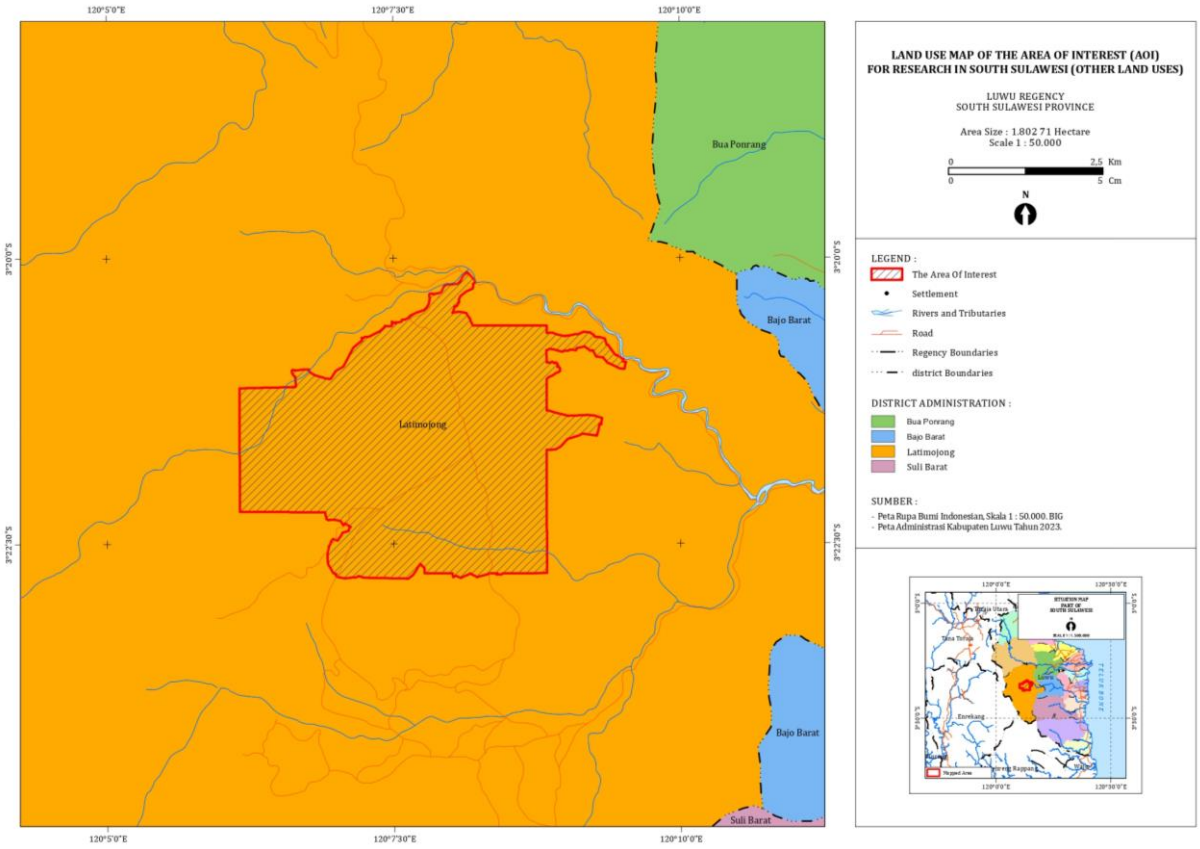

Figure 6. An area of interest for research is APL. There is the potential for gold mining in Mt. Latimojong, South Sulawesi, Indonesia

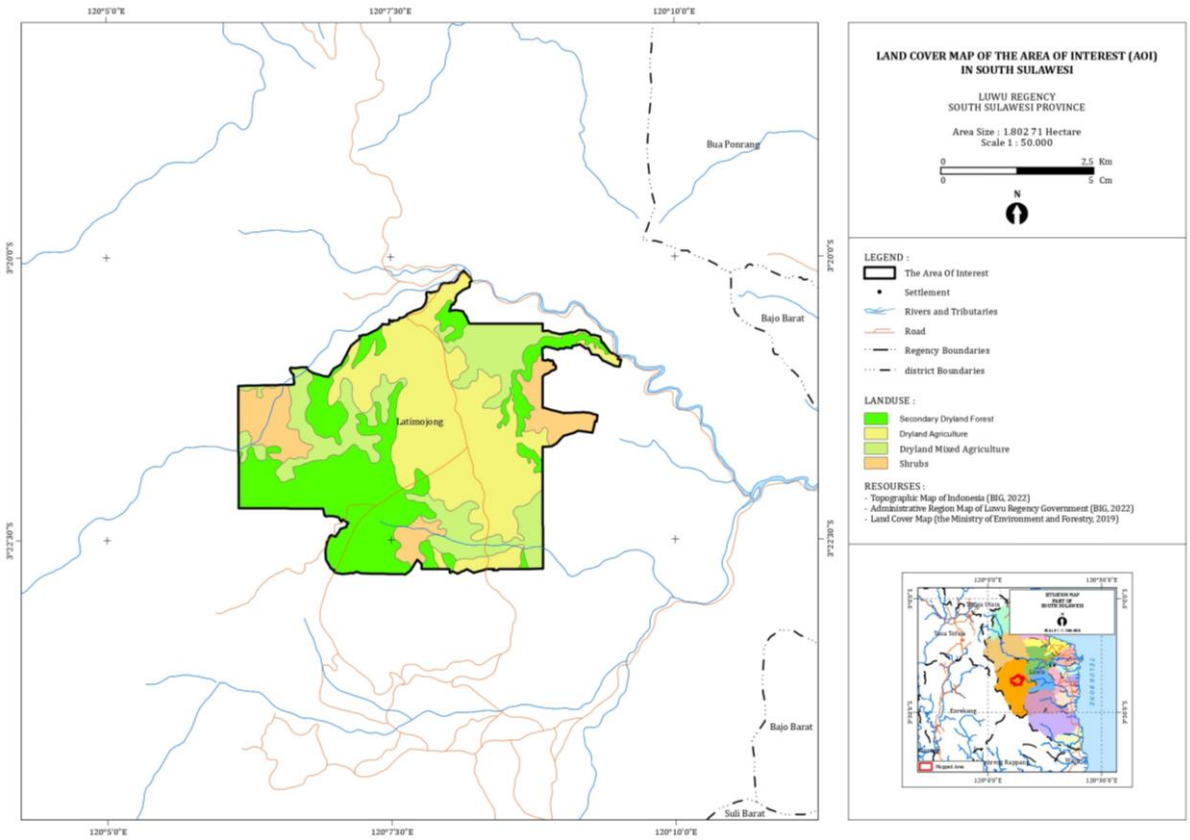

Figure 7. Land coverage in AOI in Mt. Latimojong, South Sulawesi, Indonesia

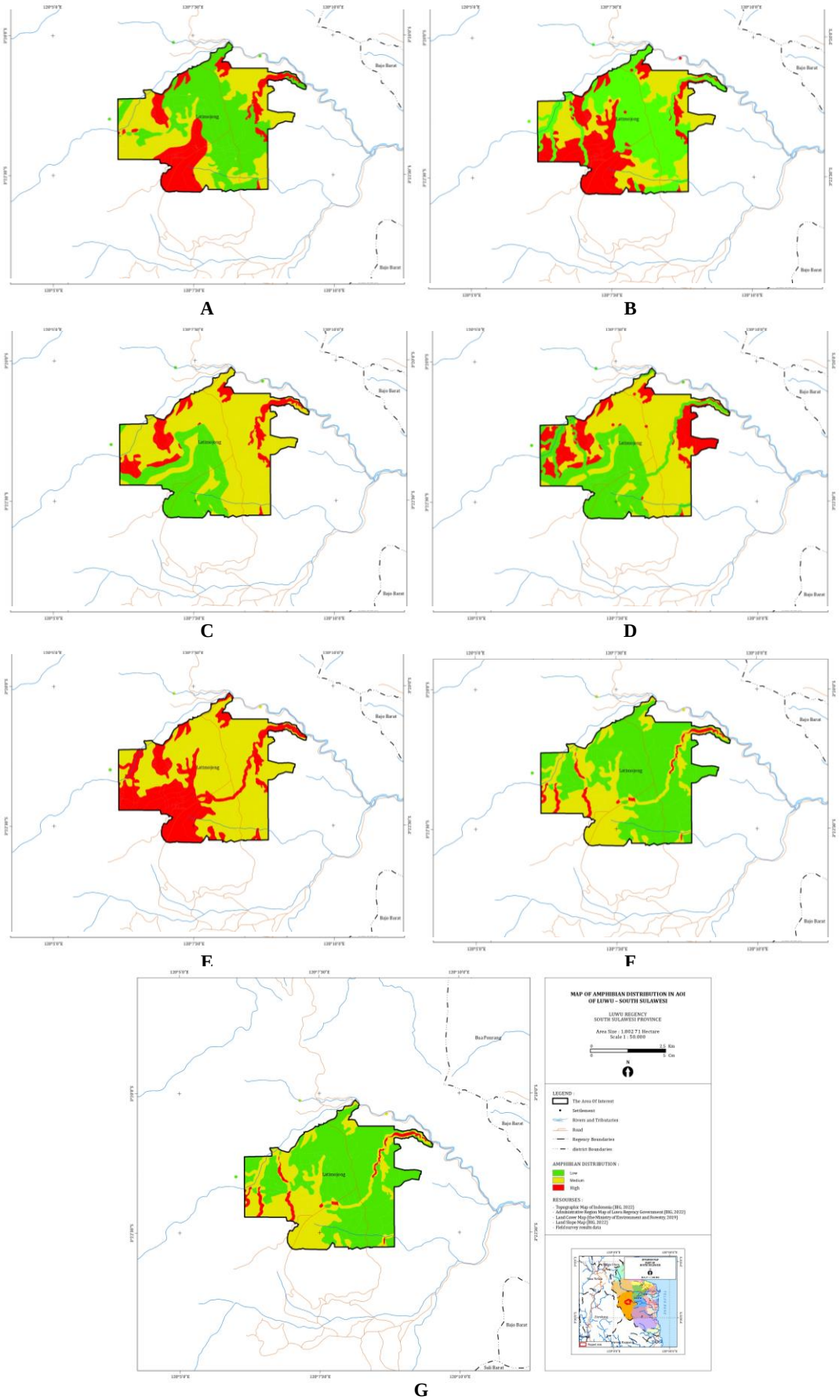

Figure 8. Distribution map of some plants and animals in Tenggamus Mountain, Lampung, Indonesia: A. Endemic vegetation; B. Black eagle; C. Hornbill's; D. Tarsius; E. Sulawesi pig; F. Amphibia; G. Eel

Discussion

Dracontomelon dao is an endemic species of lowland forests, capable of thriving in diverse soil conditions, particularly in alluvial soils and swampy (Putri et al. 2022); this species is distributed in Sumatra, Kalimantan and Sulawesi Islands (Kurniawan et al. 2008). In degraded habitats in Sulawesi, *D. dao* was one of the dominating species compositions in these sites alongside *Diospyros celebica* Bakh., *Canangium odoratum* (Lam.) King, *Ficus benjamina* L., *Pterospermum celebicum* Miq, *Kleinhovia hospita* L., and *Vitex cofassus* Reinw. ex Blume. BB, CS, FP, and PB (Nessi et al. 2023). In remnant forests throughout Visayas, Philippines, *D. dao* has to be only encountered as singletons (Peque and Hölscher 2014). In the two study sites, the APL on Tenggamus Mountain and Latimojong Mountain, *D. dao* was also found in singletons.

The primate species in Indonesia exhibit considerable diversity, ranging from the smallest to the largest. A total of 59 primate species from 11 genera inhabit Indonesian forest habitats. These include *M. nemestrina*, which is found on the islands of Kalimantan and Sumatra; *S. syndactylus*, which is found on the island of Sumatra; and *Tarsius fuscus* Fischer, 1804 (Ruskhanidar et al. 2017). In addition to natural conditions, various primates are found in modified habitats, such as farmland (Utari et al. 2023). *M. nemestrina* is classified as Endangered due to a 50% population decline in the last three generations (approximately 33 years), which is expected to continue to decline without intervention. Some of the factors leading to the decline are the conversion of prime habitat to agricultural land (e.g., oil palm, durian, rubber), mining, and habitat degradation due to deforestation, road building, and infrastructure development, as well as draining of peat swamps and seasonal forest burning (Rupert et al. 2022). In Philippines, seventeen threats to tarsiers are involved, ranging from high, medium, or low. Then, 11 threats caused and/or exacerbated fragmentation were involved. Two were assessed as serious threats, four as medium, and four as low. Those 11 of the threats identified may result from fragmentation or habitat destruction. The direct threats to tarsiers include incidental hunting for pets, sometimes with dogs. Excessive noises can sometimes be heard in the area while harvesting trees, forest fires, and typhoons. These could also cause an open canopy, allowing excessive light to penetrate the forest. The presence of houses near the forests, farms, and recreational areas in the forest would likely threaten the species in the future, possibly by exacerbating habitat loss (Torrefiel et al. 2023). The population of siamang is threatened due to the reduced quantity and quality of habitat and hunting of wild animals. Siamang has a category of endangered based on the IUCN (The International Union for Conservation of Nature) Red List (2019). Based on the threat to the wildlife trade, siamang is classified on Appendix I CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), where their population is declining in natural habitat, so their trade is very strict by the government. In Indonesia, siamang is protected by the state based on the Regulation of the Minister of Environmental and Forestry Number P.106 of 201 (Rasyid et al. 2024).

Tarsier habitats typically include secondary forests, garden forests, the edges of secondary forests adjacent to plantations or farms, and areas surrounding human settlement (Mustari et al. 2013), with resting places or nests generally in bamboo clumps, especially thorny bamboo (*Bambusa multiplex* (Lour.) Raeusch. ex Schult.f.). There are 52 plant species from 30 families in tarsier habitat and are dominated by Euphorbiaceae and Bambusaceae (Wirdateti and Dahrudin 2008), while in Central Kalimantan, it was found in 43 vegetation types (Octavianus 2020). At the research site, the APLs of Mount Tenggamus, *M. nemestrina*, and *S. syndactylus* were found to inhabit hilltops within fragmented ecosystems. Due to their dispersed distribution, these species cannot be mapped. In contrast, the APLs of Mount Latimojong, *T. fuscus*, have been observed to reside within *Ficus* sp., allowing for their mapping. The presence of tarsius and cuscus has been documented in a secondary forest that has experienced minimal disturbance. The area is also home to forage trees and human habitation, including banyan and sugar palm trees.

Sulawesi forest pig (*Sus celebensis* Müller & Schlegel, 1843) lives in various habitats, including primary forests and swamps, open grasslands, and agricultural areas. The species is found at all altitudes up to moss forests >2,500 masl, although it is less common above 1,500 masl. (Melletti and Meijaard 2018).The Sulawesi forest pig, also known as the Sulawesi warty pig (*S. celebensis*), is an extant wild pig endemic to the Indonesian island of Sulawesi. However, there is a theory that *S. celebensis* was domesticated and/or deliberately introduced to other islands in Indonesia before the advent of the Neolithic agricultural transition in the region. According to this theory, the long-standing practice of hunter-gatherers intensively rearing wild-caught *S. celebensis* piglets for adoption into human society as pets may have altered the predator-prey dynamic brought aspects of wild pig behavior and reproduction under indirect human selection and control and caused changes that differentiated pigs in contact with humans from those living in the wild (Brumm 2023). On the other island, for example, West Java, the fact that hunters frame their pig hunts as partly public service for pest control while enjoying the esoteric aspects of it as a thrill and a hobby shows that this activity has a strong psychological and moral footing for its sustainability (Mulyanto et al. 2021). The continued hunting is because wild pigs are considered a pest and as part of the survival of agriculture.

The presence of hornbills in given is closely associated with food availability. An increase in food sources leads to corresponding rise in the hornbill population. The primary food source of hornbills is fruit-bearing; therefore, their population dynamics are influenced by the fruiting seasons of these trees (Fitriansyah et al. 2022). Apart from fruiting trees, hornbills also have different trees for nesting. Mount Ungaran, Central Java, Indonesia, the trees that were used for nests were *salam klontong* (*Syzygium glabratum* (DC.) Veldkamp), *nagasari* (*Syzygium antisepticum* Blume) Merr. & L.M.Perry), and *marong* (*Cratoxylum formosum* (Jack) Benth. & Hook.fil. ex Dyer). *Syzygium glabratum* and *S. antisepticum* belong to family of Myrtaceae. The height of these trees ranged between 24-35 m with a diameter of

0.83-1.75 m (Rahayuningsih et al. 2017). The black eagle (*Ictinaetus malayensis* (Temminck, 1822)), as a raptor or bird of prey, is a top predator in the food chain as a counterweight and indicator of ecosystem health in forest areas and presence in Java Island at Bromo Tengger Semeru National Park (TNBTS) as habitat (Ningtyas et al. 2021). In India, *I. malayensis* is a major predator in the evergreen mountain forests of Mizoram, mainly preying on rodents, thus playing a very important role in controlling rodent populations (Sailo et al. 2020). The black eagle (*I. malayensis*) distribution in China was historically restricted to the Fujian, Taiwan, and Yunnan regions. However, in the last two decades, there has been an increase in the number of sightings across China, indicating an expansion of the habitat of the black eagle in suitable forests (Lei et al. 2014). Whereas in the research locations, namely on Mount Tenggamus and Mount Latimojong, hornbills were found. The food tree was *D. dao*, and the food source and nest were *Ficus* sp. However, black eagles are only found and can be mapped on Mount Latimojong, South Sulawesi Province.

The productive and physiological amphibians, ectothermic reptiles, are strongly influenced by rainfall, water availability, and temperature. So, amphibians depend on external heat sources for the thermoregulation process of distribution underlying speciation, dispersal, and local extinction vary according to climate factors (Cruz et al. 2024). In Italy, abiotic river features mainly affected the amphibian community, while otters or fish as predators did not seem to have a detrimental effect on the amphibian community (Nessi et al. 2023). The environmental categories of amphibians in Lombok were classified into three categories. Category 1 has a high influence, consisting of humidity, canopy, and tree species richness. Category 2 has a moderate influence: altitude, air temperature, and water temperature. Category 3 has a low influence, consisting of river length, river width, left and right river width explored, and river slope (Syazali et al. 2017). Likewise, in the study site, Amphibians were found in streams on various land covers in the APLs of Mount Tenggamus and Mount Latimojong. The habitat of Amphibians is located in small streams as part of larger river systems, particularly areas with forest vegetation cover and spring water. The distribution of amphibian's presence along the riverbank with widths up to 50 cm on both the right and left sides of rivers is influenced by the condition of the vegetation. By overlaying maps of tributary streams and analysing the condition of the land cover, we can gain insights into the distribution patterns of amphibians in a given region. The following map and table illustrate the results of this analysis.

The eel life cycle consists of five stages: leptocephalus, glass eel, elver, yellow eel, and silver eel. Leptocephalus stages occur in the marine environment, where it undergoes metamorphoses into glass eels stage. Glass eel then migrate from seawater to freshwater, where they grow and mature into silver eels. Upon reaching maturity, silver eels return to the sea to spawn (Rachmawati et al. 2023). The quantity of young eel immigrating to freshwater habitats has been monitored in some river mouths, using eel traps often connected to eel passes, while growing yellow eel in freshwater habitats has been paid less attention. Eel habitat is in large rivers or springs with the most natural vegetation cover, assuming that human activity is minimal (Degerman et al. 2019). The eel fish is a catadromous, so its initial habitat starts from the deep sea. After hatching will follow the flow of ocean currents to migrate to the mouth of the river. From the mouth of the river, the eel (*A. bicolor)* will live in river bodies, swamps, rice field irrigation channels, canals, waterways connected to sea waters, and up to the lake (Romadhi et al. 2022), with water quality conditions, namely, sufficient water salinity, and the river mouth remains connected to the sea even during the dry season (Sugianti et al. 2020). Because of a complex life cycle, catadromous fish species face any level threats of multiple anthropogenic activities that have resulted in worldwide decline since the beginning of the 20th century (Podda et al. 2021). Referring to information from the Ministry of Fisheries and Maritime Affairs of the Republic of Indonesia, the existence of this fish is recorded to be spread across several countries in Africa, Oceania, and Asia. This fish is found in Indonesia, Myanmar, the Philippines, Vietnam, and Thailand in Southeast Asia. In Indonesia itself, the distribution area is along the west coast of Sumatra, the south coast of Java, Bali, NTB, NTT, along the east coast of Kalimantan, Sulawesi Waters, Maluku, to Waters in Papua. At the research site, the eel distribution presence indication can be mapped both in the APL of Mount Tenggamus and in the APL of Mount Latimojong, that is, in streams of various land covers.

Management implications

Biodiversity offsets are conservation strategy designed to compensate for biodiversity losses while ensuring the protection and maintenance of biodiversity values in alternative locations. Offsets generally can be applied where biodiversity loss cannot be avoided, mitigated, or minimized from development proposals (Fallding 2014). It functions as a planning and decision-making instrument that acknowledges and assigns value to biodiversity, facilitating the mitigation of impacts as part of land-use planning processes. Offsetting enables the preservation and management of biodiversity in areas where onsite protection is infeasible or impracticable biodiversity offsets companies have voluntarily implemented to achieve no net loss or net gain of biodiversity to compensate for residual biodiversity loss from their activities. Mining industries have implemented these in Madagascar (Ta and Campbell 2023). Although biodiversity offsets are applied in many countries to compensate for environmental impacts, research on regulatory frameworks and implementation enabling effective offsets is lacking. Some aspects concern as well as the consideration is of trade-off when regulations focus only on the biodiversity aspect of ecosystems. This aspect can assess offsets of any land and support the reform of programs that balance development and conservation. Consequently, these scholars have called for a moratorium on their application. Nevertheless, it is imperative to undertake an empirical evaluation of existing programs, such as conservation banking, before arriving at a definitive conclusion regarding the merits or shortcomings

of any policy instrument (Grimm and Köppel 2019). The location that can be used as a biodiversity offset area to save wildlife on APLs is by ex-situ conservation, namely the cultivation and protection of plants and animals outside their natural habitat with several methods, namely handing over management to zoos, botanical gardens, aquaria, seed banks, pollen banks, semen banks, tissue culture banks, or through genetic engineering (Mahanayak 2024). But the most important thing is to minimize anthropogenic threats to wildlife in agricultural landscapes by establishing environmentally friendly farming practices that can sustain wildlife populations in the long term (Holzner et al. 2024). Furthermore, stringent stipulations imposed by the funding entity are poised to substantially influence the execution of biodiversity offset mechanisms.

Policies of conversion forestland to other land use (APLs) for activities not associated with the forestry sector, such as agriculture, plantations, transmigration, mining, and power generation development, should be concerned with key vegetation and animals that are stuck in APLs. If this is not a concern, these key plants and animals will soon become extinct due to habitat fragmentation, changing the ecosystem in which key plants grow and the home range of key animals. Therefore, when planning land use for agriculture, plantations, mining, or micro-hydro development, it is necessary to require biodiversity offsets if key plants and animals are found in the area to be used. To ensure their presence, mapping the distribution of key wildlife is necessary.

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REFERENCES

Anaza SO, Abdulazeez MS, Yisah YA, Yusuf YO, Salawu BU, Momoh SU. 2017. Micro hydro-electric energy generation-an overview. Am J Eng Res 6 (2): 5-12.

Brumm A. 2023. Pigs as pets: Early human relations with the Sulawesi warty pig (Sus celebensis). Animals (Basel) 13 (1): 48. DOI: 10.3390/ani13010048.

Chrismiawati M, Trisetyaningrum Y, Herniwati, Ismanto A, Iswandono E. 2023 Identifikasi potensi keanekaragaman hayati pada kawasan hutan lindung di Pulau Lembata. Prosiding Seminar Nasional Pertanian 2022 1 (1): 261-268. [Indonesian]

Cruz JA, Basanta MD, Garcia-Castillo MG, Woolrich-Piña GA, Parra-Olea G. 2024. Amphibians environmental dependence and their use in paleoecological reconstruction. In Past Environments of Mexico: Unveiling the Past Environments of a Megadiverse Country Through its Fossil Record (pp. 253-271). Springer Nature, Cham, Switzerland. DOI: 10.1007/978-3-031-51034-2_11.

Degerman E, Tamario C, Watz J, Nilsson PA, Calles O. 2019. Occurrence and habitat use of European eel (*Anguilla anguilla*) in running waters: Lessons for improved monitoring, habitat restoration, and stocking. Aquat Ecol 53 (4): 639-650. DOI: 10.1007/s10452-019-09714-3.

Fallding M. 2014. Biodiversity offsets: Practice and promise. Environ Plan Law J 31 (1): 11-33.

Fitriansyah RA, Setiawan A, Rustiati EL, Utoyo L, Sibarani MC. 2022. Spatial distribution and temporal patterns of food tree availability of hornbills (Bucerotidae) at Way Canguk Research Station, Bukit Barisan Selatan National Park, Indonesia. Biodiversitas 23 (4): 1990-1997. DOI: 10.13057/biodiv/d230433.

Grimm M, Köppel J. 2019. Biodiversity offset program design and implementation. Sustainability 11 (24): 6903. DOI: 10.3390/su11246903.

Holzner A, Mohd Rameli NIA, Ruppert N, Widdig A. 2024. Agricultural habitat use affects infant survivorship in an endangered macaque species. Curr Biol 34 (2): 410-416.e4. DOI: 10.1016/j.cub.2023.12.002.

Iskandar DT. 2021. Kategorisasi IUCN dan institusi lainnya dalam upaya melindungi spesies. In: Supriatna J (eds.). Metode dan kajian konservasi biodiversitas (33–40). Yayasan Pustaka Obor Indonesia, Jakarta. [Indonesian]

IUCN SSC Asian Rhino Specialist Group. 2020. *Dicerorhinus sumatrensis*. The IUCN Red List of Threatened Species 2020: e.T6553A18493355. DOI: 10.2305/IUCN.UK.2020-2.RLTS.T6553A18493355.en.

IUCN SSC Cat Specialist Group. 2015. *Panthera tigris* subsp. *sumatrae*. The IUCN Red List of Threatened Species 2015: e.T15966A50659951. DOI: 10.2305/IUCN.UK.2015-2.RLTS.T15966A50659951.en.

IUCN. 2019. *Symphalangus syndactylus* (siamang). The IUCN Red List of Threatened Species 2019: e.T39776A17969872. DOI: 10.2305/IUCN.UK.2019-3.RLTS.T39776A17969872.en.

Kpangui KB, Kouakou KA, Koffi NG, Sangne YC. 2021. Impact of gold mining on flora: The case of the Sissengue gold mine (Northern Cote D'Ivoire). Intl J Adv Res 9 (10): 1415-1425. DOI: 10.21474/IJAR01/13701.

Kurniawan A, Undaharta NKE, Pendit IMR. 2008. Association of dominated tree species in lowland tropical forest of Tangkoko Nature Reserve, Bitung, North Sulawesi. Biodiversitas 9 (3): 199-203. DOI: 10.13057/biodiv/d090310.

Lei Z, Xiao-Nong Y, Guang H, Qin H, Tian-Tian L, ZI-YUE DA, Qian W. 2014. A review of the distribution of black eagle *Ictinaetus malaiensis* in mainland China. Forktail 30: 45-49.

Mahanayak B. 2024. Ex-situ and in-situ conservation of wildlife. World J Biol Pharm Health Sci 18 (3): 277-282. DOI: 10.30574/wjbphs.2024.18.3.0371.

Melletti, M., and E. Meijaard, editors. 2018. Ecology, conservation and management of wild pigs and peccaries. Cambridge University Press, Cambridge, United Kingdom.

Metcalfe I. 2017. Tectonic evolution of Sundaland. Bull Geol Soc Malays 63: 27-60. DOI: 10.7186/bgsm63201702.

Muhaimin M, Hidayat IW. 2018. Plants diversity in Mount Tanggamus Protected Forest, Lampung and its conservation efforts. Pros Sem Nas Masy Biodiv Indon 4 (2): 144-150. DOI: 10.13057/psnmbi/m040208. [Indonesian]

Mulyanto D, Abdoellah OS, Iskandar J, Gunawan B. 2021. Ethnozoological study of the wild pig (*Sus* spp.) hunting among Sundanese in Upper Citarum Watershed area, West Java, Indonesia. Biodiversitas 22 (11): 4930-4939. DOI: 10.13057/biodiv/d221127.

Mustari AH, Mansyur FI, Rinaldi DO. 2013. Habitat characteristics and population of *Tarsius fuscus* in Balocci Resort, Bantimurung-Bulusaraung National Park, South Sulawesi. Media Konservasi 18 (1): 47-53. [Indonesian]

Nessi A, Cioccarelli S, Tremolada P, Gariano P, Grandinetti M, Balestrieri A, Manenti R. 2023. Environmental factors affecting amphibian communities in river basins of the Southern Apennines. Diversity 15 (5): 625. DOI: 10.3390/d15050625.

Ningtyas AN, Susilo TSSD, Aryanti NA, Prasetya KN. 2021. Identification and population density of several raptor types in the RPTN Coban Trisula and Jabung Bromo Tengger Semeru National Park. IOP Conf Ser: Earth Environ Sci 743: 012055. DOI: 10.1088/1755-1315/743/1/012055.

Octavianus R. 2020. Population and habitat characteristics of tarsier (*Cephalopachus bancanus borneanus*) in Punggualas, Sebangau National Park. Jurnal Jejaring Matematika dan Sains 2 (1): 6-11. DOI: 10.36873/jjms.2020.v2.i1.312. [Indonesian]

Peque D, Hölscher D. 2014. The abundance of rare tree species in remnant forests across the Visayas, Philippines. Biodivers Conserv 23: 2183-2200. DOI: 10.1007/s10531-014-0714-6.

Podda C, Palmas F, Pusceddu A, Sabatini A. 2021. Hard times for catadromous fish: The case of the European eel *Anguilla anguilla* (L. 1758). Adv Oceanogr Limnol 12 (2): 47-64. DOI: 10.4081/aiol.2021.9997.

Putri TDY, Dharmono D, Utami NH. 2022. Ethnobotanical study of sengkuang plant (*Dracontomelon dao*) in Sabuhur Village, Jorong Sub-district, Tanah Laut District as a popular scientific book. JUPEIS: Jurnal Pendidikan dan Ilmu Sosial 1 (2): 33-42. [Indonesian]

Qomariah S, Hatta GM, Fithria DA. 2021. Recommendations for establishing essential ecosystem areas in Panjaratan Village. Jurnal Hutan Tropis 9 (2): 282-290. DOI: 10.20527/jht.v9i2.11276. [Indonesian]

Rachmawati FN, Susilo U, Aya FA. 2023. Comparison of reproductive aspects of the tropical eel *Anguilla bicolor* (McClelland 1884) in freshwater and estuarine habitats. ILMU KELAUTAN: Indones J Mar Sci 28 (3): 260-266. DOI: 10.14710/ik.ijms.28.3.260-266.

Rahayuningsih M, Kartijono NE, Retnoningsih A. 2017. Short communication: The nest characteristics of wreathed hornbill (*Rhyticeros undulatus*) in Mount Ungaran, Central Java, Indonesia. Biodiversitas 18 (3): 1130-1134. DOI: 10.13057/biodiv/d180334.

Rasyid UA, Ningsih M, Farida A, Arlita T, Rosita I. 2024. The population of siamang (*Sympalangus syndactylus*) in Damaran Baru Forest, Timang Gajah District, Bener Meriah Regency. IOP Conf Ser Earth Environ Sci 1297 (1): 012086. DOI: 10.1088/1755-1315/1297/1/012086.

Rifaie F, Sulistyadi E, Fitriana YS. 2021. A review of patterns and geographical distribution of human-wildlife conflicts in Indonesia. Berkala Penelitian Hayati J Biol Res 27 (1): 41-50. DOI: 10.23869/bphjbr.27.1.20217.

Romadhi MA, Indarjo A, Suryono CA. 2022. Distribution of sidat fish (catadromous fish) in the waters of the Lorok Ngadirojo River, Pacitan District, East Java. J Mar Res 11 (2): 128-135. DOI: 10.14710/jmr.v11i2.33797.

Rupert N, Holzner A, Hanzen MF, Ang A, Jones-Engel L. 2022. *Macaca nemestrina*: Southern pig-tailed macaque. The IUCN Red List of Threatened Species™. DOI: 10.2305/IUCN.UK.2022-1.RLTS.T12555A215350982.en.

Ruskhanidar Fr L. 2017. Species and distribution of primates in Indonesia. Jurnal Primatologi Indonesia 14 (1): 3-8. [Indonesian]

Sailo L, Lawmsangzuala C, Lallawmkima C, Lalruatfela C, Vanlalhruaizela C, Lalnunthara K, Rochamliana A, Lalthanzara H. 2020. Indian black eagle *Ictinaetus malayensis* (Temminck, 1822): Observations on nesting biology in Mizoram, India. J Environ Biol 41 (4): 896-900. DOI: 10.22438/jeb/4(SI)/MS_1911.

Shanmukha NT, Vinayaka M, Lokeshappa B, Nadaf S. 2024. Biodiversity loss due to mining activities. In: Impact of societal development and infrastructure on biodiversity decline. IGI Global: 166-191. DOI: 10.4018/979-8-3693-6950-0.ch011.

Sugianti Y, Putri MR, Purnamaningtyas SE. 2020. Spesies ikan sidat (*Anguilla* spp.) dan karakteristik habitat ruayanya di Sungai Cikaso, Sukabumi, Jawa Barat. Limnotek: Perairan Darat Tropis di Indonesia 27 (1): 39-54. DOI: 10.14203/limnotek.v27i1.329. [Indonesian]

Syazali M, Al Idrus A, Hadiprayitno G. 2017. Multivariate analysis of environmental factors affecting amphibian community structure in Lombok Island. Bioedukasi UNS 10 (2): 68-75. DOI: 10.20961/bioedukasi-uns.v10i2.11532. [Indonesian]

Ta LH, Campbell B. 2023. Environmental protection in Madagascar: Biodiversity offsetting in the mining sector as a corporate social responsibility strategy. Extr Ind Soc 15: 101305. DOI: 10.1016/j.exis.2023.101305.

Torrefiel J, Sabanal B, Cuta CB, Embayarte I, Modina RM, Cruz C, Pogado F, Ligue KD, Gamalo LE. 2023. A detailed assessment of threats to tarsiers and its habitat: A case of tarsiers *Carlito syrichta* (Linnaeus, 1758) in Hindang, Leyte. J Wildl Biodivers 7 (3): 80-95. DOI: 10.5281/zenodo.7308755.

Utama HW, Mulyasari R, Said YM. 2021. Geothermal potential on Sumatera fault system to sustainable geotourism in West Sumatera. JGE (Jurnal Geofisika Eksplorasi) 7 (2): 126-137. DOI: 10.23960/jge.v7i2.128. [Indonesian]

Utari A, Rasyid UHA, Syafruddin S. 2023. Primate species diversity in the forest management resort area Alue Gelima Tahura Pocut Meurah Intan Aceh Besar District. Jurnal Ilmiah Mahasiswa Pertanian 8 (4): 1073-1082. DOI: 10.17969/jimfp.v8i4.27626.

Williams AC, Talukdar BK, Hedges S, Campos-Arceiz A. (2020). *Elephas maximus* subsp. *sumatranus*. The IUCN Red List of Threatened Species 2020: e.T199856A192150204. DOI: 10.2305/IUCN.UK.2020-3.RLTS.T199856A192150204.en.

Winarno GD, Charles Y, Antonio C. 2024. Inventory of wild animals along the Bengkunat-Sanggi Road in Bukit Barisan Selatan National Park, Lampung Province, Indonesia. Biodiversitas 25 (9): 2917-2924. DOI: 10.13057/biodiv/d250911.

Wirdateti W, Dahrudin H. 2008. An exploration on the habitat, feeds and distribution of Tarsius tarsier (tarsier) in Selayar Island and Patunuang Nature Reserve, South Sulawesi. Biodiversitas 9 (2): 152-155. DOI: 10.13057/biodiv/d090215.