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(RESEARCH ARTICLE)

Sensitivity of Shannon-winner diversity index and Margalef richness index values on fauna population changes in the forest revegetation of mining closing areas in east Bolaang Mongondow regency, North Sulawesi of Indonesia

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Abstract

Species diversity of fauna is an indicator of the sustainability of the ecological system and is the easiest and fastest variable to measure the ecological data qualification in term of diversity and richness index values. Therefore, the urgency of biodiversity measurement activities, knowledge of the philosophy, methods, and implementation of the concept of measuring species diversity in ecological population studies is very necessary. This study was conducted to determine the level of sensitivity of the two analysis methods, including a simulation of the calculation of species diversity using Shannon-Winner Diversity Index (H') and using Margalef Richness Index by applying various existing diversity data of fauna species population in the revegetation forest area of the PT Jresources Bolaang Mongondow (JRBM) Lanut mining site, East Bolaang Mongondow Regency, North Sulawesi of Indonesia from January 2024 to December 2024. The results showed that changes in the observation data of fauna populations affected the decrease in the number of fauna species and the number of individuals in each type of fauna. These decreasing changes in the number of fauna species and the individual populations in each type of fauna would be linearly proportional to the decrease in the index values of the Shannon-Wenner species diversity (H'). However, these decreasing changes in the number of fauna species and the individual populations in each type of fauna would be proportional to the quadratic curve pattern against the Margalef Richness index values (Dmg). This revealed that the Shannon-winner diversity index value (H') is more sensitive than the Margalef richness index value (Dmg) in the changes of the existence data of fauna populations in the revegetation forest areas.

Keywords: Fauna Population; Index Sensitivity; Margalef Richness; Shannon-Winner Diversity

1. Introduction

Biodiversity monitoring activities in a region really need the support of ecological data qualification. By quantifying, data becomes more measurable so that changes over time are easier to detect [1]. Species diversity of fauna is one of the important data in ecology [2]. Species diversity of fauna is an indicator of the sustainability (wellbeing) of the ecological system and is the easiest and fastest variable to measure [3]. Measurement of species diversity is an important issue related to habitat degradation, fragmentation and extinction [4].

To know and understand its current condition, activities are not only to measure biodiversity, but also to compare, analyze relationships and predict its development and determine management actions that need to be taken [5]. In

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relation to the urgency of biodiversity measurement activities, knowledge of the philosophy, methods, and implementation of the concept of measuring species diversity in ecological studies is very necessary [6].

Biodiversity in this study was measured through two parameters, namely species diversity using the Shannon-Winner Diversity Index (H') method [7, 8, 9] and species richness using the Margalef Richness Index (Dmg) method [10, 11, 12]. The methods of calculation of these two parameters vary widely and until now there has been no agreement on the best method, but one of the most important aspects in using these various methods is the sensitivity of the method on data changes in the field. In order to determine the level of analysis sensitivity of the two methods, a simulation of the calculation of species diversity and richness was carried out by applying various existing methods to measure the diversity of fauna species in the revegetation area of the PT Jresources Bolaang Mongondow (JRBM) Lanut mining site, East Bolaang Mongondow Regency, North Sulawesi of Indonesia.

2. Materials and Methods

2.1. Study Area

The survey location is located in the middle to the edge of the PT JRBM mining area at Lanut village, East Bolaang Mongondow (Boltim) district (Figure 1). The PT JRBM area as the location of this study included a sample of five transects with a total transect length of 5.05 km (Table 1) or an area of 2.25 km2 [13] at the PT JRBM mining site in Boltim district. The area is part of the limited production forest area system utilized by the PT JRBM mining company in Boltim district, North Sulawesi Province.

The study was conducted in the mining area of PT Jresources Bolaang Mongondow (PT JRBM) Lanut Village, East Bolaang Mongondow Regency (Boltim) from January 2024 to December 2024. Every three months (Quarter 1, 2, 3, 4) of a year observations were carried out by spending two consecutive days collecting data in each Quarter (Q). Surveyors covered five transects with a total distance of 5.05 km with an average of 1.01 km/transect (Table 1). The average results of animal/fauna observations were based on the intensity of initial encounters based on sight, footprints and animal sounds during observations [14]. Other data are supported by the results of observations by PT JRBM employees who carried out post-mining site revegetation activities. The tools and materials used in this observation were stationery, meters, stakes, machetes, cameras, compasses, tally sheets and raffia ropes.

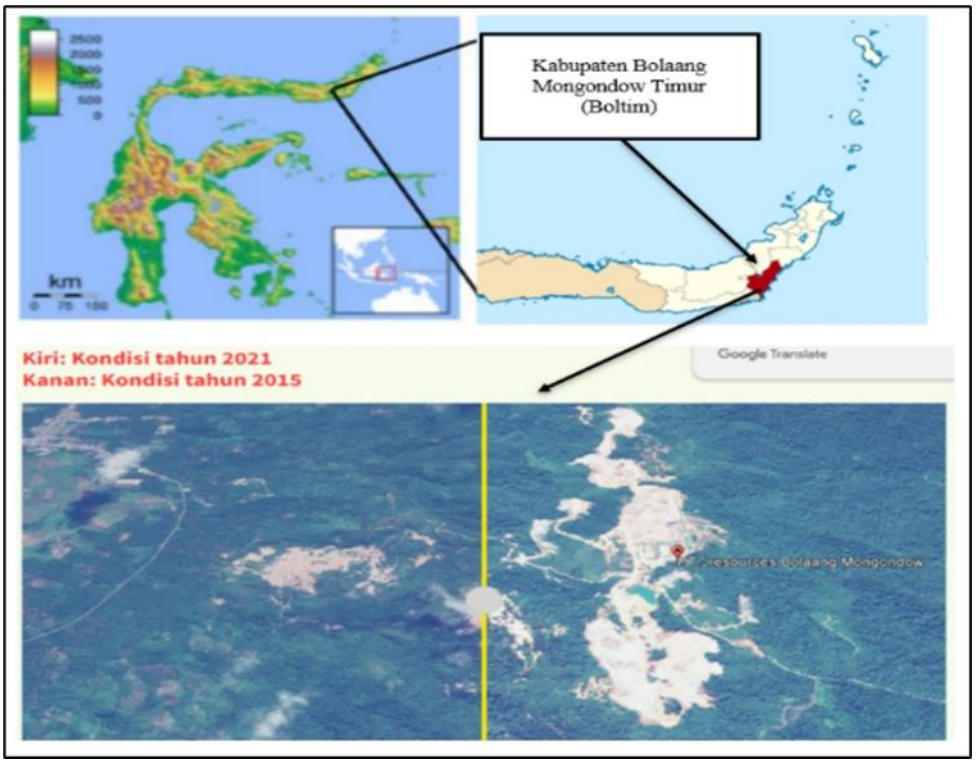

Figure 1 Map of the PT JR esources Boltim Gold Mining Area as the location of the survey transect route

Each transect was observed twice, namely in the morning and repeated in the afternoon by surveyors [15] assisted by PT JRBM employees. Transect 1 was in the southern part of Mount Rizka, transect 2 in the eastern part of Mount Rizka, transect 3 in the northern part of Mount Rizka to Mount Efendy, transect 4 in the western part of Mount Rizka and transect 5 in the southwest part below the PT JRBM Main Office. Each transect was passed repeatedly between two to three times.

An observer with two assistants moved silently along the transect at a speed of about 1.5 km/h. The animal population survey was conducted between 08:00 and 12:00 AM and repeated between 15:00 and 17:30 PM. The surveyor stopped every 100 m for approximately 2-3 minutes and observed the animals while recording the number of individuals, species of animals in each animal type group observed [16].

Table 1 Characteristics of the animal fauna survey transects at the mining area of PT Jresources Bolaang Mongondow (PT JRBM) Lanut village

Transect	Length Size (km)	Habitat Types	Disturbance
1	1.15	Roads, roadside teak, clove plantations and mixed vegetation	Vehicle noise on the border of Boltim and Bolmong regencies
2	1.20	Mixed vegetation, human settlements and clove plantation edges	Human settlement, seasonal clove pickers in Boltim regency
3	1.30	Mixed vegetation, dry riverbeds and bamboo	Firewood collecting community from Boltim and Bolmong Regency
4	0.90	Mixed vegetation, dry riverbeds, community gardens and bamboo	Firewood collecting and plant cultivation communities from Boltim and Bolmong regencies
5	0.50	Mixed vegetation, community gardens and forest edges	Firewood collectors from Boltim and Bolmong regencies
Total	5,05 (1,01 km/transect)		

2.2. Index Analysis

2.2.1. Shannon-Wenner Species Diversity Index (H')

The analysis of the species diversity index (H') was calculated using the Shannon species diversity formula [17] as follows

$$H' = -\sum i Pi * \ln (Pi)$$

Where, $\sum$ = Greek symbol meaning "number"; H' = Shannon's species diversity index; *ln* = Natural log; Pi = ni/N = The proportion of the entire community that consists of species *i;* ni = The density value of the *i-th* type; and N = Total density. The criteria for the range of values of the Shannon-Wenner Species Diversity Index (H') [14] are as follows:

H' < 1: the Shannon-Wenner species diversity index (H') is said to be low;1 < H' < 3: The Shannon-Wiener species diversity index (H') is said to be moderate; and H' > 3: The Shannon-Wenner species diversity index (H') is said to be high.

2.3. Margalef Method Species Richness Index Analysis (Dmg)

2.3.1. To measure the richness of Margaleaf, the formula used [12] is

$$Dmg = \frac{(S-1)}{Ln\ N}$$

Where, Dmg= Margalef's Richness; S = Number of species found in the Forestry Area; N = Total number of individuals in the Forestry Area. The criteria for the range of Margalef species richness index (Dmg) values are as follows:

Dmg < 3,5 = the Margalef type richness index is said to be low; Dmg = 3,5 - 5,0 = Margalef's species richness index is said to be moderate; Dmg > 5,0 = Margalef's species richness index is said to be high.

3. Result and discussion

The results of the analysis of the Shannon-Wenner species diversity index (H') and the analysis of the Margalef species richness index (Dmg) involving 60 types of fauna in the forestry area have obtained a value of H' = 3.37517 and a value of Dmg = 7.72 (Table 2).

Table 2 Results of the analysis of the Shannon-Wenner index (H') and the Margalef richness index (Dmg) involving 60 types of species in the forestry area

No.	Types of Species using local and Latin names	Category	ni
1	Babi hutan/ Wild boar (*Sus scrofa*)	Mammalia	18
2	Tikus tanah/ Gophers (*Rattus argententer*)	Mammalia	72
3	Tikus ekor putih/ White-tailed rat (*Maxomys heliwandii*)	Mammalia	43
4	Tupai Sulawesi/ Sulawesi Squirrel (*Prosciurillus murinus*)	Mammalia	18
5	Kelelawar buah/ Fruit bats (*Megachiroptera sp*.)	Mammalia	24
6	Monyet hitam/ Black monkey (*Macaca nigra*)	Mammalia	46
7	Kura-kura batok Sulawesi/ Sulawesi shell turtle (*Cuora amboinensis*)	Reptile	7
8	Ular hitam/ Black snake (*Dendroaspis polylepis*)	Reptile	13
9	Ular phiton/ Python snake (*Phiton sp*.)	Reptile	12
10	Biawak air/ Water monitor lizard (*Varanus salvator*)	Reptile	9
11	Kodok/ Frog (*Fajervarya cancrivora*)	Reptile	46
12	Kadal kebun/ Garden lizard (*Eutropis multifasciata*)	Reptile	11
13	Burung Bangau putih/ White Stork (*Ardea alba*)	Aves	1
14	Butbut Sulawesi/ Butbut Celebes (*Centropus celebensis*)	Aves	5
15	Bondol Taruk (*Lonchura molucca*)	Aves	9
16	Bubut Alang-alang/ Alang-alang Lathe (*Centropus bengalensis*)	Aves	2
17	Bubut Sulawesi/ Sulawesi Lathe (*Centropus celebensis*)	Aves	12
18	Burung Hantu/ Owl (*Ketupa ketupu*)	Aves	13
19	Burung Madu Sriganti/ Sriganti Sunbird (*Cinnyris jugularis*)	Aves	15
20	Burung-gereja Erasia/ Eurasian Sparrow (*Passer sp*.)	Aves	28
21	Cabai Panggul-kelabu/ Grey Hip Chili (*Dicaeum celebicum*)	Aves	3
22	Cabai Panggul-kuning/ Yellow-Hip Chili (*Dicaeum aureolimbatum*)	Aves	3
23	Cekakak Sungai/ River Kingfisher (*Todiramphus chloris*)	Aves	4
24	Elang Bondol/ White-bellied Eagle (*Haliastur indus*)	Aves	15
25	Elang Hitam/ Black Eagle (*Ictinaetus malaiensis*)	Aves	4
26	Gagak/ Crow (*Corvus Enca*)	Aves	18
27	Burung Gereja/ Sparrow (*Passer montanus*)	Aves	45

28	Kacamata Gunung/ Mountain Glasses (*Zosterops montanus*)	Aves	19
29	Kadalan Sulawesi/ Sulawesi bird (*Rhamphococcyx sp*.)	Aves	6
30	Kekep Babi/ Pork Crackers (*Artamus leucorynchus*)	Aves	20
31	Kekep Sulawesi/ Sulawesi Kekep (*Artamus monachus*)	Aves	20
32	Kepudang Kuduk-hitam/ Black-naped Oriole (*Oriolus chinensis*)	Aves	12
33	Kepudang-sungu Sulawesi/ Sulawesi Oriole (*Coracina morio*)	Aves	25
34	Kutilang/ Finch bird (*Pycnonotus aurigaster*)	Aves	11
35	Layang-layang batu/ Stone Kite bird (*Hirundo tahitica*)	Aves	28
36	Mandar-padi Zebra/ Zebra Peacock (*Gallirallus torquatus*)	Aves	3
37	Pelanduk Sulawesi/ Sulawesi Mouse Deer (*Trichastoma celebense*)	Aves	7
38	Perkici Dora/ Dora's Lorikeet (*Trichoglossus ornatus*)	Aves	25
39	Pipit/ Sparrow (*Lonchura punctulata*)	Aves	57
40	Raja Perling Sulawesi/ King of Sulawesi Pearls (*Basilornis celebensis*)	Aves	2
41	Raja Udang/ King Prawn (*Halcyon senegalensis*)	Aves	14
42	Rangkong Sulawesi/ Sulawesi Hornbill (*Rhyticeros cassidix*)	Aves	12
43	Serindit Sulawesi/ Sulawesi Parakeet (*Loriculus stigmatus*)	Aves	2
44	Seriti/ The series (*Collocalia esculenta*)	Aves	54
45	Sikatan-bubik Sulawesi/ Sulawesi brush-tailed shrike (*Muscicapa sodhii)*	Aves	2
46	Srigunting Jambul-rambut/ Srigunting Jasbul-hair (*Dicrurus hottentottus)*	Aves	16
47	Terkukur/ Dove (*Spilopelia chinensis*)	Aves	18
48	Tiong-lampu Sulawesi/ Chinese lights of Sulawesi (*Coracias temminckii)*	Aves	17
49	Uncal Sulawesi/Sulawesi Uncal (*Macropygia albicapilla*)	Aves	9
50	Walet Sapi/ Cow Swallow (*Collocalia esculenta*)	Aves	60
51	Ayam-hutan Merah/ Red Junglefowl (*Gallus gallus*)	Aves	1
52	Blibong Pendeta/ Blibong Pastor (*Streptocitta albicolis*)	Aves	5
53	Kupu-Kupu hitam/ Black Butterfly (*Papilio*)	Insect	27
54	Jangkrik/ Cricket (*Gryllus asimilis*)	Insect	72
55	Lalat buah/ Fruit fly (*Drosophila melanogaster*)	Insect	97
56	Lebah/ Bee (Apis *sp.*)	Insect	124
57	Ngengat/ Moth (*Lepidoptera*)	Insect	146
58	Kumbang/ Local Bee (C*oleoptera*)	Insect	138
59	Lalat/ Fly (*Diptera*)	Insect	176
60	Semut/ Ant (*Hymenoptera*)	Insect	350
		Total (N) =	2071
		H’ =	3.375
		Dmg =	7,72

To test the sensitivity of the Shannon-Wenner species diversity index analysis method (H') and the Margalef species richness index analysis method (Dmg), an analysis was conducted involving both methods on the observation data in Table 2 which has 60 types of fauna, without involving data on 8 types of fauna in the insect category, as shown in Table 3.

Table 3 Results of the analysis of the Shannon-Wenner index (H') and the Margalef richness index (Dmg) involving 52 types of species in the forestry area

No.	Types of Species using local and Latin names	Category	pi	(Pi)	Ln (Pi)	Pi * Ln (Pi)
1	Babi hutan (*Sus scrofa*)	Mammalia	18	0.0087	-4.7444	-0.0413
2	Tikus tanah (*Rattus a.*)	Mammalia	72	0.0348	-3.3581	-0.1169
3	Tikus ekor putih (*Maxomys hel.*)	Mammalia	43	0.0208	-3.8728	-0.0805
4	Tupai Sulawesi (*Prosciurillus m*)	Mammalia	18	0.0087	-4.7444	-0.0413
5	Kelelawar buah (*Megachiroptera sp.*)	Mammalia	24	0.0116	-4.4567	-0.0517
6	Monyet hitam (*Macaca nigra*)	Mammalia	46	0.0222	-3.8077	-0.0845
7	Kura2 batok Sulawesi (*Cuora am.*)	Reptile	7	0.0034	-5.6841	-0.0193
8	Ular hitam (*Dendroaspis polylepis*)	Reptile	13	0.0063	-5.0672	-0.0319
9	Ular phiton (*Phiton sp.*)	Reptile	12	0.0058	-5.1499	-0.0299
10	Biawak air (*Varanus salvator*)	Reptile	9	0.0043	-5.4491	-0.0234
11	Kodok (*Fajervarya cancrivora*)	Reptile	46	0.0222	-3.8077	-0.0845
12	Kadal kebun (*Eutropis multifasc.*)	Reptile	11	0.0053	-5.2401	-0.0278
13	Burung Bangau putih (*Ardea alba*)	Aves	1	0.0005	-7.6009	-0.0038
14	Butbut Sulawesi (*Centropus celeb.*)	Aves	5	0.0024	-6.0323	-0.0145
15	Bondol Taruk (*Lonchura molucca*)	Aves	9	0.0043	-5.4491	-0.0234
16	Bubut Alang2 (*Centropus Bengal.*)	Aves	2	0.0011	-6.8124	-0.0075
17	Bubut Sulawesi (*Centropus celeb.*)	Aves	12	0.0058	-5.1499	-0.0299
18	Burung Hantu (*Ketupa ketupu*)	Aves	13	0.0063	-5.0672	-0.0319
19	Burung Madu Sriganti (*Cinnyris j.*)	Aves	15	0.0072	-4.9337	-0.0355
20	Burung-gereja Erasia (*Passer sp.*)	Aves	28	0.0135	-4.3051	-0.0581
21	Cabai Panggul-kelabu (*Dicaeum c.*)	Aves	3	0.0014	-6.5713	-0.0092
22	Cab Panggul-kuning (*Dicaeum a.*)	Aves	3	0.0015	-6.5023	-0.0097
23	Cekakak Sungai (*Todiramphus ch.*)	Aves	4	0.0019	-6.2659	-0.0119
24	Elang Bondol (*Haliastur indus*)	Aves	15	0.0072	-4.9337	-0.0355
25	Elang Hitam (*Ictinaetus malaien*)	Aves	4	0.0019	-6.2659	-0.0119
26	Gagak (*Corvus Enca*)	Aves	18	0.0087	-4.7444	-0.0413
27	Burung Gereja (*Passer montanus*)	Aves	45	0.0217	-3.8304	-0.0831
28	Kacamata Gunung (*Zosterops mo*)	Aves	19	0.0092	-4.6885	-0.0431
29	Kadalan Sula (*Rhamphococcyx sp.*)	Aves	6	0.0091	-4.6995	-0.0428
30	Kekep Babi (*Artamus leucoryn.*)	Aves	20	0.0097	-4.6356	-0.0449
31	Kekep Sulawesi (*Artamus monac.*)	Aves	20	0.0097	-4.6356	-0.0449
32	Kepudang Kuduk-hitam (*Oriolus c*)	Aves	12	0.0058	-5.1499	-0.0299

33	Kepudang-sungu Sula (*Coracina m*)	Aves	25	0.0121	-4.4145	-0.0534
34	Kutilang (*Pycnonotus aurigaster*)	Aves	11	0.0053	-5.2401	-0.0278
35	Layang2 batu (*Hirundo tahitica*)	Aves	28	0.0135	-4.3051	-0.0581
36	Mandar-padi Zebra (*Gallirallus t*)	Aves	3	0.0015	-6.5023	-0.0097
37	Pelanduk Sulawesi (*T. celebense*)	Aves	7	0.0034	-5.6841	-0.0193
38	Perkici Dora (*T. ornatus*)	Aves	25	0.0121	-4.4145	-0.0534
39	Pipit (*Lonchura punctulata*)	Aves	57	0.0275	-3.5936	-0.0989
40	Raja Perling Sula (*B. celebensis*)	Aves	2	0.0011	-6.8124	-0.0075
41	Raja Udang (*Halcyon senegalensis*)	Aves	14	0.0068	-4.9908	-0.0339
42	Rangkong Sula (*Rhyticeros cass*)	Aves	12	0.0058	-5.1499	-0.0299
43	Serindit Sulawesi (*L. stigmatus*)	Aves	2	0.0011	-6.8124	-0.0075
44	Seriti (*Collocalia esculenta*)	Aves	54	0.0261	-3.6458	-0.0952
45	Sikatan-bubik Sulawesi (*M. sodhii*)	Aves	2	0.0011	-6.8124	-0.0075
46	Srigunting Jambul (*Dicrurus hott*)	Aves	16	0.0077	-4.8665	-0.0375
47	Terkukur (*Spilopelia chinensis*)	Aves	18	0.0087	-4.8665	-0.0413
48	Tiong-lampu Sulawesi (*Coracias t*)	Aves	17	0.0082	-4.8036	-0.0394
49	Uncal Sulawesi (*Macropygia alb*)	Aves	9	0.0043	-5.4491	-0.0234
50	Walet Sapi (*Collocalia esculenta*)	Aves	60	0.0291	-3.5371	-0.1029
51	Ayam-hutan Merah (*Gallus gallus*)	Aves	1	0.0005	-7.6009	-0.0038
52	Blibong Pendeta (*Streptocitta alb*)	Aves	5	0.0024	-6.0323	-0.0145
		Total (N) =	941		H'=	2,011
					Dmg =	12,91

Margalef species richness index (Dmg) = (52-1) / ln (941) = 51 / 3.9512 = 12.91. The Dmg value for 52 fauna species has increased to 12.91 (Table 3) compared to the Dmg index value for 60 fauna species (7.72) in Table 2. Meanwhile, the Shannon-Wenner species richness diversity index (H') has decreased to 2.011 (Table 3) compared to the H' value for 60 fauna species (3.375) in Table 2.

The percentage change for the increase in Dmg index value due to the decrease in the number of 8 types of fauna in the extreme distribution insect category is [(12.91 – 7.71)/7.71) x 100%] or 67.44%. While the percentage change in the decrease in H' value due to the decrease in the number of 8 types of fauna in the extreme distribution insect category is [(3.375 – 2.011)/3.375) x 100%] or 40.42%.

To test the sensitivity of the Shannon-Wenner species diversity index analysis method (H') and the Margalef species richness index analysis method (Dmg), an analysis was conducted involving both methods on the observation data in Table 2 which has 60 types of fauna, without involving data on 8 types of fauna in the insect category and 6 types of fauna in the reptile category, as shown in Table 4.

Table 4 Results of the analysis of the Shannon-Wenner index (H') and the Margalef richness index (Dmg) involving 46 types of species in the forestry area

No.	Types of Species using local and Latin names	Category	pi	(Pi)	Ln (Pi)	Pi * Ln (Pi)
1	Babi hutan (*Sus scr.*)	Mammalia	18	0.0087	-4.7444	-0.0413
2	Tikus tanah (*Rattus a.*)	Mammalia	72	0.0348	-3.3581	-0.1169
3	Tikus ekor putih (*Maxomys hel.*)	Mammalia	43	0.0208	-3.8728	-0.0805
4	Tupai Sulawesi (*Prosciurillus m*)	Mammalia	18	0.0087	-4.7444	-0.0413
5	Kelelawar buah (*Megachiroptera sp.*)	Mammalia	24	0.0116	-4.4567	-0.0517
6	Monyet hitam (*Macaca nigra*)	Mammalia	46	0.0222	-3.8077	-0.0845
7	Burung Bangau putih (*Ardea alba*)	Aves	1	0.0005	-7.6009	-0.0038
8	Butbut Sulawesi (*Centropus celeb.*)	Aves	5	0.0024	-6.0323	-0.0145
9	Bondol Taruk (*Lonchura molucca*)	Aves	9	0.0043	-5.4491	-0.0234
10	Bubut Alang2 (*Centropus Bengal.*)	Aves	2	0.0011	-6.8124	-0.0075
11	Bubut Sulawesi (*Centropus celeb.*)	Aves	12	0.0058	-5.1499	-0.0299
12	Burung Hantu (*Ketupa ketupu*)	Aves	13	0.0063	-5.0672	-0.0319
13	Burung Madu Sriganti (*Cinnyris j.*)	Aves	15	0.0072	-4.9337	-0.0355
14	Burung-gereja Erasia (*Passer sp.*)	Aves	28	0.0135	-4.3051	-0.0581
15	Cabai Panggul-kelabu (*Dicaeum c.*)	Aves	3	0.0014	-6.5713	-0.0092
16	Cab Panggul-kuning (*Dicaeum a.*)	Aves	3	0.0015	-6.5023	-0.0097
17	Cekakak Sungai (*Todiramphus ch.*)	Aves	4	0.0019	-6.2659	-0.0119
18	Elang Bondol (*Haliastur indus*)	Aves	15	0.0072	-4.9337	-0.0355
19	Elang Hitam (*Ictinaetus malaien*)	Aves	4	0.0019	-6.2659	-0.0119
20	Gagak (*Corvus Enca*)	Aves	18	0.0087	-4.7444	-0.0413
21	Burung Gereja (*Passer montanus*)	Aves	45	0.0217	-3.8304	-0.0831
22	Kacamata Gunung (*Zosterops mo*)	Aves	19	0.0092	-4.6885	-0.0431
23	Kadalan Sula (*Rhamphococcyx sp.*)	Aves	6	0.0091	-4.6995	-0.0428
24	Kekep Babi (*Artamus leucoryn.*)	Aves	20	0.0097	-4.6356	-0.0449
25	Kekep Sulawesi (*Artamus monac.*)	Aves	20	0.0097	-4.6356	-0.0449
26	Kepudang Kuduk-hitam (*Oriolus c*)	Aves	12	0.0058	-5.1499	-0.0299
27	Kepudang-sungu Sula (*Coracina m*)	Aves	25	0.0121	-4.4145	-0.0534
28	Kutilang (*Pycnonotus aurigaster*)	Aves	11	0.0053	-5.2401	-0.0278
29	Layang2 batu (*Hirundo tahitica*)	Aves	28	0.0135	-4.3051	-0.0581
30	Mandar-padi Zebra (*Gallirallus t*)	Aves	3	0.0015	-6.5023	-0.0097
31	Pelanduk Sulawesi (*T. celebense*)	Aves	7	0.0034	-5.6841	-0.0193
32	Perkici Dora (*T. ornatus*)	Aves	25	0.0121	-4.4145	-0.0534
33	Pipit (*Lonchura punctulata*)	Aves	57	0.0275	-3.5936	-0.0989
34	Raja Perling Sula (*B. celebensis*)	Aves	2	0.0011	-6.8124	-0.0075
35	Raja Udang (*Halcyon senegalensis*)	Aves	14	0.0068	-4.9908	-0.0339

36	Rangkong Sula (*Rhyticeros cass*)	Aves	12	0.0058	-5.1499	-0.0299
37	Serindit Sulawesi (*L. stigmatus*)	Aves	2	0.0011	-6.8124	-0.0075
38	Seriti (*Collocalia esculenta*)	Aves	54	0.0261	-3.6458	-0.0952
39	Sikatan-bubik Sulawesi (*M. sodhii*)	Aves	2	0.0011	-6.8124	-0.0075
40	Srigunting Jambul (*Dicrurus hott*)	Aves	16	0.0077	-4.8665	-0.0375
41	Terkukur (*Spilopelia chinensis*)	Aves	18	0.0087	-4.8665	-0.0413
42	Tiong-lampu Sulawesi (*Coracias t*)	Aves	17	0.0082	-4.8036	-0.0394
43	Uncal Sulawesi (*Macropygia alb*)	Aves	9	0.0043	-5.4491	-0.0234
44	Walet Sapi (*Collocalia esculenta*)	Aves	60	0.0291	-3.5371	-0.1029
45	Ayam-hutan Merah (*Gallus gallus*)	Aves	1	0.0005	-7.6009	-0.0038
46	Blibong Pendeta (*Streptocitta alb*)	Aves	5	0.0024	-6.0323	-0.0145
		Total (N) =	**843**		**H' =**	**1.794**
					Dmg =	**11.75**

Margalef species richness index (Dmg) = (46-1) / ln (843) = 45 / 3.8286 = 11.75. The Dmg value for 52 fauna species has increased to 12.91 (Table 3) compared to the Dmg value for 60 fauna species (7.72) in Table 2, while the Shannon-Wenner species diversity index (H') has decreased to 1.794 (Table 4) compared to the H' value for 60 fauna species (3.37517) in Table 2.

To test the sensitivity of the Shannon-Wenner species diversity index analysis method (H') and the Margalef species richness index analysis method (Dmg), an analysis was conducted involving both methods on the observation data in Table 2 which has 60 types of fauna, without involving data on 8 types of fauna in the insect category, 6 types of fauna in the reptile category, and 6 types of fauna in the mammal category as shown in Table 5.

Table 5 Results of the analysis of the Shannon-Wenner index (H') and the Margalef richness index (Dmg) involving 40 types of species in the forestry area

No.	Types of Species using local and Latin names	Category	pi	(Pi)	Ln (Pi)	Pi * Ln (Pi)
1	Burung Bangau putih (*Ardea alba*)	Aves	1	0.0005	-7.6009	-0.0038
2	Butbut Sulawesi (*Centropus celeb.*)	Aves	5	0.0024	-6.0323	-0.0145
3	Bondol Taruk (*Lonchura molucca*)	Aves	9	0.0043	-5.4491	-0.0234
4	Bubut Alang2 (*Centropus Bengal.*)	Aves	2	0.0011	-6.8124	-0.0075
5	Bubut Sulawesi (*Centropus celeb.*)	Aves	12	0.0058	-5.1499	-0.0299
6	Burung Hantu (*Ketupa ketupu*)	Aves	13	0.0063	-5.0672	-0.0319
7	Burung Madu Sriganti (*Cinnyris j.*)	Aves	15	0.0072	-4.9337	-0.0355
8	Burung-gereja Erasia (*Passer sp.*)	Aves	28	0.0135	-4.3051	-0.0581
9	Cabai Panggul-kelabu (*Dicaeum c.*)	Aves	3	0.0014	-6.5713	-0.0092
10	Cab Panggul-kuning (*Dicaeum a.*)	Aves	3	0.0015	-6.5023	-0.0097
11	Cekakak Sungai (*Todiramphus ch.*)	Aves	4	0.0019	-6.2659	-0.0119
12	Elang Bondol (*Haliastur indus*)	Aves	15	0.0072	-4.9337	-0.0355
13	Elang Hitam (*Ictinaetus malaien*)	Aves	4	0.0019	-6.2659	-0.0119
14	Gagak (*Corvus Enca*)	Aves	18	0.0087	-4.7444	-0.0413

15	Burung Gereja (*Passer montanus*)	Aves	45	0.0217	-3.8304	-0.0831
16	Kacamata Gunung (*Zosterops mo*)	Aves	19	0.0092	-4.6885	-0.0431
17	Kadalan Sula (*Rhamphococcyx sp.*)	Aves	6	0.0091	-4.6995	-0.0428
18	Kekep Babi (*Artamus leucoryn.*)	Aves	20	0.0097	-4.6356	-0.0449
19	Kekep Sulawesi (*Artamus monac.*)	Aves	20	0.0097	-4.6356	-0.0449
20	Kepudang Kuduk-hitam (*Oriolus c*)	Aves	12	0.0058	-5.1499	-0.0299
21	Kepudang-sungu Sula (*Coracina m*)	Aves	25	0.0121	-4.4145	-0.0534
22	Kutilang (*Pycnonotus aurigaster*)	Aves	11	0.0053	-5.2401	-0.0278
23	Layang2 batu (*Hirundo tahitica*)	Aves	28	0.0135	-4.3051	-0.0581
24	Mandar-padi Zebra (*Gallirallus t*)	Aves	3	0.0015	-6.5023	-0.0097
25	Pelanduk Sulawesi (*T. celebense*)	Aves	7	0.0034	-5.6841	-0.0193
26	Perkici Dora (*T. ornatus*)	Aves	25	0.0121	-4.4145	-0.0534
27	Pipit (*Lonchura punctulata*)	Aves	57	0.0275	-3.5936	-0.0989
28	Raja Perling Sula (*B. celebensis*)	Aves	2	0.0011	-6.8124	-0.0075
29	Raja Udang (*Halcyon senegalensis*)	Aves	14	0.0068	-4.9908	-0.0339
30	Rangkong Sula (*Rhyticeros cass*)	Aves	12	0.0058	-5.1499	-0.0299
31	Serindit Sulawesi (*L. stigmatus*)	Aves	2	0.0011	-6.8124	-0.0075
32	Seriti (*Collocalia esculenta*)	Aves	54	0.0261	-3.6458	-0.0952
33	Sikatan-bubik Sulawesi (*M. sodhii*)	Aves	2	0.0011	-6.8124	-0.0075
34	Srigunting Jambul (*Dicrurus hott*)	Aves	16	0.0077	-4.8665	-0.0375
35	Terkukur (*Spilopelia chinensis*)	Aves	18	0.0087	-4.8665	-0.0413
36	Tiong-lampu Sulawesi (*Coracias t*)	Aves	17	0.0082	-4.8036	-0.0394
37	Uncal Sulawesi (*Macropygia alb*)	Aves	9	0.0043	-5.4491	-0.0234
38	Walet Sapi (*Collocalia esculenta*)	Aves	60	0.0291	-3.5371	-0.1029
39	Ayam-hutan Merah (*Gallus gallus*)	Aves	1	0.0005	-7.6009	-0.0038
40	Blibong Pendeta (*Streptocitta alb*)	Aves	5	0.0024	-6.0323	-0.0145
	Total (N) =		**622**		**H' =**	**1.378**
					Dmg =	**6.06**

Margalef species richness index (Dmg) = (40-1) / ln (622) = 39 / 6.43294 = 6.06. The Dmg value for 52 fauna species (941 individuals) has increased to 12.91 (Table 3) compared to the Dmg value for 60 fauna species with 2071 individuals (Dmg = 7.72) in Table 2. The Dmg value for 46 fauna species (843 individuals) has decreased to 11.75 (Table 4) compared to the Dmg value for 60 fauna species with 2071 individuals (Dmg = 7.72) in Table 2. Furthermore, the Dmg value for 40 fauna species (622 individuals) has decreased to 6.06 (Table 5) compared to the Dmg value for 60 fauna species with 2071 individuals (Dmg = 7.72) in Table 2.

The Shannon-Wenner species diversity index (H') for 52 fauna species (941 individuals) has decreased to 2.011 (Table 3) compared to the H' value for 60 fauna species with 2071 individuals (H '= 3.37517) in Table 2. The H 'index decreased again to 1.79 (Table 4) for 46 fauna species (843 individuals) compared to the H' value for 60 fauna species with 2071 individuals (H '= 3.37517) in Table 2. Furthermore, the H 'index decreased again to 1.378 (Table 5) for 40 fauna species (622 individuals) compared to the H' value for 60 fauna species with 2071 individuals (H '= 3.37517) in Table 2.

The Shannon-Wenner Species Diversity Index is very sensitive to the uneven distribution of the number of species and individuals in each species, so it is very good for detecting changes or dominance of certain fauna species. Meanwhile, the Margalef Species Richness Index tends to react positively (index 12.91) to the decrease in the number of species (87% remaining) and the number of fauna individuals (45.4% remaining) so that the Richness Index value only decreases (index 11.75 – 6.06) when there is a decrease in the number of species (77 – 67% remaining) and the number of fauna individuals (40.7 – 30% remaining) as seen in Table 6.

Table 6 Calculation of the index sensitivity of the species diversity and species richness based on the changes of the number of species types and individuals

Number of species types	Number of Individuals	Index		Notes
		Shannon-Wenner Species Diversity (H')	Margalef Species Richness (Dmg)	
60 [100 %]	2071 [100 %]	3.375	7,72	Table 2
52 [87 %]	941 [45.4 %]	2,011s	12,91	Table 3
46 [77 %]	843 [40.7 %]	1.794	11.75	Table 4
40 [67 %]	622 [30 %]	1.378	6.06	Table 5

4. Discussion

With the change in the decrease in the observation results of the number of fauna species by 60 fauna species (100%) to 40 fauna species (67%) with a difference of around 10% (Figure 2), the consistency of the decrease in the value of the Shannon-Wenner species diversity index (H ') from 3.375 to 1.378 has been seen. The same thing has also been seen in the change in the decrease in the observation results of the number of fauna individuals by 2071 fauna individuals (100%) to 622 fauna individuals (30%) (Figure 3), the consistency of the decrease in the value of the Shannon-Wenner species diversity index (H ') from 3.375 to 1.378 has been seen.

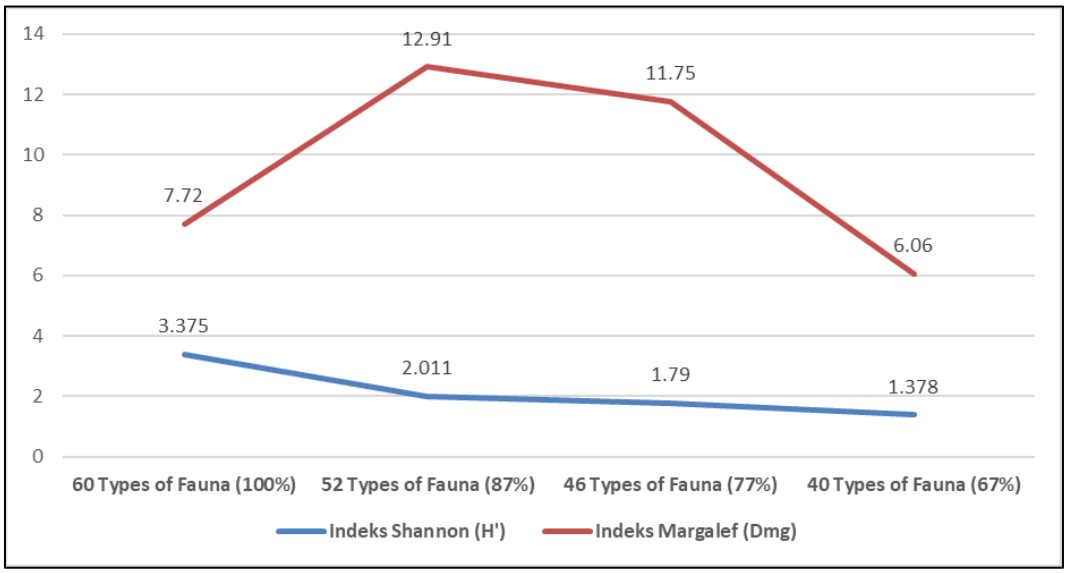

Figure 2 Comparison of the sensitivity of the Shannon-winner diversity index (H') and Margalef richness index (Dmg) values to the decline in the results of observations of the number of fauna species

The different thing is that with the change in the decrease in the observation results of the number of fauna species by 60 fauna species (100%) to 40 fauna species (67%) with a difference of around 10% (Figure 2), there has been an inconsistency in the increase and decrease in the value of the Margalef species richness index (Dmg) from a value of 7.72 to 12.91 and 11.75 then down to 6.06.

Furthermore, the same thing has also been seen in the changes in the decrease in the observation results of the number of fauna individuals by 2071 fauna individuals (100%) to 622 fauna individuals (30%) (Figure 3) there has been an inconsistency in the increase and decrease in the value of the Margalef species richness index (Dmg) from a value of 7.72 up 12.91 and 11.75 then down to 6.06. Measurement of fauna diversity is not only carried out to find out and understand its current condition, but also to compare, analyze relationships and predict its development and determine management actions that need to be taken [10, 18].

By looking at the changes in index values against the Shannon-winner diversity (H') and the Margalef richness index (Dmg) to the decrease in the observation results of the number of species and the number of fauna individuals, it can be seen that the Shannon-winner diversity index (H') is more sensitive than the Margalef richness index (Dmg). These results are in accordance with several studies [13, 19] that with the addition of the number of species, the index value increases quite significantly and vice versa. The index value only decreases when there is no increase in the number of species (Figure 2) in accordance with several previous research reports [20]. These data also show that the Shannon-winner diversity index (H') will be better if used in conditions of adding smaller species or the size of the area according to the species area curve. Meanwhile, the Margalef index value began to decrease when the number of fauna species was reduced from 77 to 67 percent, while the Shannon-winner diversity index (H') had decreased from 87 percent, 77 percent and 67 percent (Figure 2).

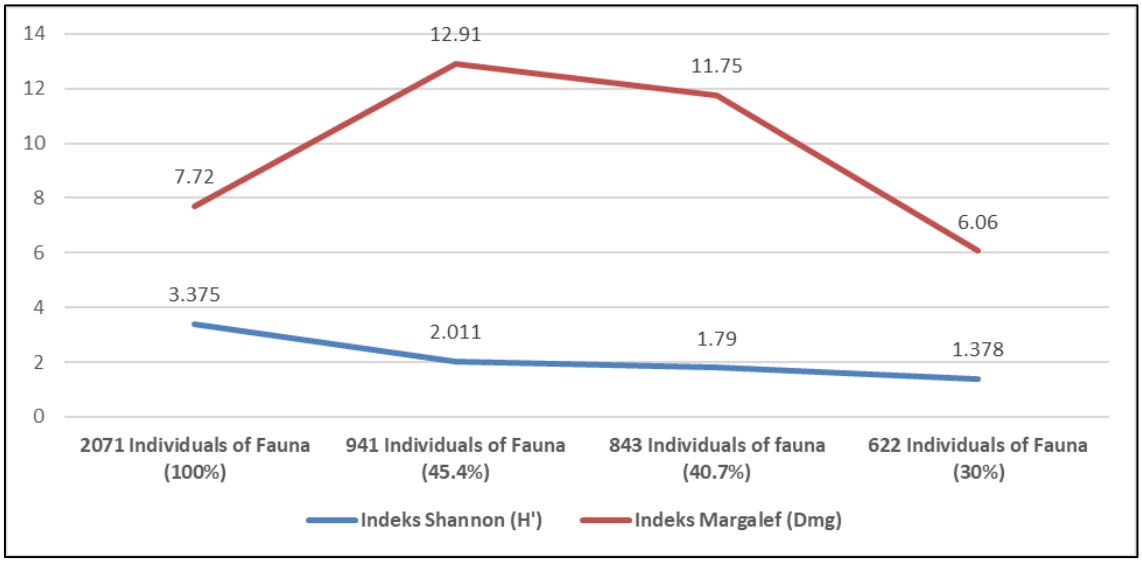

Figure 3 Comparison of the sensitivity of the Shannon-winner diversity index (H') and Margalef richness index (Dmg) values to the decline in the results of observations of the number of fauna individuals

In the same condition, the Margalef index still experienced an increase in index value from 7.72 (100 percent of species) to 12.91 at a reduction in the number of species of 87 percent (Figure 2). The Margalef index value decreased to 11.75 to 6.06 at a reduction in the number of species of 77 percent to 67 percent (Figure 2). Meanwhile, the Shannon-winner diversity index (H') decreased consistently from 3.375 (at 100 percent of species), to an index of 2.011 at a reduction in the number of species of 87 percent, an index of 1.79 at a reduction in the number of species of 77 percent to an index of 1.378 at a reduction in the number of species of 67 percent.

From the curve data in Figure 2, it can be seen that the Shannon-winner diversity index (H') has better sensitivity capabilities than the Margalef index. The Shannon-winner diversity index (H') is very sensitive to the number of species (Figure 2) or the number of individuals (Figure 3). This condition is in accordance with several research reports with the same method [21, 22]. If the increase in the number of individuals is more dominant than the increase in the number of species, the index value will also decrease. The results of this calculation are in accordance with the statements of several reports [10, 23] which state that this index has a higher level of sensitivity when compared to the Margalef index.

If the index is getting closer to the value of 1, then the community of biological species is getting more homogeneous [2, 18, 24, 25]. Therefore, the decrease in the number of fauna species causes a decrease in the value of the Shannon-winner diversity index (H'), so that if it touches the index value of 1, then the heterogeneity of the fauna species community is getting closer to the condition of fauna species homogeneity.

Based on the fluctuation of all index values along with the decrease in the number of species, the most sensitive index is the Shannon-Weiner Index [26]. This index has different sensitivities to factors that affect species diversity, such as uneven distribution of the number of individuals in a particular area, so it is very good for detecting the dominance of certain species [27, 28]. Meanwhile, the Margalef index tends to react positively to conditions when there is an addition of species so that the diversity value only decreases drastically when there is no addition of fauna species.

5. Conclusion

The decrease in the number of fauna species and the number of individual populations in each type of fauna would be linearly proportional to the decrease in the values of the Shannon-Wenner species diversity index (H'). However, the decrease in the number of fauna species and the number of individual populations in each type of fauna would be proportional to the quadratic curve pattern against the Margalef index values (Dmg). Therefore, the Shannon-winner diversity index value (H') is linearly sensitive to the population changes of species and individual numbers.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declared no conflict of interest.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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