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Habitat and Population of the Cenderawasih Bird in Papua, Indonesia

EDOWARD KRISSON RAUNSAY[1],ROSANIYA E. REHIARA[2], IBRAHIM KRISTOFOL KENDI [3],LAZARUS RAMANDEI[4]

[1-2]Biology Education Study Program, Department of Mathematics and Natural Sciences Education, Faculty of Teacher andEducational Sciences, Cenderawasih University, Jl. Pendidikan Abepura Jayapura, Papua Indoensia

[3]Department Public Administrtion, Cenderawasih University.Jl.Pendidikan III Abepura,Jayapura,Papua,Indonesia

[4]Department of Urban Regional Planning, Universitas Cenderawasih, Jl. Kampwolker, Yabansai Waena Jayapura. Papua, Indonesia

email: lazarus_ramandey@ftuncen.ac.id

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Abstract. This research investigates on the habitat quality, population dynamics, and behavioral ecology of the Cenderawasih bird in Papua, Indonesia. The study uses stratified random sampling, acoustic monitoring, and behavioral observations to demonstrate considerable differences in bird abundance and species richness across different habitat types. Primary forests had the best habitat quality, with dense canopy cover, towering trees, and abundant fruit-bearing flora, which supported the highest bird numbers and species diversity. Secondary and disturbed regions, by comparison, had much lower bird numbers and biodiversity. Regression and correlation studies revealed that canopy cover and tree height are important predictors of bird density, emphasizing the relevance of these habitat factors. Behavioral investigations indicated regular courting displays, eating, and nesting activity in primary woods, indicating ideal circumstances for the Cenderawasih bird's ecological requirements. The findings underscore the importance of primary forests in preserving bird biodiversity, as well as the necessity for focused conservation activities such as habitat protection, restoration, and community participation. This research provides a solid scientific foundation for creating effective conservation policies to preserve the long-term survival of the Cenderawasih bird in Papua.

Keywords: Cenderawasih Bird, Habitat Quality, Population Dynamics, Conservation Strategies

INTRODUCTION

The Cenderawasih bird, often known as the Bird of Paradise, plays an important role in the biodiversity of Papua, Indonesia. This region, known for its diverse ecosystem, is home to roughly 28 species of Cenderawasih, which are an important component of Indonesia's natural heritage (TheIndonesia.id, 2021; Antara News, 2021). These birds are known for their colorful plumage and dramatic courting displays, which have made them famous in both local and international ornithological communities. However, their habitats are increasingly under threat from human activity, necessitating immediate conservation actions (EcoNusa, 2021). The Cenderawasih bird lives in lowland rainforests and hilly regions across Papua, prospering in locations with rich foliage and great biodiversity (West Papua Diary, 2023). These environments provide critical resources such as food and nesting grounds, which are necessary for the birds' survival and reproduction. For example, the Lesser Bird of Paradise (Paradisaea minor) and King Bird of Paradise (Cicinnurus regius) enjoy deep forest canopies with plenty of cover and feeding possibilities (Rimbakita, 2021).

Beyond its visual appeal, the Cenderawasih bird plays an important ecological purpose. These birds play important roles in the rainforest ecology, dispersing seeds and pollinating flowers. Their interactions with nature contribute to the structural complexity and richness of their environments (Story Maps, 2021). For example, the Red Bird of Paradise (Paradisaea rubra) is known to disseminate the seeds of many tree species, so contributing in forest regeneration. The Cenderawasih bird holds equal cultural value. Indigenous Papuan cultures see these birds as symbols of beauty, independence, and spiritual connection to nature. They are significant in traditional ceremonies and art, representing the peaceful link between humans and their natural surroundings (EcoNusa, 2021; Sepie, 2017). This cultural reverence underscores the importance of preserving these species, not only for their ecological roles but also to maintain the cultural heritage of the indigenous peoples.

Despite their ecological and cultural importance, Cenderawasih birds face a variety of problems. The principal issue is habitat loss owing to deforestation caused by logging, mining, and agricultural development. Between 2018 and 2019, Papua Province lost roughly 11,212 hectares of forest, severely affecting the biodiversity that these forests provide (EcoNusa, 2021). The increase of palm oil plantations and illicit logging operations exacerbates habitat fragmentation, making it harder for birds to find adequate breeding and feeding areas (Hughes, 2017: Harrison et al., 2016).

Illegal hunting and trading offer extra risks. The Cenderawasih's stunning plumage attracts poachers, who catch and sell them to collectors and traditional adornments (TheIndonesia.id, 2021). This illicit trade not only harms bird numbers, but it also destroys the rainforest's ecosystem. Former poachers, such as Alvian Sopuiyo, have turned to conservation, demonstrating the value of community engagement in bird protection (TheIndonesia.id, 2021). The Cenderawasih bird is in danger due to habitat degradation and unlawful poaching. The loss of habitat not only reduces the available area for living and reproducing, but it also disturbs the complicated ecological relationships in which they participate (StoryMaps, 2021). This fragmentation creates isolated populations, diminishing genetic diversity and making the species more susceptible to environmental changes and illnesses (Rimbakita, 2021).

Understanding the habitat and population dynamics of the Cenderawasih bird is important for a variety of reasons. For starters, it provides critical data that conservationists and politicians may use to build focused policies to protect these species and their environment. Second, it focuses on the overall environmental health of Papua's rainforests, which are critical not just for local biodiversity but also for global ecological stability. Rainforests serve as important carbon sinks, and their preservation is critical in combatting climate change (Heinrich et al., 2021). This research emphasizes the necessity of including local communities in conservation initiatives. Indigenous knowledge and traditional methods can have a significant impact on long-term habitat management. Engaging local populations can result in more successful and culturally appropriate conservation measures, ensuring that efforts to safeguard the Cenderawasih bird also benefit the lives and traditions of those who live near these amazing birds (Setyawan et al., 2020; Rizal, 2021).

Literature Review and Previous Studies

Cenderawasih Bird Biology

The Cenderawasih bird, often known as the Bird of Paradise, is renowned for its stunning beauty and spectacular courting rituals. These birds have brilliant plumage in a variety of hues, including blue, green, yellow, and red, which is sometimes organized in fascinating patterns (Schowchow-Thalmann, 2018). Cenderawasihbirds exhibit sexual dimorphism, with males showing more elaborate feathering than females, which is important in their mating rituals (West Papua Diary, 2023). The complex feather structures and brilliant colors are the consequence of pigmentation and microstructures that reflect light, resulting in iridescence and distinct visual effects (Frith and Beehler, 1998). The Greater Bird of Paradise (Paradisaeaapoda) and the King Bird of Paradise (Cicinnurus regius) are well-known for their complicated mating dances, which include intricate motions and vocalizations intended to attract females (Rimbakita, 2021). These behaviors are critical for reproductive success, guaranteeing

the survival of the species. Males frequently clear a show area in the forest undergrowth and execute intricate dances that include spreading their plumage, jumping, and vocalizing to lure females (Beehler et al., 1986).

Habitat Requirements

Cenderawasih birds live in a range of forest types, including lowland rainforests and montane forests, particularly in Papua and neighboring areas (Sonbait et al., 2021; Fenner, 2019). These environments are distinguished by lush vegetation, which supplies critical resources like as food, shelter, and nesting areas. Forests in the Arfak Mountains and Raja Ampat are exceptionally biodiverse, sustaining not just Cenderawasih birds but also a plethora of other rare species (Albasri, 2018). Tall trees and a diverse understory provide important cover and foraging options. The Red Bird of Paradise (Paradisaea rubra) prefers locations with a high density of fruit-bearing trees since fruits are an important element of their diet (Aristizabal et al., 2019). The presence of large, mature trees is crucial as they provide optimal perching sites for courtship displays and nesting (jara et al., 2020; Pokorny et al., 2017).

Environmental Threats

The major danger to Cenderawasih birds is habitat loss from deforestation caused by logging, mining, and agricultural development (Purwanto et al., 2021; Muttaqin et al., 2019). Papua has had severe deforestation, with over 11,000 hectares destroyed between 2018 and 2019 (EcoNusa, 2021). Palm oil plantation growth and illicit logging are particularly harmful, fragmenting the forest and creating isolated areas of habitat. This fragmentation makes it difficult for Cenderawasih birds to find adequate breeding and feeding places, perhaps leading to population decreases (West Papua Diary, 2023). Illegal logging and the growth of palm oil plantations are particularly harmful, fragmenting the forest and creating isolated areas of habitat. The primary threat to Cenderawasihbirds is habitat loss from deforestation driven by logging, mining, and agricultural development (OHEE, 2016). Papua had substantial deforestation, with over 11,000 hectares lost between 2018 and 2019. Palm oil plantation expansion and illegal logging are especially damaging, fragmenting the forest and creating isolated patches of habitat. This fragmentation makes it difficult for Cenderawasih birds to find suitable breeding and feeding grounds, perhaps contributing to population decline (West Papua Diary, 2023). Illegal logging and the expansion of palm oil plantations are especially damaging, fragmenting the forest and creating isolated patches of habitat.

Previous Studies

Numerous research has been conducted on the ecology and conservation of Cenderawasih birds. Beehler et al. (1986) carried out significant fieldwork in Papua New Guinea, offering fundamental insights into the behavior, ecology, and distribution of various Bird of Paradise species. Their findings demonstrated the vital relevance of intact forest environments for the survival of these species. Frith and Beehler (1998) built on this research by recording the mating habits and ecological needs of Cenderawasih birds. Their findings highlighted the importance of complex courting displays in sexual selection, as well as the requirement for broad, undisturbed areas of forest to sustain sustainable populations.

Gregory et al. (2020) used current techniques including remote sensing and Geographic Information Systems (GIS) to map the distribution of Cenderawasih habitats and identify deforestation hotspots. These studies give useful data for conservation planning, allowing for more targeted efforts to maintain crucial habitats and corridors. EcoNusa's (2021) research has included ecological studies as well as community-based conservation activities. These programs engage local residents in the conservation of Cenderawasih habitats by offering education and alternative livelihoods to lessen hunting pressures. Such programs have demonstrated potential in developing long-term conservation approaches that benefit both birds and the humans who share their habitat.

Research Gap

While tremendous progress has been made in understanding the ecology and dangers to Cenderawasih

birds, major gaps still exist. More research is needed on the effects of habitat fragmentation and the unique habitat needs of various Cenderawasih species. Furthermore, the efficacy of community-based conservation programs requires additional assessment to ensure long-term success (EcoNusa, 2021; TheIndonesia.id, 2021).

METHOD

The technique for this study was developed to assess the habitat and population of the Cenderawasih bird in Papua, Indonesia, using quantitative research methodologies. The research spanned from January to December 2023 and included a variety of forest types from various altitude ranges.

Sampling Technique

A stratified random sample strategy was used to guarantee that the Cenderawasih bird's different habitats were adequately represented. The research region was classified into three strata based on height (lowland, mid-elevation, and highland forests) and forest type (primary, secondary, and disturbed areas). Within each stratum, one-hectare sampling plots were chosen at random. This method enabled a complete assessment of habitat conditions and bird populations over several environmental gradients (Cochran, 1977; Thompson, 2012).

Instrumentation

The primary instruments used for data collection included:

1. GPS Devices: For accurate location mapping of sampling plots and bird sightings.
2. Binoculars and Spotting Scopes: To observe and identify bird species from a distance without causing disturbance.
3. Digital Cameras: To document bird species and habitat conditions.
4. Vegetation Plots: Standard quadrats (10m x 10m) within each hectare plot to assess vegetation structure and composition.
5. Acoustic Recorders: To capture bird calls for species identification and to estimate bird density using acoustic surveys (Blumstein et al., 2011).

Data Collection Procedures

Data gathering involves numerous critical steps: Habitat Assessment: Within each sampling plot, extensive measures of vegetation structure were made, including tree height, canopy cover, and the presence of fruit-bearing trees. Soil samples were also taken to determine soil quality and composition. Bird surveys: Point count surveys were carried out at dawn and dusk, when bird activity is maximum. Observers documented all birds observed and heard within a 50-meter radius for ten minutes at each station. These counts were performed several times to account for temporal variations (Ralph et al., 1995). Acoustic Monitoring: Acoustic recorders were placed in chosen plots to constantly record bird cries over many days. These recordings were then examined to determine species and relative abundance (Blumstein et al., 2011).

Validation of Instruments

Several efforts were taken to guarantee that the instruments were valid and reliable: GPS devices were calibrated before each field session to guarantee accurate position data. Observer Training: To reduce observer bias and assure data collection uniformity, all field observers were trained in bird identification and survey methodologies (Bibby et al. 2000). Pilot research was done in a smaller region prior to the main study to develop the approach and confirm that all instruments were operating well and provided trustworthy data (Creswell, 2014).

Statistical Analysis

Data analysis entailed applying a variety of statistical approaches to test hypotheses and evaluate the correlations between habitat quality and bird population measurements. The statistical tests utilized included the following: Descriptive statistics: To describe the fundamental characteristics of the data, such as mean, median, standard deviation, and range for continuous variables like bird density and vegetation cover. T-test: Used to compare the means of two groups, such as bird populations in main and

secondary forests. ANOVA (Analysis of Variance): To determine whether there are significant variations in bird population metrics across several habitat types (e.g., lowland, mid-elevation, and highland) (Field 2013). Regression Analysis: Determine the link between bird population density and other environmental characteristics such as canopy cover, tree height, and the existence of fruit-bearing trees. Field (2013) employed both linear and multivariate regression models to uncover relevant factors. Correlation Analysis: Determines the degree and direction of connections between pairs of variables, such as bird density and plant density (Cohen, 1988). ANCOVA (Analysis of Covariance): To account for any confounding variables while investigating the primary effects of habitat type on bird population density (Tabachnick & Fidell, 2013).

Habitat Type	**Statistic**	**Canopy Cover (%)**	**Tree Height (m)**	**Number of Fruit-Bearing Trees**
Lowland Forest	Mean (SD)	75.3 (10.2)	20.5 (5.8)	15.3 (4.2)
	Median	76.0	21.0	16.0
	Range	55-90	10-30	8-22
Mid-Elevation Forest	Mean (SD)	68.7 (12.5)	18.2 (6.1)	12.8 (3.9)
	Median	70.0	19.0	13.0
	Range	45-85	8-28	6-19
Highland Forest	Mean (SD)	60.5 (15.7)	15.6 (4.3)	10.4 (3.1)
	Median	62.0	16.0	11.0
	Range	35-80	7-23	4-16
Secondary Forest	Mean (SD)	45.8 (18.6)	10.7 (3.9)	7.3 (2.5)
	Median	48.0	11.0	8.0
	Range	20-70	4-18	3-12

Disturbed Area	Mean (SD)	35.2 (20.1)	8.5 (2.8)	5.1 (1.7)
	Median	36.0	9.0	5.0
	Range	10-60	3-14	2-8

Table 1: Statistics of Habitat Variables (Canopy Cover, Tree Height, Fruit-Bearing Trees)

RESULT AND DISCUSSION

This study presents a thorough investigation of habitat quality, bird population measurements, and behavioral observations across several habitat types in Papua. This extensive examination identifies substantial variations across primary, secondary, and disturbed forests, offering insight on the essential elements impacting the Cenderawasih bird's survival and behavior. To better understand habitat quality, numerous characteristics such as canopy cover, tree height, and the quantity of fruit-bearing trees were assessed across different habitat types. These criteria are important markers of habitat quality and appropriateness for sustaining varied bird populations. The following table summarizes key habitat factors across the tested environments.

The average canopy cover in lowland forests was 75.3%, indicating a thick and healthy forest structure. The median score of 76%, with a range of 55% to 90%, supports the high vegetation density in these places. In contrast, disturbed regions had the lowest mean canopy cover (35.2%), with a range of 10% to 60%, showing severe deterioration and variability in these habitats. Tree Height: Lowland woods featured the tallest trees, with an average height of 20.5 meters and a median height of 21 meters.

The range of 10 to 30 meters emphasizes the presence of both young and older trees. In contrast, disturbed regions had the smallest trees, with an average height of 8.5 meters, reflecting the impact of deforestation and habitat disturbance. Fruit-Bearing Trees: The number of fruit-bearing trees was highest in lowland forests, with a mean of 15.3 trees per hectare. This contrasts sharply with disturbed areas, which had a mean of only 5.1 fruit-bearing trees, indicating a reduction in food resources for the Cenderawasih birds.

To better understand the variations in bird populations across different environments, measurements including bird density and species richness were examined. These measures are critical markers of the health and variety of bird communities. The table below provides an overview of bird population metrics across the examined habitats:

Table 2: Bird Population Metrics (Density, Species Richness) Across Different Habitats

Habitat Type	Statistic	Bird Density (birds/ha)	Species Richness (number of species)
Lowland Forest	Mean (SD)	25.6 (6.3)	12.4 (3.1)
	Median	26.0	13.0
	Range	15-35	8-17
Mid-Elevation Forest	Mean (SD)	20.3 (5.7)	10.7 (2.8)
	Median	21.0	11.0
	Range	10-30	6-15

Highland Forest	Mean (SD)	16.9 (4.9)	8.9 (2.6)
	Median	17.0	9.0
	Range	8-25	5-13
Secondary Forest	Mean (SD)	12.5 (3.8)	6.4 (1.9)
	Median	13.0	6.0
	Range	5-20	3-9
Disturbed Area	Mean (SD)	8.2 (2.7)	4.2 (1.4)
	Median	8.0	4.0
	Range	3-13	2-6

In lowland woods, the average bird density was 25.6 per hectare, with a median of 26.0 and a range of 15 to 35. This high density suggests that lowland woods are an ideal home for birds, with many supplies and ideal circumstances for nesting, foraging, and breeding. The thick canopy cover, large trees, and lush vegetation in these forests provide a favorable habitat for bird populations to grow. Mid-elevation woods also have large bird populations, with a mean density of 20.3 birds per hectare and a median of 21.0. Although slightly lower than lowland forests, these ecosystems provide a thriving environment for birds. The slight drop in bird numbers relative to lowland forests can be ascribed to changes in plant structure and resource availability as altitude increases. Highland woods have a lower bird density, with an average of 16.9 birds per hectare and a median of 17.0. The lower bird population in these higher-altitude environments is due to harsher climatic conditions and less diversified plant structure than in lowland and mid-elevation forests. However, these woods continue to provide vital habitat for bird species that have adapted to higher elevations.

Secondary forests that have been disturbed have much lower bird numbers, with an average of 12.5 birds per hectare and a median of 13.0. The effects of habitat disturbance, such as logging and land conversion, are seen in these woods, resulting in less canopy cover, fewer nesting places, and less food availability. As a result, bird populations in secondary forests are less resilient than in primary forests. Disturbed regions, defined by considerable habitat loss, had the lowest bird numbers, with an average of 8.2 birds per hectare and a median of 8.0. The dramatic decline in habitat quality in these locations leads in inadequate resources and unfavorable circumstances for many bird species, resulting in the lowest recorded bird numbers. Species richness follows a similar trend, with the most diversity found in lowland forests (mean of 12.4 species per hectare, median of 13.0) and the fewest in disturbed regions. The great species richness of lowland forests is due to the diversified and complex habitat structure that supports a large range of bird species. In contrast, poor habitat quality in disturbed regions reduces the number of species that can survive, resulting in lesser biodiversity.

Habitat Type	**Canopy Cover (%)**	**Tree Height (m)**	**Vegetation Density (stems/ha)**	**Number of Fruit-Bearing Trees**
Lowland Forest	75.3 (10.2)	20.5 (5.8)	1020 (150)	15.3 (4.2)
Mid-Elevation Forest	68.7 (12.5)	18.2 (6.1)	950 (140)	12.8 (3.9)
Highland Forest	60.5 (15.7)	15.6 (4.3)	870 (130)	10.4 (3.1)
Secondary Forest	45.8 (18.6)	10.7 (3.9)	620 (120)	7.3 (2.5)
Disturbed Area	35.2 (20.1)	8.5 (2.8)	480 (110)	5.1 (1.7)

Table 3: Vegetation Structure and Composition Across Different Habitat Types

Canopy Cover: Lowland woods had the highest canopy cover (75.3%), indicating a dense forest structure. This number decreases with height and disturbance, with disturbed places having the lowest canopy cover (35.2). Tree Height: The tallest trees were found in lowland woods, with an average height of 20.5 metres. Tree height declined with increasing altitude and human disturbance, with disturbed regions having the lowest trees (mean of 8.5 metres). Lowland woods had the highest plant density (1020 stems per hectare), indicating a lush and thick understory. In contrast, disturbed regions had the lowest vegetation density, indicating considerable habitat destruction. Fruit-Bearing Trees: The number of fruit-bearing trees was highest in lowland forests (15.3 trees per hectare), providing ample food resources for the Cenderawasih birds. Disturbed areas had the fewest fruit-bearing trees, further highlighting the impact of habitat degradation.

Table 6: T-Test Results Comparing Bird Density in Primary and Secondary Forests

Metric	Primary Forest (Mean ± SD)	Secondary Forest (Mean ± SD)	t-Value	p-Value
Bird Density	23.7 ± 5.8	12.5 ± 3.8	7.231	< 0.001
Species Richness	11.5 ± 2.9	6.4 ± 1.9	8.451	< 0.001

Bird Density:

Primary woods had an average bird density of 23.7 per hectare, with a standard deviation of 5.8. This suggests a very high and stable bird population density in these undisturbed areas. Secondary Forests: In contrast, secondary forests showed a much-reduced mean bird density of 12.5 birds per hectare with a standard deviation of 3.8, indicating the impact of habitat disturbance. Statistical significance: The t-test produced a t-value of 7.231 with a p-value of less than 0.001, showing a very significant difference in bird density between primary and secondary forests. The substantial p-value (< 0.001) indicates that the observed difference in bird density is unlikely to occur by chance, confirming the negative impact of habitat disturbance on bird populations.

Species Richness:
Primary forests had an average species richness of 11.5 per hectare, with a standard deviation of 2.9. This high species richness reflects a diversified bird community that is maintained by primary forests' complex habitat structures. Secondary forests exhibited a mean species richness of 6.4 species per hectare with a standard deviation of 1.9, indicating decreased biodiversity in these disturbed ecosystems. Statistical significance: The t-test yielded a t-value of 8.451 and a p-value of less than 0.001, indicating a statistically significant difference in species richness between primary and secondary forests. This finding highlights the importance of primary forests in preserving bird biodiversity in comparison to secondary, more damaged forests.
Bird Density: Primary woods had a mean bird density of 23.7 birds per hectare, which was about double that of secondary forests (12.5 birds). This significant discrepancy highlights the importance of primary forests in providing adequate habitats for larger bird populations. Primary forests' deep canopy cover, towering trees, and rich plant structure provide for a more stable and resource-rich habitat, sustaining bigger and more diversified bird populations. The much-reduced bird density in secondary forests demonstrates the detrimental impact of habitat disturbance, such as logging and agricultural expansion, which restrict the availability of nesting places, food resources, and protective cover, resulting in bird population declines. Species Richness: Primary woods have much higher species richness (11.5 species/ha) than secondary forests (6.4 species/ha). This suggests that primary forests sustain not just more birds, but also a broader range of species. Primary forests have a complex habitat structure, with numerous layers of vegetation and a greater variety of fruit-bearing trees, which provides distinct niches and supplies for various bird species. Secondary forests, on the other hand, have a simpler structure and less vegetation density, therefore they provide fewer niches and resources, resulting in decreased species richness. The large fall in species richness in secondary forests reflects the loss of habitat complexity and the resulting decline in biodiversity. Statistical significance: The low p-values (< 0.001) for bird density and species richness show statistically significant differences between primary and secondary forests, excluding random fluctuation.

These findings give compelling evidence of the negative impact of habitat disturbance on bird populations and biodiversity. The strong t-values reinforce the robustness of these findings, emphasizing the vital necessity for conservation efforts to conserve and restore primary forest ecosystems in order to maintain bird biodiversity and abundance.

Table 7: ANOVA Results for Bird Density Across Different Habitats

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-Value	p-Value
Between Groups	2100.5	4	525.125	22.45	< 0.001
Within Groups	1860.3	80	23.254		
Total	3960.8	84			

Sum of Squares (SS): The entire variance in bird density is divided into two parts: variation between habitat types (SS between groups = 2100.5) and variation within habitat types. Degrees of Freedom (DF): Between-group variance has four degrees of freedom (number of habitat categories minus one), whereas within-group variation has eighty degrees of freedom (total number of observations minus number of groups). Mean Squared (MS): The mean square (MS between groups = 525.125) is computed by dividing the total of squares by the degrees of freedom. Similarly, the mean square (MS within groups = 23.254) is computed. F-Value: The F-value of 22.45 is calculated by dividing the mean square across groups and the mean square within groups. This high F-value implies a large difference in bird density between habitat categories. p-Value: A p-value less than 0.001 shows that the variations in bird density between habitat categories are statistically significant. This shows that habitat type has a large influence on bird density.
Between Groups variance: The large sum of squares (2100.5) suggests significant variance in bird density

across habitat categories. This variance is further underscored by the high mean square value (525.125) and F-value (22.45), which indicate that the discrepancies are not due to chance. Within-Group Variation: The sum of squares within groups (1860.3) represents the variation in bird density within each habitat type. The mean square value (23.254) is much lower than the between-groups mean square, indicating that bird abundance is more consistent within habitats than across habitats. Statistical Significance:

The p-value is less than 0.001, indicating that the observed variations in bird density across habitat categories are statistically significant. This suggests that habitat type is important in influencing bird density, as various habitats sustain different bird populations.

Variable	**Coefficient (β)**	**Standard Error (SE)**	**t-Value**	**p-Value**	**R^2**
Intercept	2.50	1.20	2.08	0.040	
Canopy Cover	0.45	0.08	5.63	< 0.001	0.67
Tree Height	0.35	0.10	3.50	0.001	

Table 8: Regression Analysis of Bird Density vs. Habitat Variables (Canopy Cover, Tree Height)
Intercept: The intercept (2.50) is the estimated bird density when both canopy cover and tree height are zero. While it cannot be directly interpreted biologically, it serves as a baseline for the regression equation. Canopy Cover: The coefficient for canopy cover (0.45) implies that for every 1% increase in canopy cover, bird density rises by 0.45 birds per hectare, while tree height remains constant. The high t-value (5.63) and low p-value (< 0.001) show that canopy cover is a strong predictor of bird density. Tree Height: The coefficient for tree height (0.35) indicates that for every 1-meter increase in tree height, bird density rises by 0.35 birds per hectare when canopy cover remains constant. The t-value (3.50) and p-value (0.001) indicate that tree height is a significant predictor of bird density. The model, which incorporates canopy cover and tree height as predictors, explains 67% of the variance in bird density (R^2=0.67). The high R^2 value indicates that these environmental characteristics are significant predictors of bird density.
Canopy Cover: The positive coefficient (0.45) for canopy cover emphasizes its importance in sustaining increased bird numbers. Dense canopy cover offers important resources such as refuge, breeding places, and predator protection, resulting in increased bird populations. The extremely significant p-value (< 0.001) highlights the impact of canopy cover on bird populations. Tree Height: The positive coefficient (0.35) for tree height implies that taller trees help to increase bird numbers. Taller trees have more complex structures and biomass, which provides birds with a variety of microhabitats and food options.
The substantial p-value (0.001) emphasizes the role of tree height in affecting bird density. The R^2 value of 0.67 indicates a robust model fit, implying that canopy cover and tree height account for a significant percentage of the variance in bird density. The strong R^2 value shows that habitat features are important predictors of bird populations in Papua.

Table 9: Correlation Matrix of Bird Population Metrics and Habitat Variables

Variable	**Bird Density**	**Species Richness**	**Canopy Cover**	**Tree Height**	**Vegetation Density**
Bird Density	1.00	0.78**	0.85**	0.76**	0.70**
Species Richness	0.78**	1.00	0.73**	0.69**	0.65**

Canopy Cover	0.85**	0.73**	1.00	0.80**	0.75**
Tree Height	0.76**	0.69**	0.80**	1.00	0.68**
Vegetation Density	0.70**	0.65**	0.75**	0.68**	1.00

Note: Correlation is significant at the 0.01 level (2-tailed).

Species Richness: Bird density and species richness have a correlation value of 0.78, showing a significant positive association. Higher bird numbers correlate with greater species diversity. Canopy Cover: A correlation value of 0.85 indicates a significant positive link, implying that locations with more canopy cover have greater bird numbers. Tree Height: The coefficient of 0.76 suggests a strong positive connection, implying that taller trees are connected with higher bird populations. Vegetation Density: The correlation value of 0.70 indicates a significant positive association, implying that denser vegetation supports larger bird numbers. Species Richness: Strongly positively linked with canopy cover (0.73), tree height (0.69), and vegetation density (0.65), implying that greater species variety is supported by improved habitat conditions. Canopy Cover: Strong positive relationships with tree height (0.80) and vegetation density (0.75) suggest that regions with high canopy cover have taller trees and denser vegetation. Tree height is positively connected with plant density (0.68), indicating that higher trees are often found in places with denser vegetation.

Table 10: ANCOVA Results for Bird Density with Habitat Type and Altitude as Covariates

Source	**Type III Sum of Squares (SS)**	**df**	**Mean Square (MS)**	**F-Value**	**p-Value**
Intercept	1025.8	1	1025.8	55.12	< 0.001
Habitat Type	1500.7	4	375.175	20.16	< 0.001
Altitude	300.2	1	300.2	16.12	< 0.001
Habitat Type * Altitude	75.6	4	18.9	1.01	0.403
Error	1450.3	77	18.835		
Total	4352.6	87			

The intercept sum of squares (SS) of 1025.8 and a significant p-value (< 0.001) show that the base level of bird density differs considerably from zero, even after correcting for habitat type and altitude. Habitat type significantly affects bird density, as evidenced by the sum of squares (1500.7), mean square (375.175), and p-value (< 0.001). This demonstrates how different habitat types sustain considerably diverse bird numbers. The sum of squares (300.2), mean square (300.2), and significant p-value (< 0.001) show that altitude has a substantial effect on bird density. This implies that bird density varies with height, possibly due to differences in habitat qualities and climatic conditions at various elevations. Habitat Type * Altitude Interaction: The interaction term (75.6) and the non-significant p-value (0.403) indicate that there is no significant interaction between habitat type and altitude. This suggests that the impact of habitat type on bird density is consistent throughout altitudes. Habitat type has a substantial influence on bird density ($p < 0.001$), supporting prior findings from ANOVA and regression studies. This highlights the importance of habitat quality in determining bird populations. Primary forests, with their thick canopy and lofty trees, have higher bird numbers than secondary and damaged forests. The considerable influence of altitude ($p < 0.001$) emphasizes the need to consider elevation when investigating bird populations. Altitude effects temperature, vegetation structure, and resource availability, all of which affect bird population. Higher elevations

may have distinct species mixes and lower overall populations due to harsher environmental conditions.

Interaction Effect: The non-significant interaction between habitat type and altitude ($p = 0.403$) indicates that habitat type's impact on bird population is constant throughout elevations. This suggests that, while habitat type and altitude have independent impacts on bird density, their combined effect is not significantly different from the sum of their individual effects.

Table 11: Summary of Acoustic Recordings

Habitat Type	**Total Recording Hours**	**Number of Calls Detected**	**Number of Species Identified**	**Dominant Species Detected**
Lowland Forest	200	1200	25	Paradisaeaapoda, Cicinnurus regius
Mid-Elevation Forest	180	1000	20	Paradisaea minor, Cicinnurusmagnificus
Highland Forest	160	800	18	Paradigallacarunculata, Astrapia nigra
Secondary Forest	150	600	15	Manucodiaater, Lophorina superba
Disturbed Area	120	300	10	Ptilorisparadiseus, Semiopterawallacii

Total Recording Hours: The number of hours of acoustic monitoring varied by habitat, with lowland forests recording the most (200 hours) and disturbed regions recording the fewest (120 hours). This was intended to reflect the predicted range in bird activity and habitat complexity. Lowland woodlands had the most cries detected (1200), suggesting considerable bird activity. This figure declines with increasing altitude and habitat degradation, with damaged regions recording the fewest sounds (300). Number of Species Identified: The number of species identified follows a similar pattern, with lowland forests having the most species variety (25 species) and disturbed regions having the fewest (10 species). This highlights the importance of primary forests in sustaining varied bird groups. dominating Species Detected: The dominating species in each habitat type differed, indicating different bird species' biological niches and habitat preferences. For example, Paradisaeaapoda and Cicinnurus regius were most commonly found in lowland woods, but Manucodiaater and Lophorina superba dominated secondary forests.

Bird Activity and Habitat Quality: The larger number of calls identified in lowland forests implies more bird activity, which may be linked to the better quality of habitat, which includes dense canopy cover, towering trees, and lush vegetation. This area offers plentiful supplies and ideal circumstances for a diverse range of bird species. Species diversity: The number of species discovered by acoustic monitoring corresponds with habitat quality. Primary forests, with their complex structure and abundant supplies, support a broader range of bird species. In contrast, disturbed regions with poor habitat quality sustain fewer species, emphasizing the impact of habitat degradation on biodiversity. dominating Species: The existence of dominating species in various environments indicates the birds' unique ecological requirements and adaptations. Species such as Paradisaeaapoda and Cicinnurus regius, which once dominated lowland forests, are noted for their reliance on high-quality environments with thick canopy and many fruit-bearing trees. Manucodiaater, a species that dominates secondary forests, is better adaptive to damaged settings. Temporal patterns: The spectrograms and heat maps show temporal patterns in bird activity, with peaks at dawn and sunset, as is common for many bird species. These patterns are stable throughout habitats, although the level of activity varies, with primary forests having more dramatic peaks than disturbed regions.

Table 12: Summary of Behavioral Observations by Habitat Type

Habitat Type	Courtship Displays (observations)	Feeding Habits (observations)	Nesting Behavior (observations)	Other Behaviors (observations)
Lowland Forest	50	120	30	20
Mid-Elevation Forest	35	90	25	15
Highland Forest	25	70	20	10
Secondary Forest	15	50	15	5
Disturbed Area	10	30	10	3

Courtship Displays:

Lowland Forest: 50 courting displays were seen, the largest number among all habitat categories, showing that these settings are suitable for mating. The lush greenery and variety of resources are believed to create excellent circumstances for complex courting rituals. Disturbed Area: Only ten courting displays were seen, indicating poor habitat quality and fewer possibilities for mating activity in disturbed habitats.

Feeding Habits:

Lowland Forest: 120 feeding observations were recorded, indicating a plentiful supply of food. Birds were regularly spotted eating fruits, insects, and tiny animals. Disturbed Area: Only 30 feeding observations were recorded, indicating low food resources and potentially increased competition for available food.

Nesting Behaviour:

Lowland Forest: We observed 30 occurrences of nesting activity, indicating that birds locate acceptable nesting locations in these settings. Nesting locations were usually located in lofty trees with thick foliage. Disturbed Area: Only ten nesting behaviors were observed, emphasizing the scarcity of appropriate nesting places owing to habitat deterioration.

Other Behaviours:

Lowland Forest: Observed 20 activities, including territorial contests, grooming, and relaxing. These actions indicate a stable and safe environment. Disturbed Area: Only three additional behaviors were seen, indicating lesser activity and probably greater stress levels in these environments.

courting Displays: The abundance of courting displays in lowland forests suggests that these environments provide optimal circumstances for successful mating. The presence of huge, mature trees and lush vegetation certainly provides abundant opportunity for birds to execute and witness courting rituals, which are critical for mating success. In contrast, damaged regions lack these key supplies, resulting in far fewer courting displays. This decline in mating activities in damaged environments may result in poorer reproductive success and falling bird numbers over time. Feeding Habits: The much larger number of feeding observations in lowland forests demonstrates the ecosystems' ability to provide diverse and abundant food supplies. Birds were regularly seen feasting on a variety of fruits, insects, and tiny animals that are abundant in these pristine habitats. In contrast, disturbed regions had significantly

fewer feeding observations, indicating lower food supply and probably increased competition for scarce resources. The shortage of food in damaged environments can have a severe influence on avian health and survival. Nesting Behavior: The larger frequency of nesting behaviors found in lowland forests suggests that these environments provide excellent nesting places, such as towering trees and dense foliage, which protect birds from predators and environmental conditions. In contrast, disturbed regions had fewer nesting sightings, most likely due to a shortage of suitable nesting locations induced by deforestation and habitat degradation. Secure nesting locations are critical for breeding success and chick survival. Other Behaviours: Territorial conflicts, grooming, and relaxing were more common in lowland woods. These actions point to a stable and safe environment in which birds can pursue non-essential activities. The paucity of such actions in disturbed regions suggests a stressful situation in which birds may be more focused on survival tasks such as looking for food and avoiding predators than on social or maintenance behaviours.

Addressing the Research Questions

This study sought to answer numerous critical scientific concerns about the habitat and population of the Cenderawasih bird in Papua, Indonesia. Specifically, the study aimed to (1) assess the quality of various habitat types, (2) evaluate the population density and species richness of Cenderawasih birds across these habitats, (3) examine the impact of habitat variables on bird density, and (4) observe and document notable bird behaviors in relation to habitat conditions. The findings provide light on these concerns and make major contributions to our understanding and protection of the Cenderawasih bird.

Habitat Quality Assessment

The assessment of habitat quality indicated considerable differences between habitat categories. Lowland forests had the largest canopy cover, tallest trees, and the most fruit-bearing trees, suggesting good habitat quality (Rimbakita, 2021; West Papua Diary, 2023). These findings are consistent with prior research that has demonstrated the importance of dense, mature forests in maintaining varied and plentiful animal populations (Beehler et al., 1986; Frith & Beehler, 1998). The results revealed that primary forests had a mean canopy cover of 75.3%, tree height of 20.5 meters, and 15.3 fruit-bearing trees per hectare, all of which were much greater than secondary and disturbed forests. Secondary forests and disturbed regions, which had reduced canopy cover and fewer fruit-bearing trees, showed the harmful effects of habitat degradation (Guariguata& Ostertag, 2001; Parrotta, 1993). These results underscore the critical role of primary forests in maintaining habitat quality essential for the Cenderawasih bird's survival.

Bird Population Density and Species Richness

The assessment of habitat quality indicated considerable differences between habitat categories. Lowland forests had the largest canopy cover, tallest trees, and the most fruit-bearing trees, suggesting good habitat quality (Singh et al., 2018; Negi, 2022). These findings are consistent with prior research that has demonstrated the importance of dense, mature forests in maintaining varied and plentiful animal populations (Demarais et al., 2017; Beguin et al., 2016). The results revealed that primary forests had a mean canopy cover of 75.3%, tree height of 20.5 meters, and 15.3 fruit-bearing trees per hectare, all of which were much greater than secondary and disturbed forests. Secondary forests and disturbed regions, which had reduced canopy cover and fewer fruit-bearing trees, showed the harmful effects of habitat degradation (Zapanta et al., 2019). These results are in line with studies by Beehler et al. (1986) and Frith & Beehler (1998), which emphasize the importance of habitat structure in supporting avian diversity.

Impact of Habitat Variables on Bird Density

The regression analysis showed that canopy cover and tree height were significant predictors of bird density. Higher canopy cover ($\beta = 0.45$, $p < 0.001$) and tree height ($\beta = 0.35$, $p = 0.001$) correlate with higher bird numbers, according to the coefficients. The strong R^2 value (0.67) indicates that these environmental characteristics account for a significant amount of the variation in bird density (Field, 2013). The ANCOVA results indicated that habitat type and altitude have substantial influence on bird population. Bird numbers vary depending on habitat type and altitude ($p < 0.001$). This finding is supported by the work of Beehler et al. (1986), who noted similar variations in bird populations across different habitat types and elevations in Papua New Guinea. The non-significant interaction between habitat type and altitude ($p = 0.403$) indicates that the effect of habitat type on bird density is similar across elevations. This suggests

that, while height influences bird numbers, the relative differences across habitat types are consistent throughout altitudes. This constancy emphasizes the critical role of habitat quality, independent of height (Frith & Beehler, 1998).

Behavioural Observations

The behavioral observations made during the study offered vital information on the Cenderawasih bird's daily activities and ecological demands. Courtship displays, eating habits, and nesting activities were more commonly recorded in lowland forests, indicating that these settings are most suited to maintaining the birds' normal behaviors (Moermond & Denslow, 1985). Courtship Displays: These displays, which have been observed most often in lowland forests (50observations), are critical for mating success and reflect healthy, undisturbed settings. The reduced frequency of courting behaviours in disturbed regions (10 observations) demonstrates the negative impact of habitat degradation on reproductive activities (Setsaas et al., 2018; Tablado& Jenni, 2017). Feeding Habits: The large number of feeding observations in lowland forests (120observations) demonstrates the richness of food supplies in these ecosystems. Birds were regularly spotted feasting on fruits and insects, which are necessary for their nourishment and survival. Disturbed regions had considerably fewer feeding observations (30observations), indicating restricted food supply and increased competition for resources (Manlick & Pauli, 2020). Nesting Behaviour: Thirty nesting observations demonstrated the availability of appropriate nesting locations in lowland woods. These habitats provide the structures required for safe and secure nesting. In contrast, disturbed regions with just 10 nesting observations lack the necessary nesting circumstances, which might contribute to lower reproductive success (Zhao, et al., 2020; Harmon-Threatt, 2020).

Contribution to Conservation

This study's findings have a substantial impact on the conservation of the Cenderawasih bird by giving extensive insights into habitat quality, population dynamics, and behavioral ecology. The study's complete assessment of habitat characteristics and their influence on bird populations emphasizes the vital need of sustaining primary forests for avian biodiversity (Lindenmayer & Franklin, 2013; Bregman et al., 2014). The substantial positive relationships between bird abundance and environmental factors such as canopy cover and tree height underline the importance of conservation measures aimed at maintaining and restoring these critical habitat elements (Marzluff& Ewing, 2008; Bennet et al., 2009). By defining the Cenderawasih bird's particular habitat requirements, the study provides a scientific foundation for focused conservation efforts to reduce habitat degradation and promote habitat restoration (Gregory et al., 2020).

Furthermore, behavioral observations provide vital information about the Cenderawasih bird's ecological requirements and daily activities. Understanding these behaviors can help to shape conservation strategies that promote the birds' normal habits, such as mating and eating, increasing their chances of survival and reproduction (Stutchbury& Morton, 2022; Tobias & Pigot, 2019). The study's findings also highlight the value of community engagement in conservation initiatives. Conservation projects that involve local people in habitat protection and restoration can yield more lasting and effective results. The effectiveness of community-based initiatives, as described by Jones & Murphree (2013), demonstrates the possibility of collaborative conservation efforts to maintain the Cenderawasih bird and its habitat.

CONCLUSION

This research provides a thorough examination of the habitat quality, population dynamics, and behavioral ecology of the Cenderawasih bird in Papua, Indonesia. The findings show that primary forests, with their high canopy cover, tall trees, and thick vegetation, are critical for sustaining high bird numbers and species richness. In contrast, disturbed regions have much lower bird numbers and biodiversity, demonstrating the negative impact of habitat loss. The Cenderawasih bird's long-term existence depends on the preservation and restoration of primary forests. Conservation initiatives should prioritize the maintenance of critical habitat elements like canopy cover and tree height, which are important predictors of bird density. Furthermore, efforts should be undertaken to reduce habitat degradation by limiting deforestation and encouraging sustainable land use practices. Community engagement is critical to the success of these conservation projects. Engaging local people in habitat preservation and restoration operations can improve the efficacy and sustainability of conservation

efforts. Educational programs and alternative livelihood options can help alleviate the strain on natural resources and raise conservation consciousness.

Furthermore, continual monitoring of bird populations and environmental conditions is required to evaluate the efficacy of conservation efforts and adjust policies as needed. Advanced approaches, such as acoustic monitoring, can give useful information on bird activity and species variety, allowing for continual evaluation of habitat condition. This study emphasizes the important role of primary forests in the conservation of the Cenderawasih bird. By implementing focused conservation methods and engaging local communities, we can assure the survival of this iconic species and its unique environment in Papua. The findings establish a solid scientific foundation for implementing successful conservation policies and practices that benefit both the Cenderawasih bird and the larger environment.

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