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Bird Community in Six Successional Stages of Habitats in Manokwari, Papua

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Abstract

Succession after disturbance can affect the response of the bird community at each stage of habitat succession. Research on the impact of succession on birds has never been done in Papua, so this research is needed to understand how birds can survive habitat changes. This study aimed to analyze bird communities and their responses to successional stages of habitats, i.e., shrubs, agriculture, mixed plantation forest, young secondary forest, old secondary forest, and primary forest. Data collection was done from January 2023 to October 2023. Bird data (species and numbers) were collected using the point count method. Vegetation data (species and density) were collected by using the plot method, and abiotic data (air temperature, humidity, and light intensity) were collected using a dry-wet thermometer and a lux meter. The Shannon-Wiener diversity indices (H') were calculated for birds and trees. Correlation of the bird data against habitat and abiotic parameters was calculated. There were 11,272 birds from 55 species belonging to 25 families in the study area. The young secondary forest had the highest bird number and diversity (44 species; H' = 3,424), in line with the Intermediate Disturbance Hypothesis. Bird communities generally have a strong correlation with vegetation but a weak correlation with abiotic data. In light of conservation importance, young secondary forest held the highest bird species richness, while the primary forest provided habitat for some species that are highly dependent on natural forests.

Keywords: bird community, succession stages, habitat, environmental parameters, Manokwari Papua

1. Introduction

Disturbances that occur in a habitat impact all organisms living in that habitat. Disturbances can occur to the wildlife, habitats, or abiotic environments, such as temperature and humidity, that affect wildlife [1]. Human-caused landscape changes, such as habitat loss, fragmentation, and degradation, put pressure on wildlife populations [2]. Environmental variations often change avifauna diversity and species composition [3]. Depending on the biological features unique to a species and the variations in the modified landscape, birds react differently to different changes. Birds are an excellent indicator for determining a habitat's environmental and biodiversity conditions [4].

Changes in each habitat type resulting from human activities significantly impact community diversity, bird groups, and distribution. Widespread forest degradation and conversion lead to a decrease in the richness and abundance of bird species and can lead to local extinctions [5–7]. Intermediate Disturbance Hypothesis (IDH) theory reveals that species diversity in an ecosystem or landscape will reach its maximum in medium-scale disturbances [8]. The IDH showed a tendency for the highest number of species to be found in locations with moderate levels of disturbance [9,10]. This hypothesis is still being studied in many urban and non-urban locations.

This study examines six stages of forest habitat succession in Manokwari Regency, including mixed shrubs, agriculture, mixed plantation forests, young secondary forests, old secondary forests, and primary forests. The selection of these six habitat types is because the location of this study is in the suburbs, where accessibility is easily affordable, and the development of the area impacts the conversion of forest functions into agricultural and residential areas. Habitat changes or disturbances (fragmentation) can result in the replacement or erosion of existing functional features in the community, thereby causing changes in community function [11–13].

Research on bird communities in primary and secondary habitat types still needs to be completed, and most of it has been done in the western and central parts of Indonesia. In the eastern part of Indonesia, particularly in Papua, research on bird communities associated with vegetation succession has not been done. This study aims to examine changes in bird communities along the six stages of forest succession and determine what environmental factors at each stage of habitat succession affect the presence of bird communities. These environmental factors include the microclimate (air temperature, humidity, sunlight intensity) and vegetation density calculations. Knowing the abiotic and biotic environmental factors at each succession stage can affect habitat conservation actions. In addition, we also tested the Intermediate Disturbance Hypothesis.

2. Materials and Methods

2.1. Study area

This study was conducted in the lowland area of north and east Manokwari (00°43’51.1”-00°51’03.5” S and 133°54’55.5”-134° 05’06.6” E) in Papua (Figure 1), particularly in Mandopi Rimom Village, Arboretum (Anggori Village), and Gunung Meja Forest Park at the elevation of 10 to 227 MASL. The study was conducted in six habitat types namely mixed shrubs, crops, mixed plantation forests, young secondary forests, old secondary forests, and primary forests. There are four types of habitats in Mandopi Rimom Village, namely agricultural habitats that are 200 m away from residential areas, mixed shrub habitats that are 500 m away from agriculture habitats, young secondary forest habitats that are 100 m away from mixed shrub habitats, and primary forest habitats that are 100 m away from young secondary forests. In addition, the habitat of the mixed plantation forest 500 m away from the residential area (Anggori Village) is a forest collection forest of forestry plantations, and the old secondary forest is the conservation area of the Gunung Meja forest park on the edge of the area, where residential settlements surround the area. However, there is habitat connectivity with mixed plantation forests. The selection of these habitat types was assumed to represent the degree of forest succession, with agricultural crop and mixed shrub habitat representing the earlier successional stage, mixed plantation forest and young secondary forest representing the intermediate successional stage, and the latest successional stage represented by the old secondary forest and primary forest.

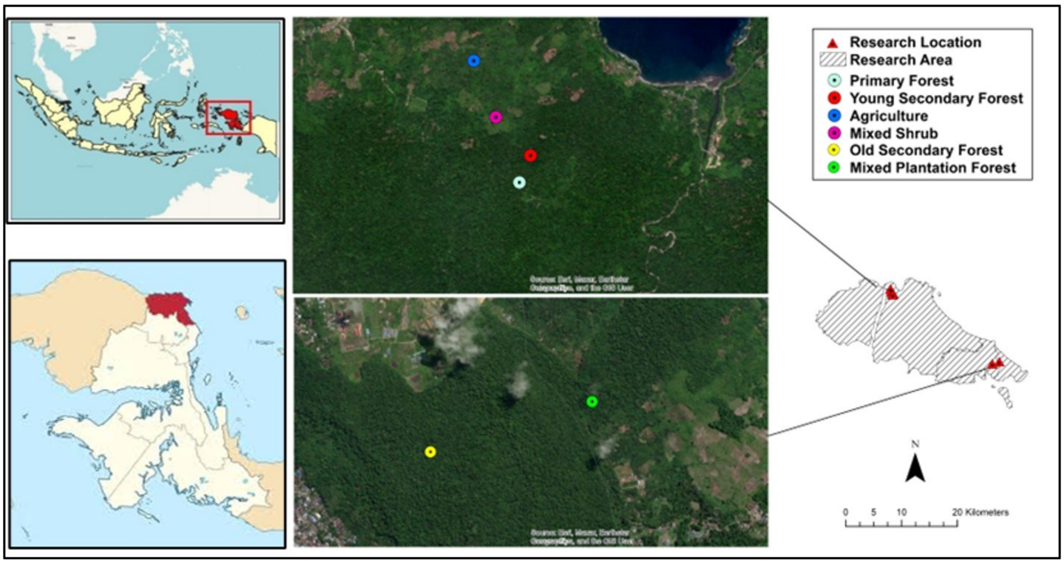

Figure 1. Map of the study area in Manokwari Regency, West Papua Province.

2.2. Survey and Data Collection

The study was conducted from January 2023 to October 2023. Bird observation was carried out for five days in each habitat type. Bird data were collected using point counts [14]. The survey was conducted mainly in the morning (6-9 a.m.) and afternoon (3-6 p.m.) in clear weather conditions. A ten-minute observation period at each point was conducted, and all birds seen or heard within a radius of 25 m were recorded. To minimize double-counting, a distance of 100 m between points was applied. The total points within a habitat type were 30 points, making a total of 180 points during this study. A binocular and bird field guide [15] was used to assist in bird identification.

Vegetation data collection was done by a combination of transects and plots. The plots were used for quantifying trees (20×20 m), poles (10×10 m), saplings (5×5 m), and seedlings (2×2 m). There were 25 plots for each habitat, totalling 150 plots for all vegetation stages. The data collected includes species names and numbers.

Leaf Area Index (LAI) for each habitat type was collected from five plots (20×20 m) using the same tree plots. The shooting was done 1.5 m above ground level by standing up and holding the camera. Shooting time in the morning or evening to avoid shadows in the photo due to the glare of the sun's rays.

Microclimate data collection included air temperature, humidity, and light intensity. Microclimate measurements at each observation location were carried out three times with an interval of one hour (i.e., 6 to 7 a.m., 12 to 1 p.m., and 4 to 5 p.m.). Air temperature and humidity measurements were carried out using dry-wet thermometers, while light intensity was measured using a digital lux meter.

2.3. Data Analysis

Birds were identified based on a field guide [15]. The bird abundance was expressed by the number of individuals per ten hours. The Shannon-Wiener diversity index was used to measure bird and vegetation diversity [16] in each habitat, while the bird species richness was expressed by the Margalef Index [16]. Bird community similarity was calculated by using the Bray-Curtis index. All calculations were done using PAST software version 4.0. LAI was estimated by using a photograph of a tree canopy with the camera equipped with a fisheye lens, followed by analysis by HemiView 2.1 software.

Microclimate data was analyzed by calculating the average temperature and humidity data, while the light intensity was interpreted as the highest value. The daily average air temperature (Temp) is obtained using the formula [17]:

$$Temperature = \frac{2 \times morning\ temp + daylight\ temp + afternoon\ temp}{4}$$

The air temperature index was categorised as very cold (< 21 °C), cold (21 °C ≤ temperature < -23 °C), somewhat cold (23 °C≤ temperature < 25 °C), cool (25 °C≤ temperature < 27 °C), somewhat hot (27 °C≤ temperature < 29 °C), hot (27°C≤ temperature < 29°C), and very hot (> 31 °C). Humidity was obtained from the measurements of the dry-wet ball thermometer (i.e., the difference between dry and wet bulb). The relative humidity (RH) values were determined based on the humidity table. The presence of birds at each succession stage in six habitat types was analyzed by descriptively considering the microclimate and the value of vegetation diversity. The relationship between environmental variables and bird communities was analysed using the Pearson correlation to have a confidence level of 95%. Pearson correlation coefficient assesses the intensity and orientation of the connection between a pair of variables having an interval of (-1≤ r ≤1) (**Table 1**) [18].

Table 1. Criteria correlation.

Interval correlation	Interpretation
0.0 ≤ r < 0.1	No correlation
0.10 ≤ r < 0.25	Very weak correlation
0.25 ≤ r< 0.5	Sufficient correlation
0.50 ≤ r < 0.75	Strong correlation
0.75 ≤ r < 0.99	Very strong correlation
1	Perfect correlation

3. Results

3.1. Bird Diversity in Six Succession Stages of Habitat

A total of 11,272 individuals from 55 species and 25 families were recorded during field research (Table 2) with total of observation time is 150 hours. The species found in the study area, the rufous owl and papuan frogmouth were the uncommon species. Our study showed that the highest species number was found in the forests in the intermediate succession stages (i.e., young secondary forest and old secondary forest). Further analysis of bird species diversity showed differences in six succession stages of habitat types.

The species richness index (D_{Mg}) reached its highest in the young secondary forests and the lowest in agricultural and mixed shrub habitats. Under the same conditions, the diversity of the Shannon-Wiener index (H') was highest in young secondary forests, followed by primary forests. In contrast, in old secondary forest habitats, mixed plantation forests, agricultural habitats, and mixed shrub habitats, the diversity values were moderate (Table 2). The high value of the species number and species richness index in the secondary forest (Figure 2) was in line with the Intermediate Disturbance Hypothesis, where species diversity in an ecosystem or landscape will reach its maximum in medium-scale disturbance.

Table 2. List of bird species and the relative abundance of birds (number of individuals/10 hours) in the study area.

No	Common name	Specific name	Early Succession		Intermediate Succession		Late Succession		Total	Value RA*
			Mixed Shrub	Agr	MPF	YSF	OSF	PF		
1	Dwarf Cassowary	*Casuarius bennetti*	0	0	0	0	0	12	12	0.8
2	Pacific Baza	*Aviceda subcristata*	0	6	0	11	0	0	17	1.1
3	Brahminy Kite	*Haliastus indus*	0	6	10	12	10	18	56	3.7
4	Grey-headed Goshawk	*Acippiter poliocephalus*	0	6	0	26	0	0	32	2.1
5	New Guinea Harpy-Eagle	*Harpyopsis novaeguineae*	0	0	0	17	0	17	34	2.3
6	Red-legged Brushturkey	*Talegalla jobiensis*	0	0	0	16	0	18	34	2.3
7	Yellow-bibbed Fruit-Dove	*Ptilinopus solomonensis*	0	0	13	80	23	34	150	10.0
8	Claret-breasted Fruit-dove	*Ptilinopus viridis*	0	0	85	151	139	60	435	29.0
9	Purple-tailed Imperial Pigeon	*Ducula rufigaster*	0	0	0	0	11	15	26	1.7
10	Pinon's Imperial Pigeon	*Ducula pinon*	0	0	25	45	76	34	180	12.0
11	Zoe's Imperial Pigeon	*Ducula zoeae*	0	0	13	15	10	11	49	3.3
12	Amboina Cuckoo-dove	*Macropygia amboinensis*	0	0	0	0	48	0	48	3.2
13	Black-billed Cuckoo-dove	*Macropygia nigrirostris*	0	0	0	27	0	0	27	1.8
14	Stephan's Dove	*Chalcophaps stephani*	39	20	13	49	0	20	141	9.4
15	Rainbow Lorikeet	*Trichogloss haematodus*	0	0	36	85	155	59	335	22.3
16	Western Black-capped lory	*Lorius lory*	0	0	28	52	50	23	153	10.2
17	Large Fig-parrot	*Psittaculirostris desmarestii*	0	0	34	64	0	0	98	6.5
18	Double-eyed Fig-parrot	*Cyclopsitta diophthalma*	0	0	39	65	10	33	147	9.8
19	Yellow-capped Pygmy-parrot	*Micropsitta keiensis*	0	0	0	0	20	0	20	1.3
20	Buffy- faced Pygmy-parrot	*Micropsitta pusio*	0	0	8	20	15	23	66	4.4
21	Eclectus Parrot	*Eclectus roratus*	0	7	13	49	30	18	117	7.8
22	Sulphur-crested Cockatoo	*Cacatua galerita*	0	0	0	30	0	15	45	3.0
23	Brush Cuckoo	*Cacomantis variolosus*	0	0	0	0	13	0	13	0.9
24	Greater Black Coucal	*Centropus menbeki*	0	0	28	0	24	0	52	3.5
25	Rufous Owl	*Ninox rufa*	0	0	0	0	3	0	3	0.2

No	Common name	Specific name	Early Succession		Intermediate Succession		Late Succession		Total	Value RA*
			Mixed Shrub	Agr	MPF	YSF	OSF	PF		
26	Papuan Frogmouth	*Podargus papuensis*	0	0	0	0	8	0	8	0.5
27	Shovel-billed Kingfisher	*Clytoceyx rex*	0	0	0	0	10	0	10	0.7
28	Collared Kingfisher	*Todiramphus chloris*	10	10	7	18	11	13	69	4.6
29	Sacred Kingfisher	*Todiramphus sanctus*	0	0	0	28	0	0	28	1.9
30	Common Paradise Kingfisher	*Tanysiptera galatea*	0	0	0	15	0	0	15	1.0
31	Papua Hornbill	*Rhyticeros placatus*	0	25	10	170	8	90	303	20.2
32	Hooded Pitta	*Pitta sordida*	0	0	0	19	0	0	19	1.3
33	Barn Swallow	*Hirundo rustica*	0	9	0	12	0	0	21	1.4
34	White-bellied Cuckooshrike	*Coracina papuensis*	0	0	0	51	21	0	72	4.8
35	Grey-headed Cicadabird	*Edolisoma schisticeps*	45	20	0	58	0	23	146	9.7
36	Black Cicadabird	*Edolisoma melas*	0	0	0	35	0	0	35	2.3
37	Emperor Fairywren	*Malurus cyanocephalus*	35	0	0	53	0	0	88	5.9
38	Frilled Monarch	*Arses telescopthalmus*	15	0	0	24	11	0	50	3.3
39	Northern Fantail	*Rhipidura rufiventris*	23	0	0	59	29	33	144	9.6
40	Sooty Fantail	*Rhipidura threnothorax*	20	0	18	21	23	0	82	5.5
41	Black Sunbird	*Leptocoma aspasia*	85	185	164	244	77	171	926	61.7
42	Olive-backed Sunbird	*Cinnyris jugularis*	219	201	233	296	227	187	1363	90.9
43	Black Myzomela	*Myzomela nigrita*	0	0	0	0	296	0	296	19.7
44	White-eared Meliphaga	*Meliphaga montana*	212	138	122	176	217	0	865	57.7
45	Mountain Meliphaga	*Meliphaga orientalis*	181	155	0	180	0	126	642	42.8
46	Scrub Meliphaga	*Meliphaga albonotata*	208	120	0	170	0	142	640	42.7
47	Helmeted Friarbird	*Philemon buceroides*	0	73	132	168	232	120	725	48.3
48	Yellow-faced Myna	*Mino dumontii*	0	0	29	53	41	30	153	10.2
49	Brown Oriole	*Oriolus szalayi*	0	22	73	122	154	0	371	24.7
50	Northern Variable Pitohui	*Pitohui kirhocephalus*	36	23	0	68	0	38	165	11.0
51	Hooded Pitohui	*Pitohui dichrous*	62	43	0	162	0	50	317	21.1
52	Spangled Drongo	*Dicrurus bracteatus*	0	31	180	185	178	155	729	48.6
53	Hooded Butcherbird	*Cracticus cassicus*	0	0	21	70	52	0	143	9.5
54	Black Butcherbird	*Cracticus quoyi*	0	0	128	130	183	93	534	35.6
55	Magnificent Riflebird	*Ptiloris magnificus*	0	0	0	0	0	23	23	1.5
Total Individuals			1190	1100	1462	3401	2415	1704	11272	
Number of species			14	19	25	44	34	31	55	
Species richness (D_{Mg})			1.84	1.29	3.29	5.29	4.24	4.03		
Shannon-Wiener Index (H’)			2.238	2.386	2.728	3.424	2.947	3.057		

Notes: Agr: Agricultural, MPF: Mixed plantation forest, YSF: Young secondary forest, OSF: Old secondary forest, PF: Primary forests; *RA: Relative abundance category: < 0.1 Rare, 0.1-2.0 Uncommon, 2.1 – 10 Frequent, 10.1- 40.0 Common, > 40 Abundant.

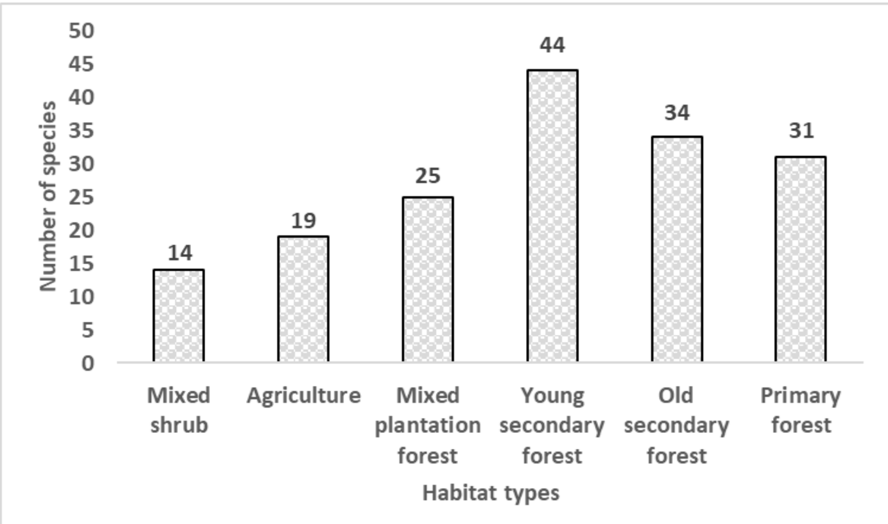

Figure 2. Trend of species number in the study areas, which in conformity with the IDH.

The succession process dramatically influences the presence of bird species, as illustrated in Figure 3. It showed that the distribution of birds at each succession stage varied. Some birds were able to inhabit all habitat types, including members of meliphaga and nectar feeders such as olive-backed sunbird. In contrast, two species occurred in only one habitat type, namely dwarf cassowary and magnificent riflebird in the primary forest.

Raptors can commonly be found in the open areas, e.g., the Pacific Baza, which can be easily spotted in agricultural areas and the young secondary forest. Parrots inhabited mostly areas having dense trees, including young and old secondary forest. However, some parrots, for example eclectus parrot, were also recorded in agricultural habitats, although they also flourished in the mixed plantations, young secondary, old secondary, and primary forests.

Figure 3. An illustration of bird distribution in six successional stages of habitat found in the study areas (common and abundant only). Adapted from the image of the stages of forest succession, by Smith (1990) [19], by entering our research data.

The similarity of bird communities, based on the Bray-Curtis index (Figure 4), resulted in two community groups. The first group consisted of non-forest areas (agriculture and mixed shrubs), with a similarity of 71.12%. The second group comprised forested habitats (mixed plantation forest, young secondary forest, old secondary forest, and primary forest), with a similarity of 63.05%.

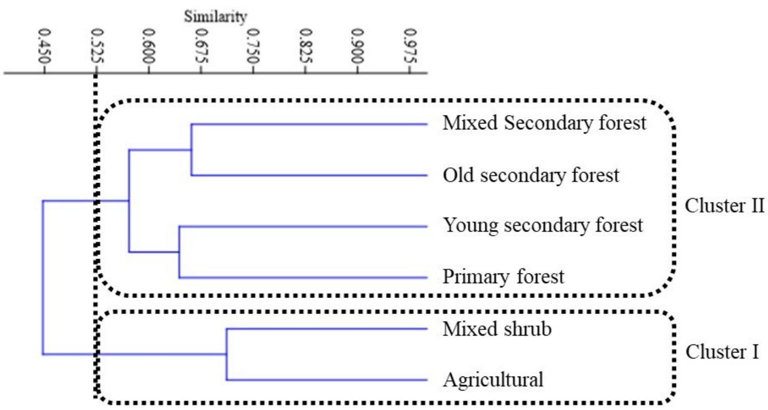

Figure 4. Dendrogram of bird community similarity in six habitat types.

3.2. Vegetation Composition and Leaf Area Index

The primary forest habitat recorded the highest number of vegetation and species diversity (i.e., Shannon-Wiener Index) (Table 3). However, LAI reached its highest in the young secondary forest. Thus, in the study area, unlike the bird community, the trend of plant species along the successional gradient was not in line with the Intermediate Disturbance Hypothesis.

Table 3. Vegetation composition and Leaf Area Index (LAI) in the study area; LAI for mixed shrub and agriculture was not measured due to the scarcity of the tree stages.

Habitat Type	Tree Density (individuals/ha)	Height (m)	Shannon-Wiener Index (H')	Leaf Area Index (%)
Mixed shrub	67	7-20	2.054	-
Agriculture	16	5-15	1.251	-
Mixed plantation forest	245	8-30	2.940	1.050
Young secondary forest	202	10-35	3.445	1.407
Old secondary forest	241	9-37	3.277	0.948
Primary forest	259	6-38	3.506	1.203

3.3. Microclimate

Temperature, humidity, and light intensity at each succession stage varied considerably (Figure 5). Primary forests tend to have stable air temperatures, air humidity, and light intensity, while in mixed shrub habitats, mixed plantation forests, young secondary forests, and old secondary forests tend to be unstable. Overall, the average air temperature and air humidity ranged from 26.2°C to 27.7°C and 75%-86%, respectively. The average daily light intensity ranged from 358.4 Lux to 1452.9 Lux.

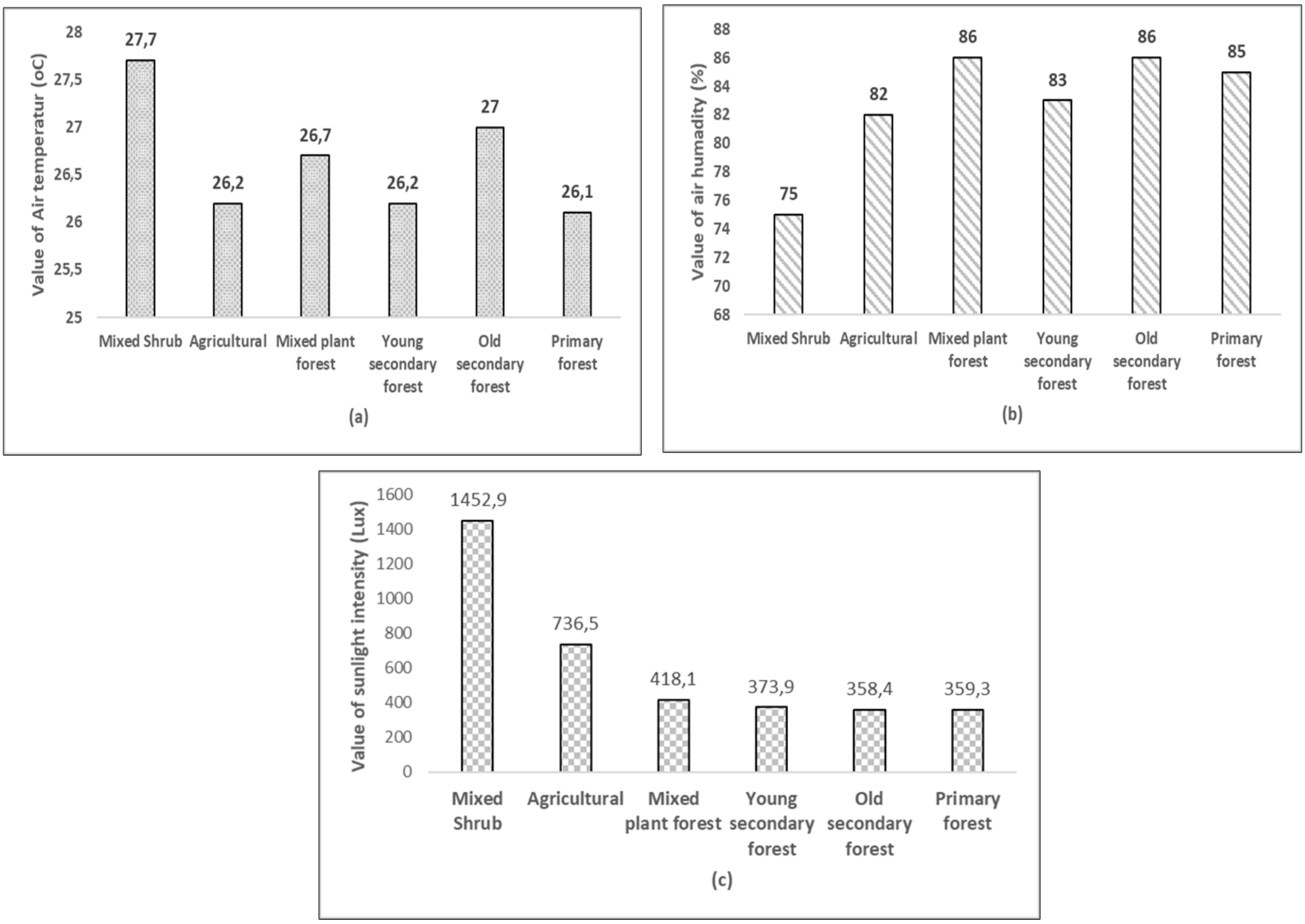

Figure 5. Average values of (a) air temperature, (b) humidity, (c) light intensity in the study area.

3.4. Correlation of Birds and Habitat Parameters

Pearson correlation analysis showed that some habitat and environmental parameters were strongly correlated with bird community parameters (Table 4). All habitat parameters have a strong correlation with the bird community, except the vegetation’s number of individuals. Meanwhile, microclimate (air temperature, air humidity, and sunlight intensity) did not have a strong correlation effect on bird communities.

Table 4. Results of Pearson correlation between environmental parameters and bird community parameters in the study area.

Habitat and Environmental Parameters	Bird Community Parameters			
	S	N	H’	D_{MG}
Number of species (S) - vegetation	0.769	0.578	**0.875***	**0.842***
Number of individuals (N) - vegetation	0.199	0.014	0.127	-0.046
Tree density	0.682	0.504	0.742	**0.829***
Vegetation stratification	**0.910***	0.773	**0.927****	**0.951****
Diversity index (H') – vegetation	0.801	0.695	**0.854***	**0.939****
Richness index (D_{MG})	0.756	0.591	**0.843***	**0.888***
Air temperature (°C)	-0.285	-0.339	-0.406	-0.512
Air humidity (%)	0.456	0.377	0.502	0.689
Sunlight Intensity (Lux)	-0.633	-0.581	-0.684	-0.838

Note: **level of significance 0.01; *level of significance 0.05, S: Number species, N: Number individuals, H’: Shannon-Wiener index, D_{MG}: Richness index.

4. Discussion

This research showed that young secondary forests, which represented the intermediate successional stages, had the highest species richness and species diversity. This showed that forest disturbance and the succession process also affect the existence of birds over time. This is in line with the statement that rapid changes in the composition of bird species at each succession stage indicate the direction of species change towards intermediate succession, namely mixed plantation forests and young secondary forests, and late succession [20]. Because at the early succession stage, the number of species and individual birds is still low, but with the progress of the succession stage, it forms a habitat that special species can inhabit. Species tolerate use the edge or stage of young forests, and forest specialists gradually use it in later stages of forest succession [21].

Index of similarity Bray-Curtis index, in mixed shrub and agricultural shows more remarkable similarities; this similarity occurs in similar environmental conditions so that the bird species that inhabit these two habitats are relatively similar. In contrast to forested habitats, even though they are forested, the composition of the constituent vegetation is different; the habitat of young secondary forests is similar to primary forests; it is clear that these two types of habitats are more as source areas for foraging and resting for birds in mixed shrubs, agricultural, mixed plantation forests and old secondary forests. The similarity of bird communities is influenced by vegetation structure as a result of habitat changes [22].

The IDH has been proven in Indonesia's western and central regions [9,10]. This study also proves a trend in the number of species in the succession stage (Figure 3). The high species richness in young secondary forests aligns with the IDH [8]. Reveals that species diversity in an ecosystem or landscape will reach a maximum in medium-scale disturbances. So, disruptions do not always have dire consequences for ecosystems, landscapes, or animals [1].

Environmental parameters along the succession (see Table 3) were found to be strongly related to the bird community. Based on the tree density and leaf area index, forested areas have a tight canopy cover supporting bird communities. This is following a previous study [22] that a more diverse vegetation structure will provide more opportunities for bird species specializing in particular vegetation layers or compositions.

Based on the temperature index criteria [23] The study areas fall into a cold to slightly hot climate (26.2 °C to 27.7 °C). Although the microclimate conditions in some habitat types were unstable (i.e., mixed shrub habitats, mixed plantation forests, young secondary forests, and old secondary forests), the overall microclimate conditions in all six successional stages were still tolerable for bird communities. The microclimate in late succession lands has a better microclimate than that of younger succession lands, with a decrease in temperature, an increase in humidity, and a decrease in light intensity each year [24]. Although tropical birds are systematically more vulnerable to climate warming, they may not be more susceptible to climate warming than temperate birds [25].

Based on the distribution of birds at each succession stage (Figure 3), it seemed that bird communities were able to adapt to the habitat changes. Some birds can be categorized as generalists, while others could be more specialists. The generalist types are usually bird species that can adapt to environmental changes, while specialist birds are species susceptible to ecological changes [21–25]. In the study area, some of the generalist species that were commonly found at various many successional stages were the olive-backed sunbird, black sunbird, white-eared meliphaga, scrub meliphaga, mountain meliphaga, spangled drongo and helmeted friarbird. In contrast, some specialist species, such as the dwarf cassowary and the magnificent riflebird, were found in only one habitat, the final succession stage of primary forest habitats. It is essential to monitor these later two species to prevent their potential extinction.

Other similar study [26] revealed that more diverse vegetation structures will provide more significant opportunities for bird species specializing in specific vegetation layers or compositions. Each bird can survive with a level of adaptability, sensitivity and tolerance [27]. Some bird species are adaptable and present in three stages of succession; it has been extensively researched by [27,28] that habitat heterogeneity and vegetation structure can be important factors in determining the richness and diversity of bird species as well as functional diversity [30]. Changes in bird communities in this study were also influenced by the distribution and abundance of tree species [31]. In addition, the existence of species occupying a certain stage of succession suggests that another factor can play an important role, namely the availability of food.

The results of our study also showed that several nectarivores and insectivores, such as the Meliphaga and Nectarinae groups, were found in the old secondary forests and primary forests. The existence of this group was contradictory to another study [32], which is usually found in a more open habitat such as mixed shrubs, agricultural, mixed plantation and young secondary forests. This could be due to the location and size of the old growth forests (i.e., primary and secondary forests) which are surrounded by other younger forest types. Thus, the bird community in the old growth forest was influenced by the young forests and open areas.

Based on the results of this study, species with relative abundance in the frequent, uncommon and rare categories in the intermediate and late succession stages to be defended from severe disturbances such as deforestation, which has an impact on decreasing species richness and diversity**.** The influence of forest succession due to disturbance impacts birds' presence at each habitat succession stage in this study, we agree with [33,34], which states that bird species that specifically live in primary forests will be negatively impacted during disturbances and can be replaced by other species associated with modified habitats.

Species responses to disturbances vary and depend on factors such as species functional traits, including body mass, forest habitat specialization, food groups, migration status, global distribution size, and foraging strata [33,34]. In addition, the condition of the research location adjacent to the settlement (Mandopi Rimom Village) has a significant impact on bird habitat, where forest habitats are disturbed by humans by clearing agricultural land, harvesting logs [35], and hunting. For this reason, it is necessary to take action to preserve the habitat by supporting the existence of birds. The intermediate and late succession stages have vegetation connectivity that can determine the spatial distribution of birds [36].

5. Conclusions

In conclusion, forest disturbance affects the existence of bird communities. The existence of bird communities increases at each stage of succession. It achieves the highest richness and diversity at the succession stage, resting on young secondary forest habitat and moving toward stability at the final succession stage. This research supports the IDH. The environmental parameters of vegetation are strongly correlated with the richness of bird species. However, microclimate parameters (i.e., temperature, relative humidity, and sunlight) are weakly correlated. Another important finding is that the highest bird species richness was found in the young secondary forest, but some species were only found in the primary forest. Therefore, focus on conservation efforts should include those habitats.

Author Contributions

HW: Conceptualization, methodology, data curation, writing-original draft, writing-review and editing; **YAM**: conceptualization, methodology, writing-review and editing, supervision; **AM**: conceptualization, methodology, writing-review and editing, visualization; **SBR**: writing-review and editing, methodology.

Conflicts of interest

The authors declare that they have no conflicts of interest

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