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Avifauna Diversity of Ternate Island for Geotourism Development in Aspiring Geopark

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ABSTRACT: Ternate Island, part of the Wallacea region in North Maluku, harbors rich avifaunal diversity that holds ecological and tourism significance. This study assessed bird species diversity across ten sites to support geotourism initiatives in the Aspiring Ternate Geopark. Surveys were conducted from May 2023 to February 2024 using the MacKinnon List method, complemented by incidental observations and literature review. A total of 60 species from 35 families were recorded, including 11 species endemics to North Maluku and nine migratory taxa. The Columbidae family was the most represented, while the Endangered white cockatoo (Cacatua alba) highlighted the island's conservation value. Species richness was highest at Ngade Lagoon (26 species) and lowest at Nukila Park (7 species). The Shannon–Wiener diversity index (H' = 2.88) indicated moderate diversity. These findings provide essential baseline data for biodiversity management and demonstrate the potential of avifauna as a flagship resource for birdwatching-based geotourism development.
Keywords: avifauna, ternate, geo-tourism, birds, Wallacea

INTRODUCTION

Ternate Island, located in North Maluku Province within the Wallacea biogeographic region, embodies an exceptional intersection of volcanic geology, cultural heritage, and ecological diversity. As a small island with significant natural resources, Ternate has become increasingly recognized for its potential to develop sustainable forms of tourism, particularly geotourism. The concept of geoparks integrates geological, ecological, and cultural values within a framework of conservation and community-based tourism. In this context, biodiversity, and especially avifauna, provides both ecological services and cultural-symbolic value that can enhance the attractiveness of a geopark while contributing to conservation education.

Avifauna plays a particularly important role in tourism development because of its aesthetic appeal, ecological function, and capacity to attract specialized visitors. Birdwatching, or avitourism, has emerged globally as a rapidly expanding segment of nature-based tourism. It has been shown to provide multiple benefits, including contributions to local economies, incentives for biodiversity protection, and increased environmental awareness among local communities and visitors (Sekercioglu, 2002; Steven et al., 2018).

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Within small islands such as Ternate, where natural resources are finite and pressures from land-use change are growing, bird-based tourism can serve as an effective model for promoting sustainable development.

Historically, the ornithological importance of Ternate and the surrounding Maluku Islands has been acknowledged since the nineteenth century. Alfred Russel Wallace, during his explorations in the region, documented Wallace's standardwing (Semioptera wallacii), a bird of paradise that has since become emblematic of the unique avifauna of North Maluku (Wallace & Bambu, 2009). (North Maluku is now recognized as supporting approximately 350 bird species, of which 40 are endemic, while Ternate alone, despite its small area of only 99 km², hosts around 140 species. Previous surveys reported at least 51 species across 17 families in a range of habitats such as mixed plantations, coastal forests, lakes, residential settlements, and open spaces (Tamnge, 2013). The relatively high level of species richness, even under conditions of increasing land-use change, suggests the ecological resilience of Ternate's habitats and underscores their importance for both conservation and tourism development.

Nevertheless, ecological pressures continue to pose challenges to avifaunal diversity on Ternate. Coastal reclamation, expansion of nutmeg and clove plantations, and the conversion of natural vegetation threaten the integrity of bird habitats (Izah & Aigberua, 2023). Although some sites such as Tolire Lake continue to exhibit high bird diversity, other locations, including Tobololo and Sulamadaha, reveal reduced richness (Haileselasie, 2022). These uneven patterns indicate that avian diversity is highly sensitive to habitat quality, a condition that reinforces the need for careful management if birdwatching is to be promoted as a sustainable tourism activity. Lessons from other regions, such as the birdwatching programs developed in West Flores and the Bogor Botanical Gardens, demonstrate the potential of integrating biodiversity monitoring into ecotourism development (Paramita & Septiviari, 2014).

Despite the ecological and tourism potential of avifauna in Ternate, existing studies remain limited, fragmented, and geographically restricted. Most research has focused on easily accessible sites and has not provided a comprehensive island-wide assessment (Abdurahman et al., 2017). This lack of systematic coverage represents a major knowledge gap, particularly when considering the need for scientific data to support both biodiversity management and geotourism planning. Addressing this gap, the present study evaluates bird species abundance and diversity across major ecological settings in Ternate. By producing baseline data on species composition, endemicity, and richness, this research aims to contribute to avian conservation strategies while simultaneously strengthening the scientific foundation for positioning birdwatching as a flagship attraction within the Aspiring Ternate Geopark.

METHODS

This study was conducted at ten observation points strategically distributed across Ternate Island to represent diverse ecological settings. The sites included Sasa Beach, Tongole Village, Gambesi Waterfall, Ngade Lagoon, Tolire Besar, Kastela Beach, Moya Park, Sulamadaha Beach, Pulo Tareba, and Nukila Park. Observations were carried out between May 2023 and February 2024 during peak bird activity hours (07:00–11:00, GMT+9). Both primary field surveys and secondary literature sources were employed to obtain comprehensive data on bird diversity.

The study population consisted of all bird species occurring across natural and human-modified habitats on Ternate Island. Samples were derived from bird communities recorded at the ten observation sites. These locations were chosen to encompass a wide range of ecological conditions, including coastal areas, forest patches, freshwater systems, urban parks, and mixed agroforestry landscapes, thereby providing a representative overview of avifaunal diversity on the island.

Standard ornithological equipment was utilized to ensure accurate field identification and recording. Tools included binoculars for distant observation, a handheld Global Positioning System (GPS) for mapping survey routes, digital cameras for photographic documentation, and field notebooks for recording species counts. Bird identification was guided by Birds of the Indonesian Archipelago: Greater Sundas and Wallacea James A Eaton et al. (2020), which provided updated taxonomic references.

Primary data were obtained using the MacKinnon List method, a widely applied approach in avifaunal surveys. This method involves walking at a constant pace along predetermined transects and recording bird species sequentially, with each list containing a maximum of ten species before initiating a new list (Bibby, 2000). This technique minimizes sampling bias by ensuring equal observation effort across sites. Incidental

observations recorded outside transects were also noted, while secondary data from previous studies were reviewed to contextualize and validate the findings.

Species data collected from each observation point were analyzed to determine abundance and diversity patterns. A species abundance curve was constructed to illustrate distribution trends, and diversity was quantified using the Shannon–Wiener Index (H'). The index was calculated using the following formula:

$$H' = -\sum(p_i l_n p_i)$$

Where $p_i l_n p_i$, with n_n representing the number of individuals of species *i* and NNN the total number of individuals of all species. Data processing was performed in Microsoft Excel. Interpretation of diversity values followed Fachrul (2007), with thresholds as follows: H'<1 indicates low diversity and high ecological pressure, H'<3 indicates moderate diversity and moderate ecological pressure, and H'>3 indicates high diversity and low ecological pressure.

RESULTS AND DISCUSSION

Survey Effort and Sampling Overview

Field surveys were conducted over a nine-month period, spanning from May 2023 to February 2024, at ten observation sites distributed across Ternate Island. A total of 18 observation events were carried out, with each site visited at least once (Table 1). Some locations, such as Ngade Lagoon, Tolire Besar, and Kastela Beach, were sampled multiple times, allowing for more robust assessments of species composition and abundance. In contrast, other sites, including Sasa Beach, Gambesi Waterfall, Sulamadaha Beach, Pulo Tareba, and Nukila Park, were surveyed only once due to logistical constraints.

Table 1. List of repeated observation points

Observation Point	Repetitions	Dates of Observation(s)
Sasa Beach	1	1 January 2024
Tongole Village	1	31 December 2023
Gambesi Waterfall	1	31 December 2023
Ngade Lagoon	4	12 May 2023; 22 June 2023; 22 October 2023; 11 December 2023
Tolire Besar	3	4 June 2023; 30 July 2023; 4 December 2023
Kastela Beach	3	17 September 2023; 15 October 2023; 29 October 2023
Moya Park	2	21 May 2023; 3 September 2023
Sulamadaha Beach	1	11 June 2023
Pulo Tareba	1	5 February 2024
Nukila Park	1	18 December 2023
Total	18	—

Source: Halmahera Wildlife Photography, 2022-2024

Variations in sampling frequency were primarily the result of external factors, including adverse weather conditions and accessibility challenges. Heavy rainfall and rough sea conditions occasionally limited access to coastal and lagoon sites, while scheduling difficulties reduced opportunities for repeated surveys in urban areas such as Nukila Park. Despite these limitations, the overall survey effort was sufficient to provide a representative overview of avifaunal diversity across the island.

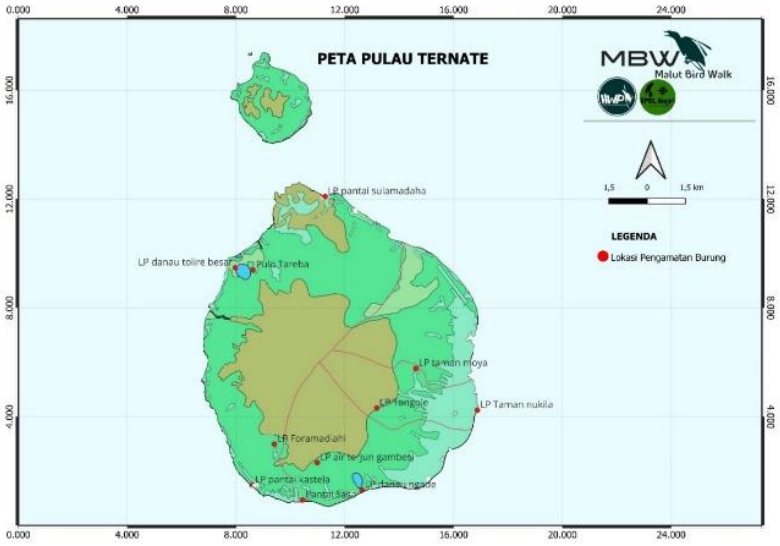

Figure 1. Map of observation points

The spatial distribution of the ten survey locations is shown in Figure 1. These sites were selected to capture the heterogeneity of Ternate's ecological settings, encompassing coastal beaches, freshwater lakes, waterfalls, agroforestry landscapes, urban parks, and forested areas. This distribution ensured coverage of both natural and human-modified habitats, thereby enabling a comprehensive assessment of avian diversity in the context of geotourism development.

Species Richness and Composition

Field observations conducted across the ten survey sites recorded a total of 60 bird species belonging to 35 families. This assemblage includes 11 species endemic to North Maluku and 9 migratory species that were documented during the survey period. The presence of both endemic and migratory birds highlights the ecological significance of Ternate Island as a habitat that supports species with restricted ranges as well as those dependent on broader migratory flyways.

Table 2. Summary of avifaunal diversity on Ternate Island

Category	Number Recorded	Notable Details
Total species	60	Across 35 families
Endemic species	11	e.g., North Moluccan Pitta *Erythropitta rufiventris*
Migratory species	9	Recorded during peak migratory season
Most represented family	Columbidae (6)	Includes *Chalcophaps indica*, *Columba livia*
Threatened species	1	White cockatoo *Cacatua alba* (Endangered)

Among the recorded families, Columbidae was the most represented, with six species identified. Other families contributing significantly to the diversity included Ardeidae, Sturnidae, and Pycnonotidae, each represented by multiple species. This distribution suggests that both forested and open coastal habitats provide important ecological niches for a variety of avian taxa. Notably, flocking behavior was commonly observed in coastal families such as Fregatidae, while forested sites harbored a greater number of frugivorous and insectivorous species, reflecting the heterogeneity of available food resources across habitats.

The findings of this study extend and refine earlier surveys of avifauna in Ternate. Abdurahman et al. (2017) reported 64 species across four observation points, while Muñoz et al. (2019) recorded fewer species in tourist areas, with three of their sites overlapping with the present study. The greater number of species documented here can be attributed to wider spatial coverage and a longer observation period, which increased the likelihood of detecting both resident and migratory taxa. This provides stronger evidence of the island's high avifaunal diversity relative to its limited geographic area of only 99 km².

A particularly significant result was the documentation of the white cockatoo (Cacatua alba), a species endemic to North Maluku and listed as Endangered by the International Union for Conservation of Nature (IUCN). The presence of this species in the survey highlights the conservation value of Ternate's habitats, as it demonstrates that even heavily visited or human-influenced landscapes continue to harbor species of high ecological and conservation importance. The occurrence of such flagship species strengthens the case for integrating avian conservation into geotourism planning, positioning birdwatching as a central attraction in the Aspiring Ternate Geopark.

Site-Based Diversity Patterns

Species richness varied considerably across the ten observation sites, reflecting differences in habitat structure, vegetation cover, and anthropogenic influence. The highest richness was recorded at Ngade Lagoon with 26 species, followed closely by Tolire Besar with 25 species, Kastela Beach with 22 species, and Tongole Village with 21 species. These locations are characterized by relatively dense vegetation, availability of freshwater, and habitat heterogeneity, which provide abundant food and nesting resources.

In contrast, Sulamadaha Beach and Nukila Park supported the lowest richness, with 8 and 7 species respectively. Sulamadaha Beach, being a narrow coastal strip, offers limited vegetation and structural diversity, while Nukila Park, located in the urban center of Ternate, is subject to significant human disturbance despite containing a variety of planted tree species. Nevertheless, Nukila Park remains ecologically valuable as an urban green space that continues to attract avifauna.

Table 3. Species richness across survey sites on Ternate Island

Observation Site	Number of Species	Notable Features / Observations
Ngade Lagoon	26	Highest richness; heterogeneous vegetation and freshwater habitat
Tolire Besar	25	Forested volcanic lake; dense canopy cover
Kastela Beach	22	Coastal site; large flocks of lesser frigatebird (*F. ariel*)
Tongole Village	21	Agroforestry mosaic; presence of North Moluccan Pitta (*E. rufiventris cyanonota*)
Moya Park	17	Urban green space with planted trees
Sasa Beach	16	Coastal habitat with moderate vegetation cover
Gambesi Waterfall	8–10	Small forest patch; limited survey repetitions
Pulo Tareba	11	Small island habitat; moderate species richness
Sulamadaha Beach	8	Coastal strip with limited vegetation; lowest richness
Nukila Park	7	Urban park; highly disturbed but ecologically important

Unique observations further emphasize the ecological significance of individual sites. Tongole Village, despite its proximity to human settlements, was notable for hosting the North Moluccan Pitta (*Erythropitta rufiventris cyanonota*), a subspecies endemic to Ternate and surrounding islands. Similarly, Kastela Beach not only supported high species richness but also recorded large congregations of the lesser frigatebird (*Fregata ariel*), illustrating the role of coastal habitats as foraging grounds for flocking seabirds.

Abundance of Individual Birds

Across the ten observation sites, a total of 1,225 individual birds were recorded, representing the 60 species identified during the survey. Abundance patterns varied considerably between sites, reflecting both ecological characteristics and species-specific behaviors. Kastela Beach accounted for the highest number of individuals, with 305 birds observed. This high abundance was largely attributed to the flocking behavior of the lesser frigatebird (Fregata ariel), which forages in large groups along the coastal zone. The dominance of this species illustrates how coastal habitats provide essential feeding grounds for seabirds that rely on collective foraging strategies.

In contrast, Ngade Lagoon and Tolire Besar exhibited high species richness but relatively lower overall abundance. These inland sites are characterized by dense vegetation and heterogeneous habitats, which tend to support a broader variety of species with smaller population sizes rather than large aggregations of single taxa. This pattern highlights the ecological distinction between coastal habitats that favor colonial seabirds and inland forests and freshwater systems that support diverse assemblages of frugivores, insectivores, and nectarivores.

Urban and disturbed habitats, such as Nukila Park and Sulamadaha Beach, recorded the lowest numbers of individuals, corresponding to their reduced species richness. Nevertheless, the presence of even small populations in these areas underlines their continued ecological value as supplementary habitats within an increasingly urbanized landscape.

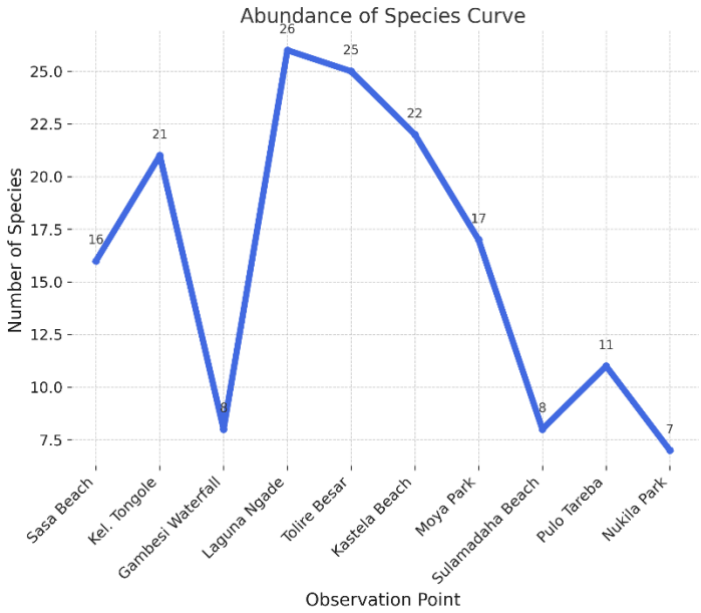

Figure 2. Species Abundant Curve

The overall distribution of species abundance is depicted in the species abundance curve (Figure 2). The curve demonstrates a typical pattern for moderately diverse ecosystems, where a few species are highly abundant while the majority occur in relatively low numbers. This structure reflects both habitat specialization and the ecological dynamics of island environments, in which certain generalist or flocking species dominate while rare or endemic species persist at lower densities.

Conservation and Protected Status

The avifaunal assemblage documented on Ternate Island includes a number of species with significant conservation importance. A total of 15 species recorded during the survey are legally protected under the Ministry of Environment and Forestry of the Republic of Indonesia. These protections underscore the national recognition of Ternate's role in sustaining key avian populations and highlight the necessity of integrating conservation priorities into future land-use and tourism planning.

Particularly noteworthy is the presence of the white cockatoo (Cacatua alba), an endemic species to North Maluku that is currently listed as Endangered on the IUCN Red List. This species is threatened by both habitat loss and illegal wildlife trade, making its persistence on Ternate Island a critical indicator of remaining habitat quality. The recording of C. alba in this study emphasizes the need to ensure strict enforcement of existing wildlife protection regulations and to strengthen habitat management strategies within the proposed geopark area.

The documentation of nine migratory bird species also adds an important conservation dimension. These species rely on Ternate as part of broader migratory flyways, indicating that the island provides essential stopover and foraging habitats. Protecting coastal zones, wetlands, and lagoon ecosystems is

therefore vital not only for resident avifauna but also for sustaining global migratory networks. Habitat degradation in these areas could have cascading effects that extend far beyond Ternate's borders.

Comprehensive species lists, including conservation status under national legislation, CITES appendices, and IUCN categories, are provided in Appendix Tables 1 and 2. These records offer a valuable baseline for ongoing biodiversity monitoring and conservation planning, supporting both national obligations and international efforts to conserve avifauna in the Wallacea region.

Diversity Index and Comparative Analysis

The calculation of the Shannon–Wiener diversity index across the ten observation sites yielded a value of H' = 2.88, which falls within the range of moderate diversity. According to Fachrul (2007), this category indicates that the island's avifaunal community reflects a balance between species richness and evenness, but also suggests that certain ecological pressures may be influencing species distribution. The presence of both highly abundant species, such as the lesser frigatebird (Fregata ariel), alongside numerous species occurring in relatively low numbers, supports this interpretation.

When compared with other birdwatching destinations in Indonesia, the diversity index for Ternate is competitive. For instance, Bantimurung–Bulusaraung National Park in South Sulawesi, a well-established ecotourism destination, reported diversity index values ranging from 2.25 to 3.02 (Asrianny et al., 2018). The value recorded in Ternate lies near the upper limit of this range, indicating that the island supports avian communities of comparable diversity despite its much smaller geographic area of only 99 km². This finding underscores the ecological importance of Ternate as a biodiversity hotspot within the Wallacea region.

Ecologically, the moderate diversity recorded on Ternate reflects the heterogeneity of available habitats, from coastal zones and freshwater systems to urban green spaces and agroforestry landscapes. However, the index also suggests that species richness is constrained by habitat disturbance, urban expansion, and localized land-use change. The presence of both endemic and migratory species further demonstrates the ecological resilience of Ternate's avifauna, while also highlighting the island's vulnerability to environmental pressures. Protecting diverse habitat types across the island is therefore essential to maintaining and potentially enhancing species diversity in the future.

Ecological and Geotourism Implications

The diversity of avifauna recorded in Ternate provides important ecological insights and practical opportunities for sustainable geotourism development. Bird species are widely recognized as effective bioindicators of habitat quality, as their distribution and abundance reflect the integrity of ecological processes and the availability of critical resources (Kamaluddin et al., 2019). The presence of both endemic and migratory species on Ternate suggests that the island continues to provide suitable habitats across multiple ecological niches, despite increasing anthropogenic pressures.

Vegetation structure plays a central role in shaping avian diversity. Habitats with dense canopy cover, layered vegetation, and diverse food sources tend to sustain higher species richness, as they offer shelter, nesting sites, and foraging opportunities. This was evident in sites such as Ngade Lagoon and Tolire Besar, where heterogeneous vegetation supported some of the highest bird species richness on the island. These findings align with broader ecological studies showing that structurally complex landscapes enhance resource availability and facilitate the coexistence of multiple avian guilds (Téllez-Hernández et al., 2023). Conversely, urbanized or simplified landscapes such as Nukila Park and Sulamadaha Beach supported lower richness, illustrating the sensitivity of avifauna to habitat alteration.

From a geotourism perspective, the study identifies several priority sites with strong potential for birdwatching-based tourism. Ngade Lagoon and Tolire Besar are distinguished by high species richness and scenic volcanic landscapes, making them attractive destinations for both ecological and cultural tourism. Kastela Beach stands out as a coastal habitat that supports large congregations of seabirds, while Pulo Tareba offers an island setting that could diversify tourism routes. Together, these sites provide opportunities to develop thematic birdwatching trails that integrate ecological education with recreational experiences.

The integration of avifauna diversity into the Aspiring Ternate Geopark framework would not only promote conservation but also generate socio-economic benefits for local communities. Developing interpretive materials, training local guides, and embedding birdwatching activities into geotrail development can foster community-based tourism initiatives. Such efforts would align biodiversity conservation with

sustainable livelihoods, positioning birdwatching as a flagship attraction that strengthens the geopark's appeal while safeguarding Ternate's ecological heritage.

CONCLUSION

This study provides the first comprehensive assessment of avifaunal diversity across multiple ecological settings on Ternate Island, offering a critical baseline for conservation planning and geotourism development. A total of 60 species from 35 families were recorded, including 11 species endemic to North Maluku and nine migratory taxa. The overall Shannon–Wiener diversity index (H' = 2.88) indicates a moderate level of diversity, reflecting the ecological heterogeneity of the island while also signaling the presence of localized environmental pressures.

Spatial variation in species richness demonstrated that Ngade Lagoon, Tolire Besar, Kastela Beach, and Tongole Village represent priority habitats for bird conservation and avitourism, while urban and disturbed sites such as Nukila Park and Sulamadaha Beach supported lower richness. The documentation of the Endangered white cockatoo (Cacatua alba) and other legally protected species highlights the global and national conservation significance of Ternate's avifauna. Furthermore, the presence of migratory species underscores the island's role in regional and international flyway networks.

These findings carry both ecological and practical implications. Ecologically, they confirm that avifauna can serve as bioindicators of habitat quality, with diversity patterns strongly linked to vegetation structure and resource availability. Practically, they emphasize the potential of integrating birdwatching into the Aspiring Ternate Geopark framework, where sites of high avian richness and scenic value can be promoted as flagship attractions. Such integration would support biodiversity conservation while generating sustainable economic opportunities through community-based tourism initiatives.

While the study contributes important baseline data, it is constrained by the limited temporal scope of nine months and uneven sampling across sites. Future research should extend to year-round monitoring to capture seasonal dynamics, particularly migratory patterns, and incorporate habitat quality assessments to better understand species–environment interactions. Despite these limitations, the present findings provide a scientific foundation for strengthening Ternate's position as both a biodiversity hotspot and a promising destination for birdwatching-based geotourism within the Wallacea region.

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AUTHOR CONTRIBUTIONS

All authors contributed equally.

CONFLICT OF INTEREST

The authors hereby declare no conflict of interest in the publication of the research result.

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DATA AVAILABILITY

All relevant data generated or analyzed during this study are included in this published article. Further data can be made available by the corresponding author upon reasonable request.

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