

Mountain tourism impact on bird diversity along hiking trails of Mount Prau, Central Java, Indonesia

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Abstract. *Abdullah M, Hakim L, Siswanto D, Setyowati DL. 2024. Mountain tourism impact on bird diversity along hiking trails of Mount Prau, Central Java, Indonesia. Biodiversitas 25: 4690-4698.* Hiking represents a significant dimension of mountain tourism and has gained considerable popularity among travelers. Unfortunately, the perception of hiking activities as a form of mass tourism raises significant concerns regarding potential environmental degradation and the threats posed to biodiversity in mountainous regions. Birds are organisms that are sensitive to human activities. Therefore, a critical component for assessing the impact of mountain tourism on biodiversity is to analyze the diversity of bird species on several hiking trails. This study aims to examine the differences in bird species diversity on several hiking trails with different visitor frequencies on Mount Prau, Indonesia. Surveys for bird observations were conducted systematically using the Variable Circular Plot (VCP) method along the hiking trail. Bird species diversity data were analyzed to obtain Margalef's species richness index, Shannon diversity index, and Pielou's evenness index. In addition, correspondence analysis was also used to see the differences in the composition of bird community species on different hiking trails. Trails with high visitor preferences showed lower species richness, diversity, and evenness indices than rarely visited trails. Ordination analysis showed a clear grouping of bird communities based on species composition between highly visited and less visited routes. Less frequented Mount Prau trails host diverse endemics and high conservation status birds, while heavily frequented trails show reduced diversity. This finding confirms the negative impact of mountain tourism on bird biodiversity in the mountain area. This also signifies the need for a conservation strategy to balance mountain tourism with biodiversity conservation in Mount Prau. It should be able to limit the number of visitors, control access in sensitive areas, and involve methods of ecotourism that would favor wildlife.

Keywords: Bird diversity, diversity index, ecotourism, hiking trail, Mount Prau

INTRODUCTION

Tourism in the mountains has been developed and publicized throughout the world, including Indonesia. This activity not only gives recreation to humans but also potentially affects the environment, especially biodiversity. Recent trends in nature-based tourism in mountainous areas have transitioned from mountain hiking by a few experienced individuals to mass tourism with significantly greater visitor numbers (World Tourism Organization 2018). The recent increase in mountain hiking is often associated with limited awareness of sustainable practices and environmental ethics. This situation has the potential to impact sensitive mountain ecosystems. Previously tranquil areas are now tourist hotspots, facing ecological pressure due to increasing visitor numbers. Several research findings have been documented on the vulnerability of mountainous ecosystems to various anthropogenic disturbances, habitat degradation, higher waste accumulation, and the introduction of non-native species (Santarém 2013; Canteiro et al. 2018).

Mountain tourism expansion and management practices have the potential to create environmental conflicts and impacts, with implications for biodiversity. A particularly significant impact resulting from this is noise pollution, which may well perturb wildlife by limiting avian distribution, reducing reproductive success, and altering avian assemblages (Francis et al. 2009). In addition, human use of pathways or corridors in tropical forests can impact animal movement along these routes (Blake et al. 2017; Hesler and Corbit 2018). The presence of hikers on trails may disrupt wildlife, leading to temporary or permanent displacement from the pathway. Different species exhibit varying responses to visitor interactions, which differ notably in terms of both spatial and temporal aspects (Marion 2019). Research has consistently shown that carnivores tend to avoid areas heavily used by humans, with encounters being less likely during the day than at night (Bandak et al. 2020). Red deer are found more commonly in remote areas during the day than near observation points close to trails but are more frequently detected near trails at night. There is also a notable decrease in red deer sightings during peak hiking periods

(Marion et al. 2019). Well-established hiking trail systems show lower cumulative wildlife numbers and species richness than newer trail systems (Hesler and Corbit 2018). Observations indicate significant differences in abundance, diversity index, and richness of dung beetle communities between tourism and non-tourism areas (Noriega et al. 2020).

One of the most important aspects to consider with mountain tourism is its impact on local bird populations. Birds are very crucial, serving as indicator species in exploring the state of health and diversity within an ecosystem. Their populations show how human activity, including tourism, may impact their habitats and the wider environment. The existing literature often provides valuable insights into the general effects of tourism on natural habitats (Brandt and Buckley 2018; Brandt et al. 2019). Most of the related studies conducted in Indonesia are limited to exploring the species diversity and conservation status of the populations of birds inhabiting mountainous areas (Purnamaningrum et al. 2021; Yodhy et al. 2022). However, none of these studies evaluates the impact mountain climbing tourism makes, specifically concerning the species of birds. The specific effects on the composition of bird species of different communities and their populations in the context of hiking trails are less understood. One example is research in the Himalayas revealed that high levels of mountain tourism were associated with reduced species diversity along popular trekking routes (Brandt et al. 2019). Furthermore, there is a need for comparative studies that examine the differences in bird diversity between heavily frequented hiking trails and less frequented ones. By doing so, researchers can identify whether certain mountain tourism activities have more pronounced effects on bird populations and which areas require priority conservation efforts.

MATERIALS AND METHODS

Study area

The research was conducted on the hiking trails of Mount Prau, a popular mountain tourism destination in Indonesia. Mount Prau is located at coordinates 7°11'13"S - 109°55'22"E, it spans several districts, including Batang, Kendal, Temanggung, Wonosobo, and Banjarnegara, within the Central Java Province. Due to its rich and diverse avian population, it also distinguishes itself as an important bird area in Indonesia (Burung Indonesia 1993; Rombang and Rudyanto 1999). This makes it a picturesque location and a significant case study for understanding the impact of mountain tourism on bird diversity. Four hiking trails were selected for the study, representing a range of ecotourism activity levels. The investigation was carried out in Patak Banteng and Dieng Villages (Wonosobo District), Wates Village (Temanggung District), and Purwosari Village (Kendal District) (Figure 1). These villages are located at the base of Mount Prau and are known for their hiking trails. Mount Prau's peak is 2,650 meters above sea level and is surrounded by well-preserved tropical rainforest vegetation. Bird species diversity observations were conducted along the selected hiking trails of Mount Prau, which comprises Patak Banteng Village, Kalilembu (Dieng Village), Wates Village, and Kenjuran (Purwosari Village).

Data collection

Four hiking trails, representing a range of visiting levels, were selected based on a survey to ascertain hikers' preferences when selecting hiking routes on Mount Prau. This study utilized an online questionnaire disseminated across multiple social media communities comprising hikers in Indonesia. The survey was terminated upon reaching the saturation point, which is the stage where no significant changes were observed in the percentage proportions of each hiking trail selected by the respondents.

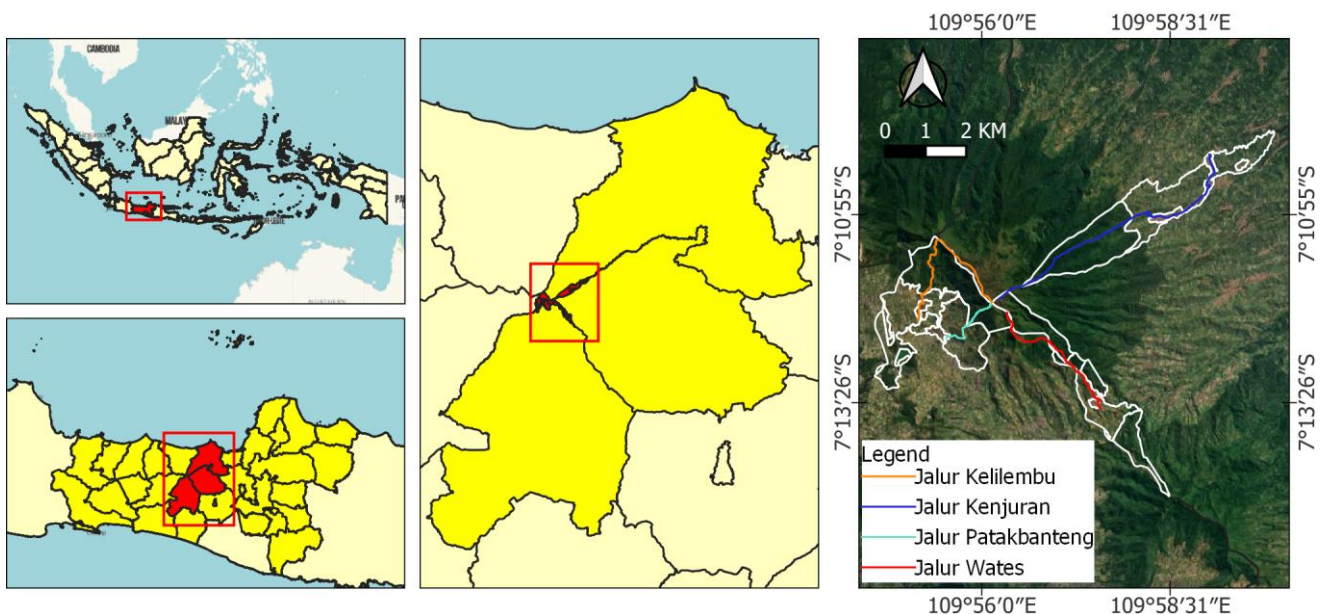


Figure 1. Map of the study area at four hiking trails of Mount Prau, Central Java, Indonesia

Systematic bird surveys were conducted along the four hiking trails. Species and abundance of birds were recorded during high-visited seasons to capture the potential impact of visitor influx (Storni et al. 2007). Bird observations were carried out utilizing the Variable Circular Plot (VCP) methodology (Reynolds et al. 1980) to ensure comprehensive coverage of the study area. VCPs with a radius of 50 meters each were strategically deployed at observation points along a 500-meter transect in each land use area on hiking trails, with a distance of 100 meters between points. These observations were conducted in the morning (6:00 AM to 11:00 AM) and afternoon (2:00 PM to 5:00 PM), encompassing the full spectrum of ecological activity during the day.

Data analysis

The collected data were then analyzed to determine various biodiversity indices. In bird ecology, the biodiversity indices can be grouped for the interpretation of species richness, diversity, and community structure by the Margalef Index (Margalef 1958), Shannon Index (Shannon and Weaver 1949), and Pielou's Evenness Index (Pielou 1967). In general, for the Margalef Index, which measures species richness, values are classified as follows: low ($DMg < 2$), moderate ($2 < DMg < 4$), or high ($DMg > 4$), with higher values reflecting greater variety among bird species and usually healthier or less disturbed habitats (Iglesias-Rios and Mazzoni 2014). The Shannon Index, which considers species richness and abundance, is often grouped under low diversity ($H' < 1$), moderate diversity ($1 < H' < 3$), or high diversity ($H' > 3$). Higher values would, therefore, imply a diverse and balanced community of birds, while lower values might be an indication of habitat disturbance or dominance by only a few species (Tramer 1969). Pielou's Evenness Index (J') measures how well the individuals are distributed over the species and is scaled to qualify as follows: low evenness, $J' < 0.4$; moderate evenness, $0.4 < J' < 0.6$; high evenness, $J' > 0.6$. High values of J' indicate a very balanced community, whereas lower values suggest that species may be dominated, usually as an effect of ecological stressors. Taken together, these indices convey the overall health of bird communities and the quality of their habitats, aiding ecologists in tracking environmental changes and guiding conservation efforts. Then, we compared the biodiversity indices between heavily frequented and less frequented trails to identify any significant differences in bird diversity.

Correspondence analysis was utilized to compare species composition and distribution of birds among different hiking trails. PAST statistical software (Hammer et al. 2001) was used to calculate diversity indices and plot ordination. In addition, each bird species conservation status was meticulously examined using various sources such as the International Union for Conservation of Nature (IUCN) Red List and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix. Furthermore, we conducted an in-depth analysis of the endemism status and their protection under Indonesian government according to Ministry of

Environment and Forestry Regulation No. 106 of 2018, and their status relating to limited distribution. This comprehensive assessment provided a detailed understanding of these avian populations ecological challenges and allowed for insights into potential conservation strategies.

RESULT AND DISCUSSION

Preference of hikers in selecting trails

As part of the preliminary study, a questionnaire was distributed to determine hikers preferences in choosing hiking trails in Mount Prau. The distribution of hikers preferences on each trail is shown in Figure 2. A total of 220 respondents were achieved since the number of returns achieved a point of diminishing utility. The majority of respondents prefer the Patak Banteng route, which constitutes 43% of the total respondents. It would mean that the Patak Banteng route is relatively seen to be more accessible compared to other hiking trails. The Wates route follows through with 25% of respondents, implying a considerable attractiveness amongst trekkers. The Kalilembu route was selected by 10% of the respondents, while the least popular was the Purwosari route, which had only 7% of the respondents choosing that route. It means that though Kalilembu and Purwosari are beautiful, their overall popularity is way below that of Patak Banteng and Wates. Another 15% had opted for other trails, including Dwarawati, Igirmanak, Dieng, and Genting Gunung, to experience the diversity of routes.

Considering these preferences, it is crucial to assess the influence of ecotourism on avian species diversity in the vicinity of these hiking routes. Most-frequented trails like Patak Banteng and Wates are expected to encounter greater habitat disruptions due to increased hikers foot traffic.

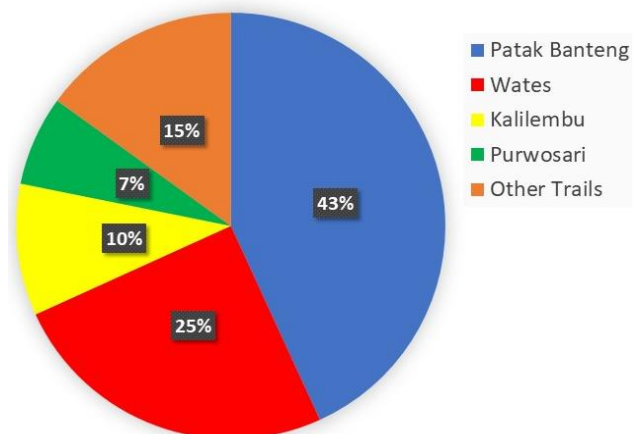


Figure 2. The proportion of each hiking trail selected by respondents in mountaineering tourism of Mount Prau, Central Java, Indonesia

Bird diversity of hiking trails in Mount Prau

The field observations conducted along the four selected hiking trails revealed nuanced patterns in bird species composition and diversity. The number of bird species and individuals discovered on Mount Prau comprises 72 species from 32 families (Figure 3). The Pycnonotidae (bulbuls), Apodidae (swifts), and Campephagidae (cuckoo-shrikes) families are predominant, each with over 100 individuals, suggesting their common prevalence in the area. In contrast, some families, for instance, Irenidae, Pittidae, and Stenostiridae, are represented by very low numbers of species or individuals, indicating that these families are sensitive to disturbances or their habitats are more restricted.

The diversity index measurements of bird populations along four distinct trails on Mount Prau: Patak Banteng, Wates, Kalilembu, and Purwosari, are illustrated in Figure 4. The indices used are Margalef, Shannon, and Evenness. Bird diversity in Purwosari trail has Margalef Index estimates a very high, almost close to 9 species richness. The Shannon Index for Purwosari points out the value of about 3.3, showing the diversity to an extremely high category of Shannon Index. However, while showing a high level of general diversity, according to data based on low values of the Evenness Index, in Purwosari trail, certain species exhibit a dominant position in comparison to others.

Kalilembu trail also demonstrates a high level of species diversity, with a Margalef Index of approximately 6 and a Shannon Index of about 2.9. However, Kalilembu trail also has low Evenness Index, suggesting that certain species are more dominant. Wates trail exhibits moderate species richness and diversity with a Margalef Index of around 4 and a Shannon Index of approximately 2.5. The low Evenness Index in Wates trail suggests that the distribution across species is not even and that there is some form of dominance by certain species. Overall, the

data would suggest that trails with more hiker traffic may have more disturbances to habitat, such as Patak Banteng, and this may have an impact on species diversity. This only serves to underscore the necessity of conservation efforts that prioritize the preservation and enhancement of biodiversity along all trails, with a particular emphasis on high-diversity trails like Purwosari and Kalilembu, while also addressing the effects of large numbers of visitors on trails like Patak Banteng.

Composition of bird communities among trails

Correspondence analysis provides a graphical representation of interrelationships between avian communities along four hiking trails on Mount Prau, including Patak Banteng, Wates, Kalilembu, and Purwosari, as depicted in Figure 5. This graphical representation shows important characteristics of the differences and similarities in the distribution of bird species along these routes. Furthermore, Table 1 presents of the similarity index among bird communities across the hiking trails using the Bray-Curtis Index.

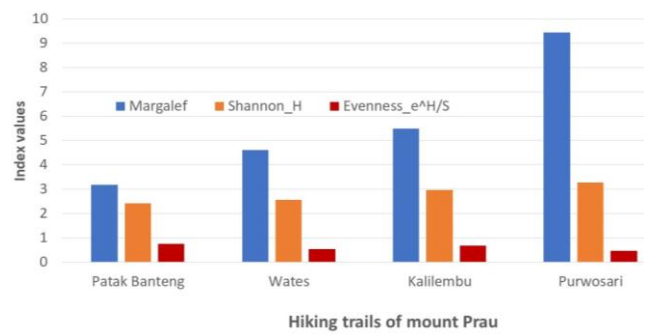


Figure 4. Bird diversity indices found in four different hiking trails of Mount Prau, Central Java, Indonesia

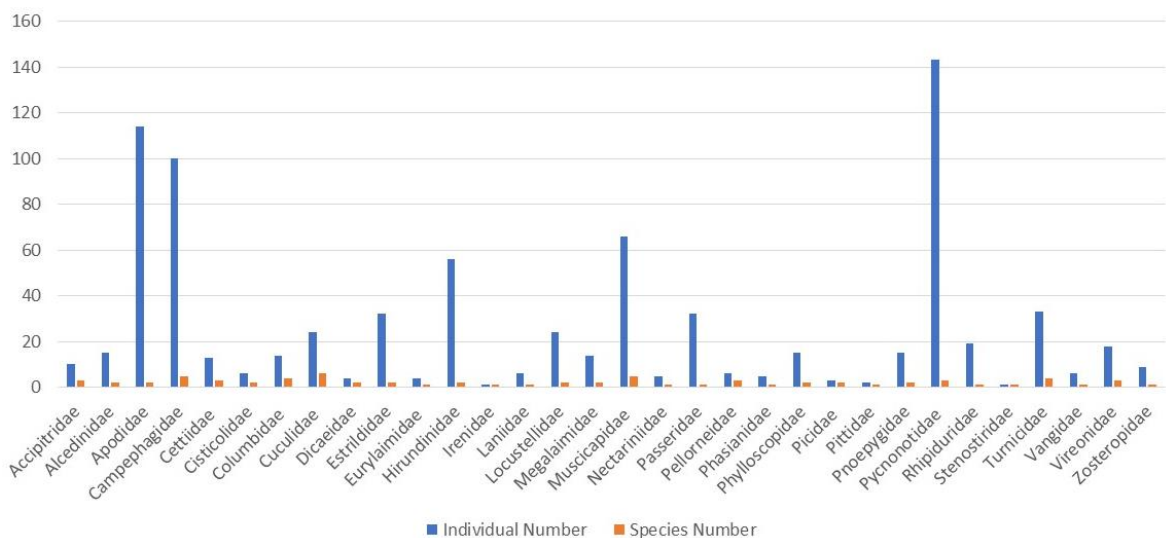


Figure 3. The number of species and individuals for each family of bird found in four different hiking trails of Mount Prau, Central Java, Indonesia

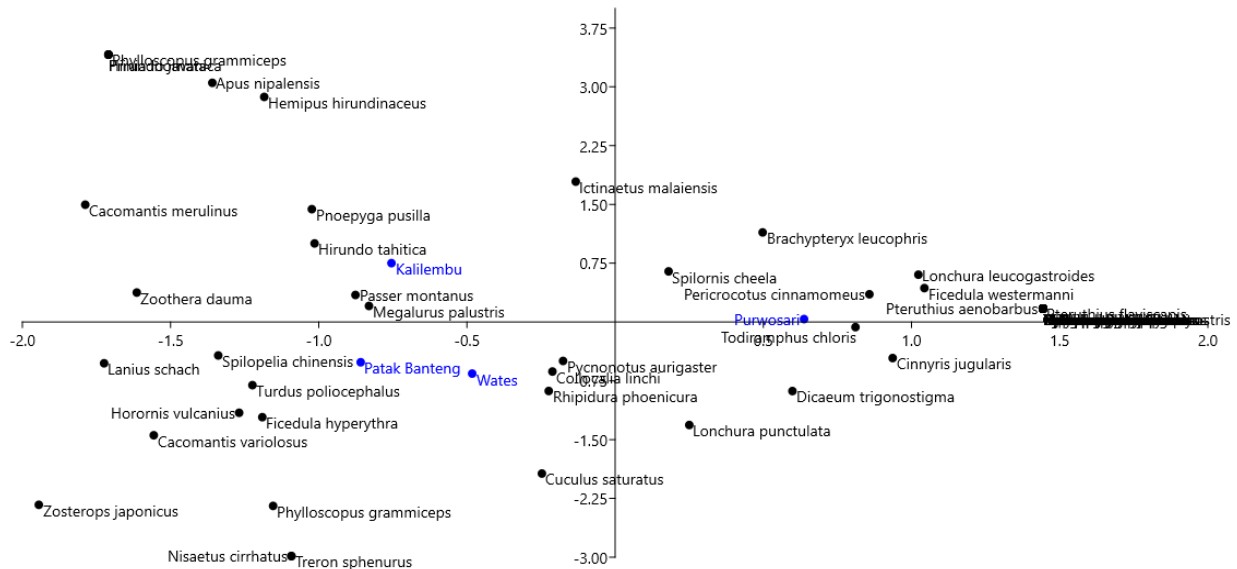


Figure 5. Correspondence analysis and similarity index of bird communities in four different hiking trails of Mount Prau, Central Java, Indonesia

Table 1. Similarity index of bird communities among hiking trails in Mount Prau, Central Java, Indonesia

Trails	Patak Banteng	Wates	Kalilembu	Purwosari
Patak Banteng	1			
Wates	0.54	1		
Kalilembu	0.52	0.50	1	
Purwosari	0.23	0.40	0.31	1

The Purwosari trail is characterized by prominent differences in the ordination graph from all other trails, indicating strong differences in its avian community. Species such as *Spilornis cheela* (Latham, 1790), *Pericrocotus cinnamomeus* (Linnaeus, 1766), and *Lonchura leucogastroides* (Moore, 1858) show a significant association with the Purwosari point, indicating that these species are relatively more abundant in this area. Such a characteristic composition of bird species points toward the ecological uniqueness of Purwosari and, therefore, its importance for conservation efforts. The Kalilembu trail is a very unique avifauna community, although some of them share with the other trails. More precisely, the species *Pnoepyga pusilla* Hodgson, 1845 and *Hirundo tahitica* Gmelin, 1789 seem to strongly associate with the Kalilembu area, indicating a higher abundance along this particular trail. The proximity of Kalilembu to Wates in the ordination graph suggests that their bird communities have some similarities, while each maintains unique characteristics that set them apart.

Bird composition in Patak Banteng and Wates trails is somewhat similar because of the closeness in the ordination plot and a Bray-Curtis similarity index value of 0.54. This once more demonstrates that certain species are frequently observed in both trails, such as *Passer montanus* (Linnaeus, 1758) and *Megalurus palustris* Horsfield, 1821, doing well within these environments. From this, given the similarities

observed to occur between Patak Banteng and the Wates, similar ecological demands or perturbations of these sites may be inferred to account for the presence of a particular species in either habitat. There were low similarities between Purwosari and Patak Banteng, reaching only 0.23, indicating large differences in their bird assemblages. These data, taken together, indicate that the assemblages of all habitats are different; some habitats are thus more similar to others. Similarly, correspondence analysis and the Bray-Curtis similarity index have shown subtlety in the assemblage of birds along the various trails in Mount Prau. The understanding of such subtleties maximizes conservation efforts toward specific demands of each trail for the continued conservation of the total bird diversity in this ecologically important area. The uniqueness of the Purwosari trail avifauna provides strong reasons why certain conservation actions are particularly required for the site's specialties. In contrast, the similarity of the two Patak Banteng and Wates suggests that more general actions are needed to address shared ecological threats despite the marked distinctiveness of Kalilembu itself.

The distribution pattern of the birds observed shows that it is moderately adaptable to the various kinds of environmental conditions faced on the trails. Continuous presence throughout all the trails is indicative of ecological persistence and their continued importance in the maintenance of biodiversity and ecological balance within the hiking zone of Mount Prau. Understanding the spread and occurrence of omnipresent species may indicate the rationale for conservation programs, considering focusing on areas with highly diverse biological ensembles.

The following graph, shown in Figure 6, presents the number of bird species with high conservation status found along four mountain trails at Mount Prau: Patak Banteng, Wates, Kalilembu, and Purwosari. Information on how important each trail is in amassing totals of protected birds expresses the priorities for specific conservation efforts at

each site. Table 2 displays the bird species with high conservation importance along four hiking routes of Mount Prau. The conservation status encompasses various categories such as those from the IUCN Red List, CITES Appendix, protection under Indonesian government law (GPL), endemism in Indonesia, and Birds with Limited Distributions (BLD). This table offers an overview of the distribution of bird species that require specific attention for conservation efforts on each hiking trail.

Purwosari is characterized by a high diversity of birds with higher conservation values for both the endemic and restricted distribution categories. In fact, this area supports 16 endemic species and about 5 species with limited distributions, showing that Purwosari area indeed provides a special ecosystem for the perpetuation of various bird species worthy of protection. Also, Purwosari trail has the highest number of bird species and high conservation status. Species such as *Cochoa azurea* (Temminck, 1824), *Ictinaetus malaiensis* (Temminck, 1822), and *Eurylaimus javanicus* Horsfield, 1821 can be found along this trail. Those species are under the protection of the Indonesian government and are mentioned either in the IUCN or CITES databases, so Purwosari is an important trail for conservation, having a high biodiversity and certain species. The exceptional nature of Purwosari makes it a critically important conservation area that demands special efforts to safeguard its habitat from human interference and environmental shifts.

The management of the hiking basecamp and the local community in Purwosari has designated the route as a limited ecotourism trail with stricter climbing regulations. Consequently, the trail remains in a natural state with extensive forest cover. This hiking tourist corridor, known as a "conservation trail," represents a trail dedicated to environmental conservation through responsible travel behavior while passing the route.

Both Kalilembu and Wates pathways serve equally as habitats for several species of enhanced conservation values, though the magnitude stands minute against the Purwosari pathway. Suitable management and protection of the habitats standing within the paths are also urgent to secure the survivability of protected species such as *S. cheela*. The presence of this species on the two trails suggests that, while not as uniquely diverse as Purwosari, they are still crucial for bird conservation in Mount Prau. The Kalilembu trail stands out regarding categories protected by the Indonesian government and endemics. In comparison, the Wates trail demonstrates a more balanced distribution across all categories, including IUCN, CITES, and GPL. Both trails thus have a high value of bird diversity that needs protection. Proper management, therefore, with the implementation of a valid conservation strategy for these trails, could prove to be an effective mechanism for the long-term survival of the threatened species in their natural habitats.

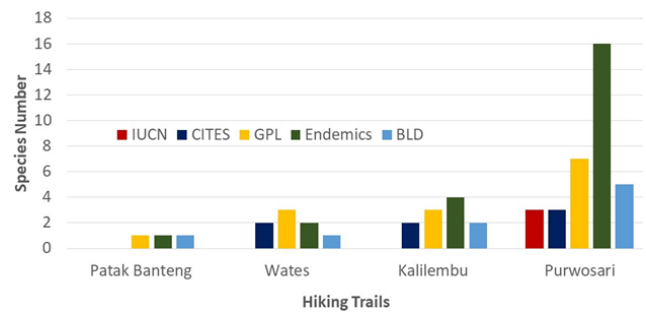


Figure 6. Species number of birds with high conservation status found along four mountain trails of Mount Prau (Conservation status based on IUCN Redlist, CITES Appendix, Protected by Indonesian Government Law/GPL, Endemics in Indonesia, and BLD/Bird with Limited Distribution no more than 50,000 km²)

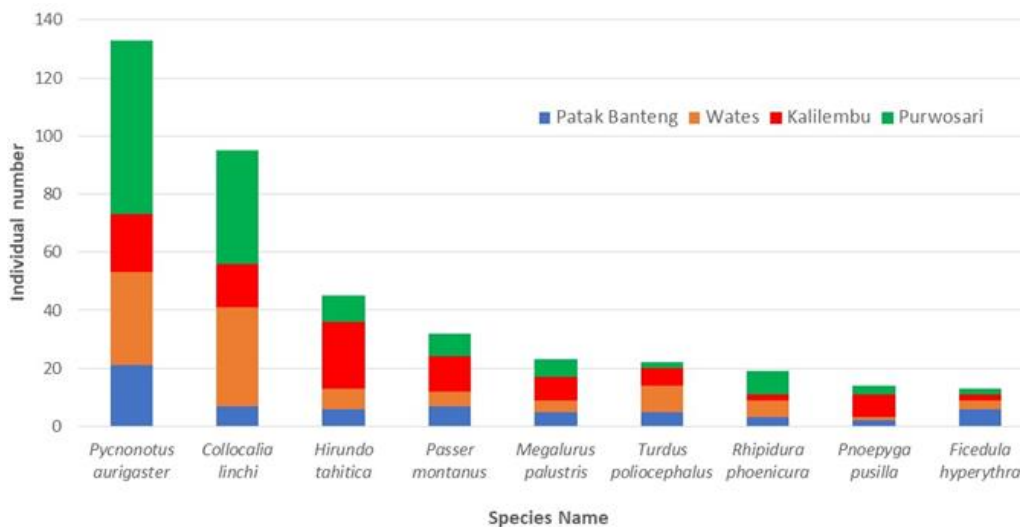


Figure 7. The most common birds found in four hiking trails in Mount Prau, Central Java, Indonesia

Table 2. List of bird species with high conservation importance status (by one or more categories) found along four hiking routes of Mount Prau, Central Java, Indonesia

Family	Species name	Patak Banteng	Wates	Kalilembu	Purwosari	IUCN	CITES	GPL	Endemic	BLD
Accipitridae	<i>Spilornis cheela</i>	Absent	Present	Present	Present	LC	II	YES	NO	NO
Accipitridae	<i>Ictinaetus malaiensis</i>	Absent	Absent	Present	Present	LC	II	YES	NO	NO
Accipitridae	<i>Nisaetus cirrhatus</i>	Absent	Present	Absent	Absent	LC	II	YES	NO	NO
Alcedinidae	<i>Halcyon cyanoventris</i>	Absent	Absent	Absent	Present	LC	NO	NO	YES	NO
Campephagidae	<i>Pericrocotus miniatus</i>	Absent	Absent	Absent	Present	LC	NO	NO	YES	NO
Cettiidae	<i>Tesia superciliaris</i>	Absent	Absent	Absent	Present	LC	NO	NO	YES	YES
Columbidae	<i>Ptilinopus porphyreus</i>	Absent	Absent	Absent	Present	LC	NO	NO	YES	YES
Estrildidae	<i>Lonchura leucogastroides</i>	Absent	Absent	Present	Present	LC	NO	NO	YES	NO
Eurylaimidae	<i>Eurylaimus javanicus</i>	Absent	Absent	Absent	Present	NT	NO	NO	YES	NO
Locustellidae	<i>Locustella montis</i>	Absent	Absent	Absent	Present	LC	NO	NO	YES	NO
Megalaimidae	<i>Psilopogon australis</i>	Absent	Absent	Absent	Present	LC	NO	NO	YES	NO
Megalaimidae	<i>Psilopogon armillaris</i>	Absent	Absent	Absent	Present	LC	NO	YES	YES	YES
Pellorneidae	<i>Pellorneum capistratum</i>	Absent	Absent	Absent	Present	LC	NO	NO	YES	NO
Phylloscopidae	<i>Phylloscopus grammiceps</i>	Absent	Present	Present	Absent	LC	NO	NO	YES	NO
Pittidae	<i>Hydornis guajanus</i>	Absent	Absent	Absent	Present	LC	II	YES	YES	NO
Pycnonotidae	<i>Pycnonotus bimaculatus</i>	Absent	Absent	Absent	Present	NT	NO	NO	YES	NO
Rhipiduridae	<i>Rhipidura phoenicura</i>	Present	Present	Present	Present	LC	NO	YES	YES	YES
Turdidae	<i>Cochoa azurea</i>	Absent	Absent	Absent	Present	VU	NO	YES	NO	NO
Vireonidae	<i>Psaltria exilis</i>	Absent	Absent	Absent	Present	LC	NO	YES	YES	YES
Vireonidae	<i>Pteruthius flaviscapis</i>	Absent	Absent	Absent	Present	LC	NO	NO	YES	NO

Notes: IUCN: the Red List of Threatened Species from the International Union for Conservation of Nature; CITES: the appendices classify species according to the Convention on International Trade in Endangered Species of Wild Fauna and Flora; GPL: Indonesia Government Protected by Law; BLD: Bird with Limited Distribution no more than 50,000 km square

Conversely, the Patak Banteng trail has the lowest number of species with high conservation status. Only *Rhipidura phoenicura* S.Muller, 1843 (rufous paradise flycatcher) is documented to have high conservation status along this trail. This species can be found in all trails. *Rhipidura phoenicura* is protected under Indonesian government law also endemics in Indonesia with limited distribution. Nevertheless, it is crucial to prioritize conservation efforts to ensure that the habitat along this trail can support existing species and promote biodiversity in the future.

Mountain tourism's impact on bird diversity

The present study provided information on bird diversity differences between heavily visited and less-visited trails within the hiking paths, hence serving conservation and management. In general, this study on human visit patterns and their effects on bird populations is one important step toward developing sustainable mountainous tourism practices that would not harm local bird communities. The shift from nature-based tourism into mass tourism in mountainous areas can have several adverse effects on bird diversity. The increased human presence results in habitat degradation, disturbance at their nesting sites, and reduced food resources for the birds (Bötsch et al. 2018; Putri et al. 2019; Garima and Chandra 2021).

The study's results revealed significant differences in bird diversity between heavily frequented hiking trails and less frequented ones in Mount Prau. The heavily visited trails exhibited lower species richness, Shannon-Weiner diversity, and Pielou's evenness indices than the less frequented trails. This suggests that increased ecotourism activity may have a negative impact on the overall bird

diversity in the region. The heavily visited trails were found to have a greater dominance of a few common bird species, while the less frequented trails displayed a more even distribution of species. This pattern indicates that ecotourism may favor generalist bird species (Figure 7) that are more adaptable to human disturbance, while specialist species with narrower habitat requirements are being negatively impacted.

The findings of this study contribute to the growing body of evidence on the complex relationship between mountain tourism and biodiversity conservation (Posa and Sodhi 2006; Tu et al. 2020). The observed decline in bird diversity along heavily frequented hiking trails suggests that if not properly managed; ecotourism can adversely affect the delicate ecological balance of natural areas. The lower species richness, diversity, and evenness indices recorded on popular trails indicate that ecotourism may favor more adaptable, generalist bird species while leading to the decline of specialist and sensitive species. These results align with previous studies findings that have reported negative impacts of tourist activities on wildlife, particularly birds (Bateman and Fleming 2017). The mechanisms behind these impacts may include habitat degradation, increased disturbance, and changes in resource competition and predation dynamics (Khan et al. 2024).

The results were further supported through an ordination analysis that indicated clear segregation of the avian community between the heavy and less-visited trails, hence providing strong support for the proposal that mountain tourism is one of the most important drivers for changes to the composition of the bird community within Mount Prau's hiking route. The observed patterns are consistent with previous studies on the effects of human

activity on bird diversity in natural areas (Eadens et al. 2009; Ibáñez-Álamo et al. 2020; Tu et al. 2020).

Analysis of several trails in Mount Prau showed that the least visited Purwosari trail hosts a distinctively different and rich bird assemblage, comprising many ranges-restricted species and endemics, which deserves consideration as an important supplier of habitat for this range of bird species. All these findings underpin the urgent need to strengthen conservation efforts so that this ecosystem is better safeguarded against human impacts. Kalilembu and Wates trails are similarly rich in birds, although the species composition is much less unique than at Purwosari. Species at both these trails also occur more or less equally across the different conservation categories of IUCN, CITES, and those under protection from the Indonesian government. For comparison, the Patak Banteng trail, although much more used, had fewer species of high conservation status, presumably reflecting greater disturbance or less supportive habitat. All these, put together, show the urgency of the need for comprehensive and integrated conservation efforts across all hiking trails within Mount Prau for the long-term sustainability of biodiversity in the area.

The findings reveal major implications for mountain tourism management in Mount Prau as well as other areas with a similar status. Limiting the number of visitors, restricting access to sensitive areas, and implementing plans to reduce the impact of disturbance would help mitigate the negative effects on bird species (Marion et al. 2019). Developing ecotourism activities that promote wildlife-friendly practices, such as guided birdwatching tours, can help foster a more symbiotic relationship between tourism and biodiversity conservation (Xu et al. 2009).

In conclusion, the result of this study greatly informs about the impacts of mountain tourism on avian diversity within mountainous areas. Indeed, it overconfirms that high mountain tourism levels affect birds by reducing species richness, diversity, and evenness along trails with high visitor pressure. In addition, this study shows the huge impact of nature-based tourism that has grown into mass tourism regarding avian diversity in Mount Prau, Indonesia. The more utilized Patak Banteng trail showed lower indices of species richness, Shannon-Weiner diversity, and Pielou's evenness, while trails that are less utilized, like Wates, Kalilembu, and Purwosari, had relatively high avian diversity. The highly significant separation of the bird assemblages between the high and low-visit rates further establishes the negative impact of mountain tourism on the avian biodiversity in the area. With strict regulations and the application of a limit to the number of visitors, tourism to Purwosari Mountain contributes to the conservation of many species with a rank of high significance in their conservation value. The research findings recommend broad conservation programs that would include incorporating mountain tourism management into biodiversity conservation at Mount Prau. Limiting the number of visitors, restricting them from accessing those sensitive areas, or adopting ecotourism-

friendly wildlife practices can greatly minimize impacts on bird diversity.

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