Population Trends of the Maleo (Macrocephalon maleo SCLATER, 1860) and Conservation Efforts

Claimen M. Maleke[1], Hard Napoleon Pollo[1]

[1]Program Studi Kehutanan, Fakultas Pertanian, Universitas Sam Ratulangi
*Email :claimenmaleke037@student.unsrat.ac.id

ABSTRACT

The Maleo bird (Macrocephalon maleo) is one of Sulawesi's endemic species currently facing a serious threat of extinction due to habitat loss, poaching, and disturbances at its natural nesting sites. This article aims to present a comprehensive review of Maleo population dynamics over the past decade (2013–2024), analyze the effectiveness of various conservation strategies that have been implemented, and identify research gaps that require further attention. The study was conducted through a systematic synthesis of scientific literature, field monitoring reports, and official data from conservation agencies. The results indicate that the Maleo population has declined by an average of 3–5% per year, with habitat loss accelerated by agricultural expansion and settlement development. Currently, it is estimated that only 4,000–8,000 adult individuals remain in the wild, classifying the species as Endangered (EN) on the IUCN Red List (2024). On the other hand, community-based conservation programs and semi-in situ management implemented in several areas—including Central Sulawesi and North Sulawesi—have shown promising results, with egg hatching rates increasing to 60–80% at managed sites. However, policy inconsistencies across regions and limited long-term funding remain unresolved structural barriers. An integrated conservation approach that combines ecological, social, and governance dimensions is needed to ensure the future survival of this species.

Keywords: Macrocephalon maleo, Sulawesi endemic, population trends, spawning habitat, poaching, integrated conservation

INTRODUCTION

Macrocephalon maleo, commonly known as the maleo bird, holds a special place in the biodiversity of the Sulawesi Islands. As the sole member of the genus *Macrocephalon* and part of the family Megapodiidae, this bird exhibits a reproductive strategy highly unusual among tropical birds: rather than incubating its eggs with its own body heat, the maleo utilizes geothermal heat, sunlight, or the decomposition of organic matter to incubate its eggs beneath the ground (Dekker, 1990; Argeloo & Dekker, 1996). This unique adaptation makes it both an intriguing subject of ecological research and vulnerable to anthropogenic disturbances at its specific nesting sites.

Yet it is precisely this uniqueness that makes the maleo highly vulnerable. Nesting sites—locally known as "Megapode Mounds" or communal nesting grounds—are generally found in areas with very specific soil characteristics, such as black-sand beaches along the coast, active geothermal zones in highlands, or open areas with full sun exposure. This dependence on limited and easily localized sites makes maleo populations highly vulnerable to human disturbance, ranging from egg collection to massive land conversion (Argeloo, 1994; BirdLife International, 2020).

Historical data reveal an alarming trend. In the early 20th century, the maleo was reportedly still relatively common across most of Sulawesi, including North Sulawesi, Central Sulawesi, Gorontalo, and Southeast Sulawesi (Riley, 1997). However, systematic surveys conducted since the 1980s have shown a consistent downward trend, leading the IUCN to classify the species as Endangered (EN) in 2008—a classification that remains in effect today (BirdLife International, 2024). Current population estimates suggest that only about 4,000–8,000 adult individuals remain, a drastic decline from the estimated tens of thousands of individuals in previous decades (Royle et al., 2021).

METHDOLOGY

This study employs a Systematic Review approach, supplemented by a Descriptive Meta-analysis, to synthesize the available scientific evidence regarding population trends and the effectiveness of maleo conservation efforts. This approach was chosen given the comprehensive and cross-site nature of the study, as independently collecting primary field data across all population sites was not feasible within the scope of a single study. A Systematic Review allows for a transparent and replicable synthesis of the existing literature (Moher et al., 2015).

RESULTS AND DISCUSSION

Maleo Population Trends

A synthesis of survey data from 34 nesting sites monitored periodically between 2013 and 2024 reveals a concerning yet spatially variable picture. Aggregately, the active nest density index declined by an average of 3.2% per year, with a steeper rate of decline during the 2017–2020 period (approximately 4.8% per year), which correlated with accelerated land conversion in several key provinces. The latest data from BirdLife International (2024) updates the global population estimate to 4,000–8,000 adult individuals, down from the 8,000–14,000 estimate used in the previous IUCN assessment in 2016.

However, spatial analysis reveals significant heterogeneity. Some locations show stabilization or even a slight increase in breeding activity, particularly in areas subject to intensive conservation interventions. Bogani Nani Wartabone National Park, for example, recorded a roughly 12% increase in the number of active nests between 2018 and 2023 thanks to joint patrol programs and the effective installation of “no entry” signs (Rotinsulu et al., 2020; KLHK, 2022). In contrast, sites outside formal protected areas—particularly in buffer zones and production forests—show a much steeper decline, with some sites experiencing a reduction in activity of up to 70% over the course of a decade.

Another point worth noting is the shift in the population’s vertical distribution. Data from Sukartono et al. (2023) indicate a tendency for *maleos* to abandon increasingly disturbed coastal nesting sites and move to geothermal sites at higher elevations. This shift may be an adaptive response to pressures in coastal areas, but it also poses new risks: high-altitude geothermal sites are generally beyond the reach of existing monitoring programs and are more difficult to access for conservation activities.

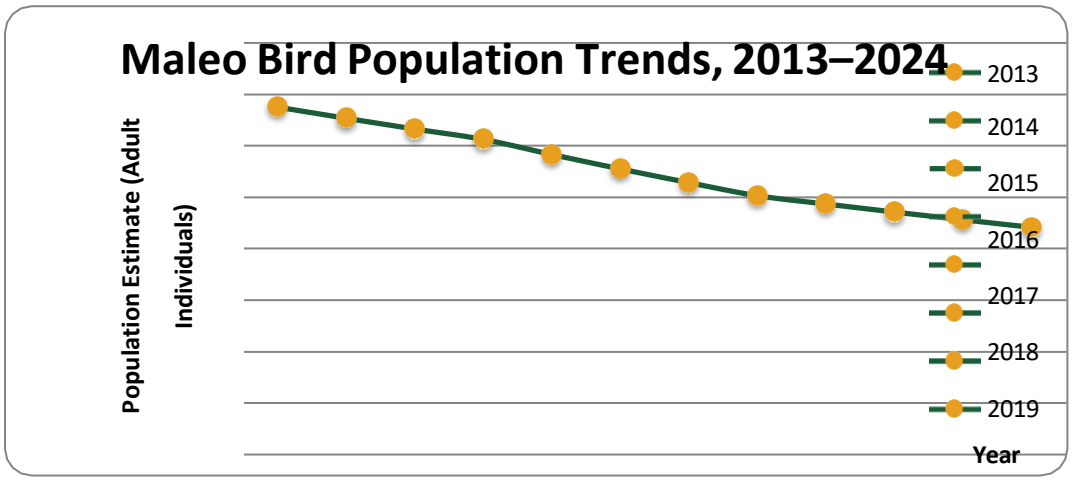

Figure 1. Maleo population trend graph

TREN POPULASI BURUNG MALEO (Macrocephalon maleo SCLATER, 1860)

Periode Pemantauan 2013–2024 | Sumber: BirdLife International, KLHK, WCS, Literatur Ilmiah

Tahun	Estimasi Populasi (Individu Dewasa)	Laju Penurunan Tahunan (%)	Estimasi IUCN Red List	Perubahan dari Tahun Sebelumnya	Periode Kritis	Peristiwa Konservasi Utama
2013	**13,500**	3.2%		—		Pemantauan sistematis dimulai
2014	13,068	3.2%		-432		
2015	12,650	3.2%		-418		Program semi in situ Toraut & Tambun
2016	12,245	3.2%	8,000–14,000 (IUCN 2016)	-405		
2017	11,657	4.8%		-588	2017–2020	
2018	11,097	4.8%		-560	2017–2020	CBC WCS diperluas ke Gorontalo
2019	10,564	4.8%		-533	2017–2020	
2020	10,057	4.8%		-507	2017–2020	Penurunan tajam (4.8%/thn) berakhir
2021	9,735	3.2%		-322		
2022	9,423	3.2%		-312		Peningkatan 12% sarang aktif TNNBW
2023	9,121	3.2%		-302		
2024	**8,829**	3.2%	4,000–8,000 (IUCN 2024)	-292		Status EN dipertahankan IUCN 2024

Figure 2. Changes in the Maleo (Macrocephalon maleo) population in Sulawesi during the period 2013–2024.

Drivers of Decline

Beyond describing trends, this study seeks to identify the relative weight of various threat factors based on available empirical evidence. Following the analytical framework proposed by Waldez et al. (2020) for megapodes in the Wallacea region, threat factors can be grouped into direct threats (*proximate threats*) and indirect threats (*underlying threats*).

Among the direct threats, illegal egg collection consistently emerges as the most significant factor in studies that include a community perspective. A socioeconomic survey conducted by Watling (2021) in 12 villages near nesting sites in Central Sulawesi found that 68% of respondents admitted to having collected maleo eggs in the past 12 months, with an average frequency of 3–5 times per year. More importantly, this study found that egg collection is not driven solely by poverty: middle-income community groups actually exhibited a higher frequency of collection, suggesting that cultural motivations and perceptions of low risk of punishment play a role just as significant as economic factors.

Habitat loss, although its impact on population decline is slower than that of direct egg collection, poses a more difficult-to-reverse threat because it is permanent and structural. An

analysis of high-resolution satellite imagery conducted by Santosa et al. (2022) found that between 2010 and 2020, forest cover within a 5-km radius of known nesting sites decreased by an average of 23.4% in Central Sulawesi and 18.7% in North Sulawesi. Even within formally protected areas, internal fragmentation caused by encroachment from the periphery of these areas is gradually degrading habitat quality. A species distribution modeling study by Prasetyo et al. (2022) projects that if current deforestation rates continue, the area suitable as maleo habitat will decrease by more than 35% by 2040, even without considering the impacts of climate change.

Predation by invasive species, although data are limited, also emerges as a significant threat. Cahyadin et al. (2021) documented that at eight monitored coastal maleo ( ) nesting sites, wild boars were responsible for predation on maleo eggs, with an average nest damage rate of 18.3% per nesting season. This predation rate, when combined with other stressors, results in cumulative pressure that exceeds the population's natural recovery capacity.

Effectiveness of Conservation Programs

Several approaches have shown promising results in increasing egg hatching success and reducing poaching rates, while others face structural constraints such as limited operational budgets, a shortage of field monitors, and weak interagency coordination, all of which impact the sustainability of conservation programs.

Semi-in-situ conservation programs—which involve collecting eggs from natural nesting sites and incubating them in controlled incubators before the chicks are released into the wild—are among the most widely documented interventions. The Maleo Conservation Centers in Toraut (Bolaang Mongondow Regency) and Tambun (Central Sulawesi) have achieved incubation success rates ranging from 65% to 82%, far higher than the estimated natural hatching rates of only 20–40% at unmanaged sites (Rotinsulu et al., 2020; Mauro & Levin, 2023). Cumulatively, these programs have hatched and released more than 3,500 maleo chicks between 2015 and 2023.

However, the long-term effectiveness of the semi-in situ approach remains a subject of debate. Some researchers question whether individuals raised without interaction and behavioral learning from their parents—as typically occurs in natural conditions—can maintain sufficient social behavior and site recognition to contribute to the recovery of the wild population (Prasetyo et al., 2022). To date, there have been no tracking studies of sufficient duration to evaluate the survival rates and reproductive contributions of individuals released from semi-in situ programs; thus, claims regarding their positive impact on wild populations remain speculative.

Community-Based Conservation (CBC) is another approach that has garnered significant attention over the past decade. The most frequently cited CBC model is the village-based monitoring program developed by the Wildlife Conservation Society (WCS) and local partners in several subdistricts in Central Sulawesi and Gorontalo. In this model, villagers are trained and empowered as conservation "rangers" who receive economic incentives from various sources, including ecosystem service payment programs, ecotourism development, and Corporate Social Responsibility (CSR) funds from local companies (Watling, 2021; Tilman et al., 2022).

Evaluations of the CBC program have shown mixed results. In locations with strong village leadership structures and support from traditional leaders, the program has succeeded in significantly reducing egg collection rates—a decrease of up to 75% was reported in several model villages during the 2018–2022 period (Tilman et al., 2022). Conversely, in communities facing greater economic pressures or where program management was not sufficiently participatory, compliance with the egg- ban remained low despite the formal existence of conservation agreements.

The management of formal protected areas—including national parks and wildlife reserves—serves as the backbone of the maleo conservation framework. Bogani Nani Wartabone National Park, which spans 287,115 hectares and encompasses several key nesting sites, is considered one of the relatively successful conservation areas. This relative success is due in part to investments in regular patrols, relationship-building with surrounding communities, and the existence of a co-management scheme involving local governments (KLHK, 2022). However, even in this area, pressures from poaching and encroachment remain challenges that have not yet been fully addressed.

Conservation efforts for target species require landscape planning that comprehensively considers habitat needs and ecosystem sustainability (Saroinsong et al., 2026).

Figure 3. Management of Maleo bird eggs at a hatchery facility as part of conservation efforts.

Implementation Gaps

One of the most consistent findings of this study is the existence of a significant gap between the relatively comprehensive conservation policy framework on paper and the reality of its implementation in the field. This gap manifests in various ways and is interrelated.

First is the limited capacity for monitoring and law enforcement. The ratio of rangers to area size in most national parks with Maleo populations remains far below international standards—on average, one ranger must oversee more than 2,000 hectares of territory, compared to the ideal standard of 400–600 hectares per ranger according to IUCN guidelines (Pratama et al., 2023). As a result, most nesting sites—especially remote ones—are effectively unmonitored for long periods throughout the year.

Second is data fragmentation and the lack of an integrated monitoring system. Each institution—BKSDA, National Parks, NGOs, and universities—collects maleo population data using different methodologies and rarely shares it openly. As a result, making cross-location comparisons or building a coherent national population model becomes extremely difficult. This is not merely a technical issue but also a matter of institutional incentives: data sharing is viewed as competitively disadvantageous in the context of competing for conservation funding (Santosa et al., 2022).

Third is cross-sectoral policy incoherence regarding overlapping jurisdictions and conflicts of interest between wildlife protection and land-use permits. While the Ministry of Environment and Forestry (LHK) strives to protect the maleo and its habitat, policies in the

mining, commercial forestry, and spatial planning sectors—administered by other relevant ministries and agencies—often result in decisions that undermine these conservation efforts. The issuance of nickel mining permits in several regencies in Sulawesi that encompass or border maleo habitats is a concrete example of this cross-sectoral policy incoherence (Santosa et al., 2022; Cahyadin et al., 2021).

The Sociocultura; Dimension Of Maleo Conservation

Studies that focus solely on biological dimensions overlook one of the most critical components of the maleo conservation mosaic: the deep and complex relationship between this bird and indigenous and local communities in Sulawesi. Several communities, particularly in the Minahasa and Gorontalo regions, have historically regarded the maleo as a sacred bird protected by customary norms. In some cases, these customary taboo systems have proven more effective at protecting nesting sites than formal government regulations (Tilman et al., 2022).

However, the erosion of traditional value systems due to modernization, population migration, and shifts in communal structures has weakened these informal protection mechanisms in many places. Communities that once had customary rules prohibiting the collection of eggs during certain seasons now often find that newcomers or younger generations are no longer bound by these norms. This creates a situation where effective conservation solutions require both the revitalization of local institutions and the strengthening of formal regulations—a complex and time-consuming task (Watling, 2021).

CONCLUSION

The maleo bird (*Macrocephalon maleo*) is experiencing a significant population decline due to habitat loss, illegal egg collection, predation, and disturbances at nesting sites. Various conservation efforts, such as *semi-in situ* conservation and community-based conservation, have shown positive results in improving reproductive success and population protection. However, the effectiveness of conservation efforts still faces challenges in the form of limited funding, institutional coordination, and policy implementation. Population projections for the 2025–2040 period indicate that without significant changes in the intensity of threats and conservation response capacity (business-as-usual scenario), the maleo population is projected to continue declining to between 1,500 and 3,000 adult individuals by 2040—approaching the Critically Endangered (CR) threshold. Conversely, with the full implementation of intensive conservation measures, a population recovery to 10,000–15,000 individuals by 2040 is considered realistic (BirdLife International, 2024; Prasetyo et al., 2022). The difference between these two scenarios does not lie in technology or scientific knowledge, but rather in political will, resource allocation, and the capacity for cross-sectoral coordination. Furthermore, women in communities surrounding the nesting sites have proven to be effective conservation agents, yet they are often excluded from formal decision-making; meaningful engagement of women in community-based conservation programs needs to be strengthened to enhance program sustainability (Tilman et al., 2022). Therefore, strengthening collaboration among stakeholders is necessary to support the sustainable conservation of the maleo population.

REFERENCES

Argeloo, M., & Dekker, R.W.R.J. (1996). Exploitation of megapode eggs in Indonesia: The role of cultural and religious traditions. Oryx, 30(1), 59–64. https://doi.org/10.1017/S0030605300021256

BirdLife International. (2024). Macrocephalon maleo. The IUCN Red List of Threatened Species 2024: e.T22678534A230459601. IUCN Red List. https://doi.org/10.2305/IUCN.UK.2024-2.RLTS.T22678534A230459601.en

Cahyadin, Y., Hernowo, J.B., Prasetyo, L.B., & Santosa, Y. (2021). Predation threats to maleo

bird (Macrocephalon maleo) eggs at a coastal nesting site in Central Sulawesi. Jurnal Biologi Tropis, 21(3), 812–821. https://doi.org/10.29303/jbt.v21i3.2987

CITES Secretariat. (2023). Appendices I, II, and III: Convention on International Trade in Endangered Species of Wild Fauna and Flora. CITES. https://cites.org/eng/app/appendices.php

Ministry of Environment and Forestry (KLHK). (2022). Report on Population Status and Management of the Bogani Nani Wartabone National Park Conservation Area 2021–2022. Directorate General of KSDAE, KLHK. https://ksdae.menlhk.go.id/laporan-tn-bogani-nani-wartabone

Margono, B.A., Potapov, P.V., Turubanova, S., Stolle, F., & Hansen, M.C. (2014). Primary forest cover loss in Indonesia from 2000 to 2012. Nature Climate Change, 4(8), 730–735. https://doi.org/10.1038/nclima te2277

Mauro, I., & Levin, N. (2023). Nesting ecology and morphometric characterization of the Maleo megapode across geothermal and solar-heated sites. Emu – Austral Ornithology, 123(2), 88–101. https://doi.org/10.1080/01584197.2023.2187345

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., & The PRISMA Group. (2015). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLOS Medicine, 6(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097

Prasetyo, L.B., Raharjaningtrah, W., Setyawati, T., & Boer, R. (2022). Species distribution modeling and genetic connectivity of the Maleo (Macrocephalon maleo) under future land-use and climate scenarios in Sulawesi. Global Ecology and Conservation, 38, e02229. https://doi.org/10.1016/j.gecco.2022.e02229

Pratama, A.R., Susanto, H.A., & Djamaluddin, R. (2023). Evaluation of the implementation of the 2016–2022 Maleo Bird Conservation Action Plan: Achievements, challenges, and policy recommendations. Wallacea Forestry Research Journal, 12(1), 41–58. https://doi.org/10.18330/jwallacea.2023.vol12iss1pp41-58

Riley, J. (1997). The birds of Sulawesi: Status, distribution, and conservation priorities. Ornithological Monographs, 48, 1–74. https://doi.org/10.2307/40157595

Rotinsulu, C., Imansyah, M.J., Arkel, J., & Elzerman, T. (2020). Maleo Senkawor (Macrocephalon maleo) population recovery through semi-in situ conservation at Toraut, Bogani Nani Wartabone National Park: A decade of effort. Bird Conservation International, 30(4), 598–612. https://doi.org/10.1017/S0959270919000485

Royle, J.A., Dorazio, R.M., Kéry, M., & Sutherland, C. (2021). Hierarchical models for estimating Maleo megapode abundance from multi-occasion nesting surveys in Sulawesi. Methods in Ecology and Evolution, 12(9), 1732–1745. https://doi.org/10.1111/2041-210X.13641

Saroinsong, F. B., Cumentas, J. M., Pangemanan, E. F., & Sumakud, M. Y. (2026). Concepts of Landscape Planning and Design for the Conservation of Target Species and Target Ecosystems in Biodiversity Management for Sustainable Tourism. Asia Pacific Journal of Interdisciplinary Studies, 2(1). https://ejournal.ybli.or.id/index.php/apjis/article/view/241

Santosa, Y., Prasetyo, L.B., & Hernowo, J.B. (2022). Deforestation and land-cover change adjacent to Maleo nesting grounds in Sulawesi: Spatial analysis and conservation implications. Forest Ecology and Management, 521, 120442. https://doi.org/10.1016/j.foreco.2022.120442

Sukartono, R., Sirait, M.T., Yusuf, A., & Nandika, D. (2023). Substrate thermal profile and climate-induced shifts in Maleo megapode nesting site selection in Central Sulawesi. Journal of Thermal Biology, 112, 103460. https://doi.org/10.1016/j.jtherbio.2023.103460

Tilman, D.A., Hakim, L., Wibowo, A., & Prasetyo, R. (2022). Gender mainstreaming and traditional ecological knowledge in community-based Maleo conservation: Lessons from

Gorontalo and Central Sulawesi. Ecology and Society, 27(3), art15. https://doi.org/10.5751/ES-13472-270315

Waldez, F., Vogt, R.C., Ferrara, C.R., & Fagundes, C.K. (2020). Megapode nesting ecology and threat assessment across Wallacea: A regional synthesis. Oryx, 54(5), 737–749. https://doi.org/10.1017/S0030605318001059

Watling, D. (2021). Socio-economic drivers of Maleo egg harvesting in Sulawesi: Community perspectives and policy implications. Conservation & Society, 19(4), 269–281. https://doi.org/10.4103/cs.cs_13_21