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On the Study of Structural Equivalency for Animal Conservation in Species-Habitat Network Form

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Abstract:

Kerinci Seblat National Park is a combination of 17 forest groups located on the island of Sumatra. This study will discuss modeling the relationship between animals and their habitats in the form of an ecological network. The relationship between species and habitat is an essential topic in animal conservation. This relationship can be modeled as a graph called the habitat-species network, with two types of vertices: species (V^s) or habitat (V^h). The edge connecting a species vertex and a habitat vertex represents the species ever visiting the habitat. This study aimed to discuss three measures for describing the relationship between species and habitats: structural equivalence, Jaccard similarity, and Pearson's correlation coefficient. Structural equivalence of a group of habitats represents the similarity of animals that visit the same habitat, the Jaccard similarity describes the percentage of habitats visited by a pair of different animals, and Pearson's correlation coefficient shows the significance of the relationship between the two species.

Keywords: conservation, habitat, network, species.

1. Introduction

Animal conservation is a crucial issue concerning various parties, such as environmental activists, researchers, and policymakers. The Government of the Republic of Indonesia is carrying out conservation efforts by making the Law of the Republic of Indonesia Number 5 of 1990 concerning the Conservation of Living Natural Resources and their Ecosystems. In this law, the government makes rules regarding protected areas for plants and animals, usage limits, monitoring systems, and criminal provisions for violators of these regulations [1].

Organizing ecological data is one of the conservation efforts carried out by researchers. This study used graph theory to manage the relationship between habitat and species. The graph formed from these relationships is called the species-habitat network (SHN). Albert et al. (2017) [2], who studied land management for 14 vertebrate species in the Canadian suburb of Montreal, was the first researcher to use this method. Studies of SHN covered butterfly networks in northeastern Italy [3]; networks in island forests [4]; spider networks [5]; insect networks such as spiders, ground beetles, wild bees, and flies [6]; species networks in Polylepis forests [7]; species networks in coastal areas [8]; a bobcat network in southern Belgium [9]; and a spider network on a farm [6].

The national park is one of the areas mentioned in [1]. Its primary function is to preserve natural and native ecosystems for research, scientific, and educational purposes and to support cultivation, tourism, and recreation. The Kerinci Seblat National Park (KSNP) is one of the national parks in Indonesia. It is currently the largest national park on the island of Sumatra, with an area of around 1,389,509.867 hectares. The KSNP area combines protected forests, nature reserves, and wildlife sanctuaries in Jambi, West Sumatra, Bengkulu, and South Sumatra. Animals in the KSNP include 371 species of birds, 17 species of birds that are endemic to Sumatra, 85 species of mammals, seven species of primates, six species of amphibians, and ten species of reptiles. Wild boar (Wb), pig-tailed macaque (Pm), wild goat (Wg), mouse deer (Md), barking deer (Bd), marbled cat (Mc), golden cat (Gc), leopard cat (Lc), and clouded leopard (Lc) also live in the KSNP.

Each animal also has a relationship with its habitat. Every animal needs four essential components: food, cover, water, and space. The habitat provides all of these components. Each component's type, quantity, and quality vary from animal to animal. Food is the most crucial component that animals need to live [10-11]. The availability of abundant food sources is one of the reasons animals frequently visit habitats. Habitat protects animals from weather and predators. Most animals need surface water, such as rivers, lakes, waterfalls, or puddles, to meet the needs of fluids in the body. In addition, animals need sufficient space to carry out ecological needs, such as finding resources, finding partners, and reproductive activities.

Interactions between animals and between animals and their habitat should be carried out under direct observation so as not to cause bias. However, direct observation is inefficient and ineffective for many reasons, such as the fact that the researcher cannot observe continuously and most animals are shy. Using a camera trap is an alternative method that can be used to observe animal interactions efficiently [12]. The advantages of using camera traps are that the results are almost the same as observing directly, while its disadvantages include higher costs, theft, damage due to natural conditions, and damage caused by animals.

After collecting information through camera traps, the data contains animal and habitat data. The problem here is how to evaluate and interpret the data obtained. Therefore, a systematic analysis of animal interactions is needed. Social network analysis is a method for visualizing interactions between animals and the places where they live in the form of graphs or networks [13]. A graph $G = (V, E)$ is an ordered pair of vertex set V and edge set E such that $E \subseteq [V]^2$. Let $u, v \in V$, the notation uv denotes the edge with end vertices u and v. The vertices u and v are called *neighbor*, if $uv \in E$. The notation $N(u)$ shows the neighbor's set from vertex u. The degrees from the vertex u, denoted by $d(u)$, are the number of neighbors of u [14]. A SHN is a graph whose vertex set consists of species (V^s) and habitat vertices (V^h). The edge connecting a species vertex and a habitat vertex is defined as the occurrence of a species s in a habitat h. The SHN is in the form of a bipartite graph.

Marini et al. [15] created a tool to visualize the relationship between animals and the places where they live. In some cases, animals are referred to as species, and the location of the camera trap is called a habitat. These tools are referred to as SHNs. The network is a bipartite network whose vertex sets can be partitioned into two classes: the species vertex set (V^s) and the habitat vertex set (V^h). The edge of the network connecting a species vertex v_s and a habitat vertex v_h indicates that species s has occurred in habitat h.

Connectance [3, 5, 15], modularity [3-6, 15], nestedness [3-4, 15], robustness [2-4, 15], key habitat [3], nestedness contribution, dispersal capacity [4], and habitat quality [2] are the tools and measures used by researchers to determine conditions in SHNs. In addition, research on SHNs also examines habitat specialization [3-5, 7], influence [6, 8, 15], the magnitude of effect [15], centrality [2, 7], density [2, 5], habitat selectivity [6], species richness, species evenness [6-8], and connectivity [2, 7, 9].

This research started with the problem of determining similarity in a network. One of the early studies on this problem was carried out by [16] regarding semantic similarity using network theory. The problem is increasingly important at this time, especially for the sake of creating a better search engine. In ecology, determining similarity in a network is a fundamental problem. In this research, we discuss the vertex similarity measure in the SHN, which [15] introduced to make it easier to manage ecology data with multi-species and multi-habitats.

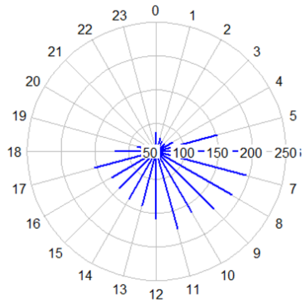
This study mainly aims to measure and describe the relationship between species and habitats in the Bungo area, KSNP. This study discusses three measures: structural equivalence, Jaccard similarity, and Pearson's correlation coefficient. Structural equivalence of a group of habitats can show the similarity of animals that visit the same habitat. The Jaccard similarity describes the percentage of the same habitat visited by a pair of different animals. Finally, Pearson's correlation coefficient shows the significance of the relationship between the two species.

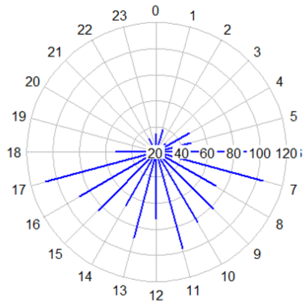
The rest of this paper is structured as follows: Section 2 presents constructing a species-habitat network from camera trap data installed in the Bungo area. Section 3 shows structural equivalence and vertices grouping. Section 4 presents the results of measuring the Jacccard similarity of a pair of habitats or species. Section 5 presents the results of calculating Pearson's correlation coefficient. Finally, Section 6 presents the conclusions of this study.

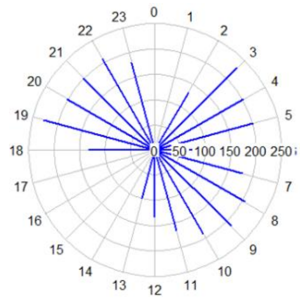
2. Daily Activity Patterns

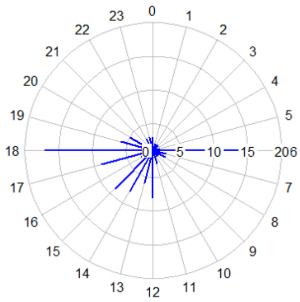
Each animal at KSNP has a special daily activity pattern. The daily activity pattern of an animal is the distribution pattern of an animal's activities in 24 h; these activities include interaction, adaptation, and meeting needs [17].

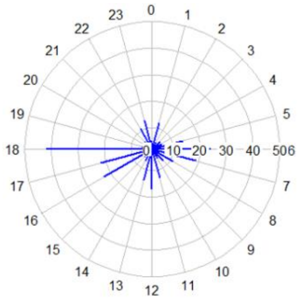
Animals have daily activity patterns that can be divided into four types: diurnal (active during the day), crepuscular (active during dawn), cathemeral (active during the day and night), and nocturnal (active during the night). Figure 1 shows the hourly animal activity patterns, while Table 1 shows the types of activity patterns for each animal.

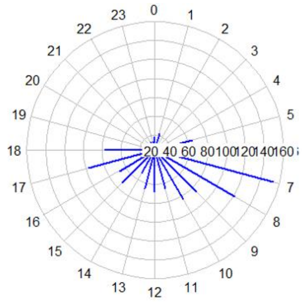

(a) Wild boar

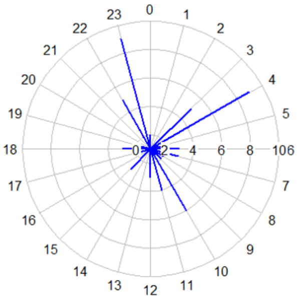

(b) Bearded pig

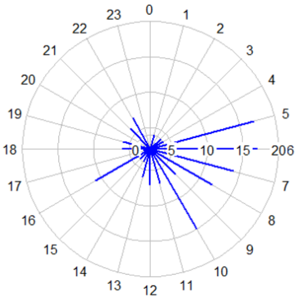

(c) Pig-tailed macaque

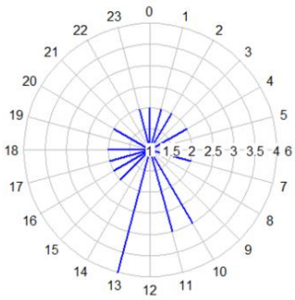

(d) Wild goat


(e) Mouse deer


(f) Barking deer


(g) Marbled cat


(h) Golden cat


(i) Leopard cat

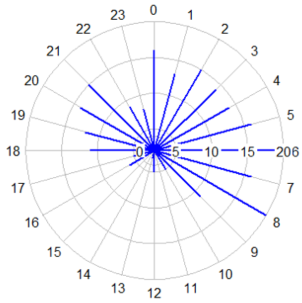

(j) Clouded leopard

Figure 1. Daily activity patterns of each animal in the Kerinci Seblat National Park.

Table 1. Daily activity pattern of species in KSNP.

Species	Animal activity pattern and their reference
Wild boar	Diurnal [18]
Bearded pig	Diurnal [19]
Pig-tailed macaque	Diurnal [20]
Wild goat	Diurnal and crepuscular [21]
Mouse deer	Diurnal and crepuscular [22]
Barking deer	Diurnal [23]
Marbled cat	Cathemeral [24]
Golden cat	Diurnal [25]
Leopard cat	Cathemeral [26]
Clouded leopard	Nocturnal [27]

3. Species-Habitat Network in Bungo Area

Based on camera trap data from [28], data on the appearance of animals recorded in each habitat in the Bungo area is shown in Table 2, and the frequency of their appearance is shown in Table 3. Data on animal presence in Bungo is modeled into the network shown in Fig. 2. A total of 79 camera traps are installed and labeled K001-K079, only 73 of which captured the presence of the species, shown on the right side of the network in Fig. 2. The network is formed from nine species vertices representing the nine animals that have appeared and a set of 73 habitat vertices representing 73 camera trap locations.

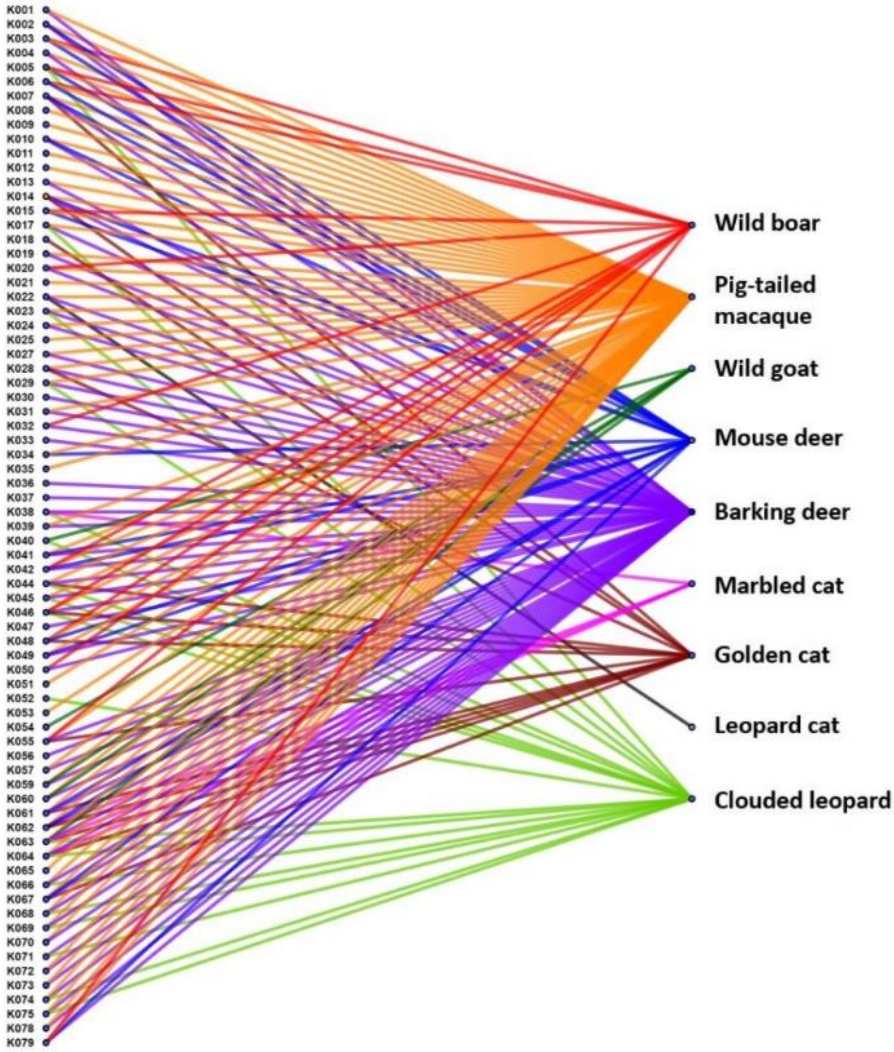


Figure 2. Species-habitat network from animal occurrence data in the Bungo area.

Table 2. The presence of each species in the habitats.

	Wb	Pm	Wg	Md	Bd	Mc	Gc	Lc	Cl
K001	0	1	0	0	1	0	0	0	0
K002	0	1	0	1	1	0	0	0	0
K003	1	1	0	1	0	0	0	0	0
K004	0	1	0	0	1	0	0	0	0
K005	1	1	0	1	0	0	0	0	1
K006	1	1	0	1	0	0	0	0	0
K007	0	1	0	1	1	0	1	0	0
K008	0	1	0	0	0	0	0	0	0
K009	0	1	0	1	0	0	0	0	0
K010	0	1	0	1	1	0	0	0	0
K011	0	1	0	0	0	0	0	0	0
K012	0	1	0	0	0	0	0	0	0
K013	0	1	0	0	1	0	0	0	0
K014	0	1	0	1	1	0	1	0	0
K015	1	1	0	1	0	0	0	0	0
K017	0	1	0	0	1	0	0	0	1
K018	0	0	0	0	0	0	1	0	0
K019	0	1	0	0	1	0	0	0	0
K020	1	1	0	0	1	0	0	0	0
K021	0	1	0	0	0	0	0	0	0
K022	0	1	0	0	1	0	0	1	0
K023	0	1	0	0	1	0	0	0	1
K024	0	1	0	0	1	0	0	0	0
K025	0	1	0	0	0	0	0	0	0
K027	0	1	0	0	1	0	0	0	0
K028	0	1	0	0	1	0	1	0	0
K029	0	1	0	0	1	0	0	0	1
K030	0	0	0	0	1	0	0	0	0
K031	0	1	0	0	1	0	0	0	0
K032	1	0	0	0	1	0	0	0	0
K033	0	0	0	0	1	0	0	0	0
K034	0	1	0	1	0	0	0	0	0
K035	0	1	0	0	0	0	0	0	0
K036	0	0	0	0	1	0	0	0	0
K037	0	0	0	0	1	0	0	0	0
K038	0	0	0	0	1	1	0	0	1
K039	0	1	0	0	1	0	0	0	0

	Wb	Pm	Wg	Md	Bd	Mc	Gc	Lc	Cl
K040	0	0	1	0	0	0	0	0	1
K041	0	1	0	1	1	0	0	0	0
K042	1	1	0	1	1	0	0	0	0
K044	0	1	0	0	1	0	1	0	1
K045	0	1	0	0	1	0	0	0	1
K046	1	1	0	0	1	0	1	0	1
K047	0	0	0	0	1	0	0	0	0
K048	1	1	0	1	1	0	1	0	0
K049	0	1	0	1	1	0	0	0	0
K050	1	0	0	0	1	0	0	0	0
K051	0	1	0	0	0	0	0	0	0
K052	0	0	0	0	0	0	0	0	1
K053	0	1	0	0	0	0	0	0	0
K054	0	0	1	0	0	0	0	0	0
K055	1	1	0	0	1	0	1	0	0
K056	0	1	0	0	1	0	0	0	0
K057	0	1	0	0	1	0	0	0	0
K059	0	1	1	0	1	0	0	0	0
K060	0	1	1	0	1	0	0	0	0
K061	0	1	0	1	1	0	1	0	0
K062	0	1	0	1	1	1	1	0	0
K063	0	1	1	0	1	1	1	0	1
K064	0	1	0	0	1	1	1	0	1
K065	0	1	0	0	0	0	0	0	0
K066	0	1	0	0	1	0	0	0	1
K067	0	1	0	1	1	0	1	0	0
K068	0	1	0	0	1	0	0	0	1
K069	0	1	0	0	1	0	0	0	1
K070	0	1	0	0	1	0	0	0	0
K071	0	0	0	0	1	0	0	0	1
K072	0	1	0	0	1	0	0	0	0
K073	0	1	0	0	1	0	0	0	0
K074	0	1	0	0	1	0	0	0	1
K075	0	1	0	0	1	0	0	0	1
K078	0	1	0	0	1	0	0	0	0
K079	1	1	0	1	1	0	0	0	0

The bipartite matrix formed from the SHN is called the species-habitat matrix (SHM), denoted by $M = \left[m_{\{ij\}}\right]$. The SHM is a matrix of size $h \times s$, where h is the number of habitats and s is the number of species. The matrix is a binary matrix, where element one indicates a species that has ever visited the habitat and zero indicates other conditions. The SHM contains the presence numbers in Table 2, arranged in descending order according to the camera name from smallest to largest. The matrix for animal presence data in the Bungo area has a size of 73×9. The matrix is used to calculate the three similarities discussed in this study.

This study presents three similarity measures of species: structural equivalence, Jaccard similarity, and Pearson's correlation coefficient. Structural equivalence is used to see the resemblance, Jaccard similarity to measure the similarity percentage, and Pearson's correlation coefficient to determine the degree of similarity (positive value) or dissimilarity (negative value) of a pair of vertices in the same class.

Table 3. The frequency of presence of each species in the habitats.

	Wb	Pm	Wg	Md	Bd	Mc	Gc	Lc	Cl
K001	0	4	0	0	6	0	0	0	0
K002	0	3	0	1	3	0	0	0	0
K003	6	6	0	5	0	0	0	0	0
K004	0	2	0	0	3	0	0	0	0
K005	1	6	0	3	0	0	0	0	1
K006	4	7	0	2	0	0	0	0	0
K007	0	4	0	1	5	0	3	0	0
K008	0	3	0	0	0	0	0	0	0
K009	0	5	0	10	0	0	0	0	0
K010	0	6	0	2	3	0	0	0	0
K011	0	1	0	0	0	0	0	0	0
K012	0	2	0	0	0	0	0	0	0
K013	0	1	0	0	1	0	0	0	0
K014	0	4	0	1	3	0	1	0	0
K015	1	1	0	8	0	0	0	0	0
K017	0	1	0	0	2	0	0	0	1
K018	0	0	0	0	0	0	1	0	0
K019	0	6	0	0	5	0	0	0	0
K020	1	5	0	0	18	0	0	0	0
K021	0	4	0	0	0	0	0	0	0
K022	0	1	0	0	1	0	0	1	0
K023	0	7	0	0	6	0	0	0	1
K024	0	9	0	0	2	0	0	0	0
K025	0	1	0	0	0	0	0	0	0
K027	0	1	0	0	3	0	0	0	0
K028	0	2	0	0	13	0	1	0	0
K029	0	1	0	0	6	0	0	0	2
K030	0	0	0	0	2	0	0	0	0
K031	0	1	0	0	1	0	0	0	0
K032	1	0	0	0	2	0	0	0	0
K033	0	0	0	0	1	0	0	0	0
K034	0	3	0	5	0	0	0	0	0
K035	0	2	0	0	0	0	0	0	0
K036	0	0	0	0	2	0	0	0	0
K037	0	0	0	0	1	0	0	0	0
K038	0	0	0	0	7	1	0	0	2
K039	0	1	0	0	3	0	0	0	0

	Wb	Pm	Wg	Md	Bd	Mc	Gc	Lc	Cl
K040	0	0	1	0	0	0	0	0	1
K041	0	6	0	2	2	0	0	0	0
K042	2	4	0	2	2	0	0	0	0
K044	0	1	0	0	2	0	1	0	3
K045	0	1	0	0	8	0	0	0	4
K046	1	1	0	0	4	0	1	0	3
K047	0	0	0	0	16	0	0	0	0
K048	1	6	0	1	2	0	1	0	0
K049	0	8	0	2	3	0	0	0	0
K050	1	0	0	0	2	0	0	0	0
K051	0	1	0	0	0	0	0	0	0
K052	0	0	0	0	0	0	0	0	1
K053	0	2	0	0	0	0	0	0	0
K054	0	0	4	0	0	0	0	0	0
K055	1	2	0	0	2	0	2	0	0
K056	0	1	0	0	8	0	0	0	0
K057	0	5	0	0	27	0	0	0	0
K059	0	1	2	0	4	0	0	0	0
K060	0	3	3	0	1	0	0	0	0
K061	0	2	0	3	1	0	2	0	0
K062	0	14	0	3	3	1	1	0	0
K063	0	15	1	0	10	2	1	0	2
K064	0	6	0	0	6	1	2	0	1
K065	0	1	0	0	0	0	0	0	0
K066	0	2	0	0	3	0	0	0	1
K067	0	8	0	5	19	0	1	0	0
K068	0	2	0	0	1	0	0	0	1
K069	0	8	0	0	13	0	0	0	3
K070	0	2	0	0	4	0	0	0	0
K071	0	0	0	0	2	0	0	0	4
K072	0	20	0	0	12	0	0	0	0
K073	0	4	0	0	3	0	0	0	0
K074	0	10	0	0	4	0	0	0	1
K075	0	3	0	0	1	0	0	0	1
K078	0	1	0	0	1	0	0	0	0
K079	3	8	0	8	3	0	0	0	0

These measures have interesting statistical properties: They have different levels of stringency and sensitivity. Structural equivalence is a stringent measure of similarity where a pair of vertices in the same group have precisely the same neighbors. The measure determines whether a pair of vertices are in the same species/habitat group. Two structurally equivalent vertices have a Jaccard similarity percentage of 100% and Pearson's correlation coefficient of 1. However, the sensitivity of this measure is very low compared to other measures because the results are only binary decisions.

Jaccard similarity has less strict rules, not just binary values. This concept can determine the percentage of the same species visiting a pair of habitats or the same habitats visited by a pair of species. The value of this similarity inclusively ranges from 0 to 100%, and the level of sensitivity is better than structural equivalence. This measure can be used for several practical purposes in ecology that require information regarding the similarity percentage of habitats or species.

Pearson's correlation coefficient can determine not only the level of similarity but also the level of dissimilarity, so it has high sensitivity and low strictness. In Jaccard similarity, dissimilarity is given a value of 0, while the correlation coefficient shows a value of -1 for it. The dissimilarity value (negative) is calculated by the similarity value (positive) to see whether each pair of vertices has more substantial similarities or dissimilarities. The lowest and highest values of Pearson's correlation coefficient of a pair of vertices are -1 and +1, respectively. A value of -1 is obtained by a pair of species vertices if the two species never visit the same habitat, while a value of +1 is received by both if the same species always visit them.

4. Jaccard Similarity

Jaccard similarity was developed by [29]. The similarity of a pair of habitat vertices indicates the percentage of the same species that appear in both habitats. The similarity between the two species shows the percentage of the same habitats visited by the two species. The similarity of the two species' vertices is determined by the ratio between the number of the same habitat visited and the number of all habitats visited by both.

The similarity of the two habitat vertices is determined by comparing the number of the same species and the number of all species that visit the two habitats. The similarity of the two habitat vertices can help decide how to treat the two habitats. The two points' similarity shows that they have the same tendencies or characteristics. Jaccard similarity can be calculated by:

$$J(v_i, v_j) = \frac{\left|N(v_i) \cap N(v_j)\right|}{\left|N(v_i) \cup N(v_j)\right|}.$$

Jaccard similarity percentage is used for a pair of vertices v_i and v_j of the same type. These two vertices are species or habitat vertices. For the similarity of a pair of habitat vertices, the value $\left|N(v_i) \cap N(v_j)\right|$ is the i-th row and j-th column entry of the matrix MM^T. In contrast, for the similarity of a pair of species vertices, value $\left|N(v_i) \cap N(v_j)\right|$ is the entry of the i-th row and j-th column of the matrix M^TM. For a pair of species points, the value $\left|N(v_i) \cup N(v_j)\right|$ can be calculated by $\sum_k max\{m_{ik}, m_{jk}\}$, which $1 \leq i, j \leq h, 1 \leq k \leq s$. Meanwhile, for a pair of habitat points, the value can be calculated by $\sum_l max\{m_{li}, m_{lj}\}$, which $1 \leq i, j \leq s, 1 \leq l \leq h$.

Table 4. Criteria for Jaccard similarity

Category	Criteria	Color
High	$J \geq 0.8$	(red)
Moderate	$0.2 \leq J < 0.8$	(yellow)
Low	$J < 0.2$	(green)

The similarity between the vertices contained in one class is divided into three criteria in the Table 4. Based on the criteria in the Table 4, a Jaccard similarity matrix is obtained for the species vertices in Fig. 3 and for the habitat vertices in Fig. 4. Based on the entries in the Jaccard similarity matrix of the species vertices in Fig. 3, 9 entries are classified as high, 16 as moderate, and 56 as low.

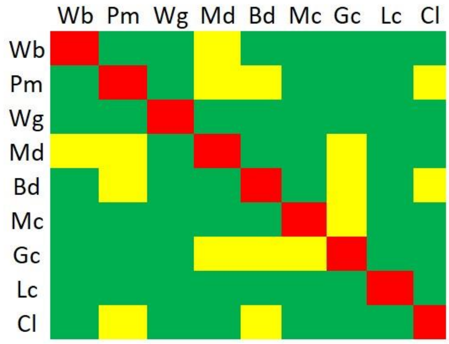


Fig. 3. Jaccard similarity matrix from species vertices

As for the entries in the Jaccard similarity matrix of the habitat vertices amounting to 5,329 in Fig. 3, 12% of the entry is classified as high, 57% as moderate, and 31% as low. A pair of species that have high similarity tends to share the same habitat for a particular purpose. In contrast, a pair of animals with low similarity almost rarely visit the same habitat or have less tendency to share space. Figure 4 shows the similarity between each pair of habitats. Habitats that are highly similar tend to be visited by many of the same species. Meanwhile, habitats that have low similarity tend to be visited by different species.

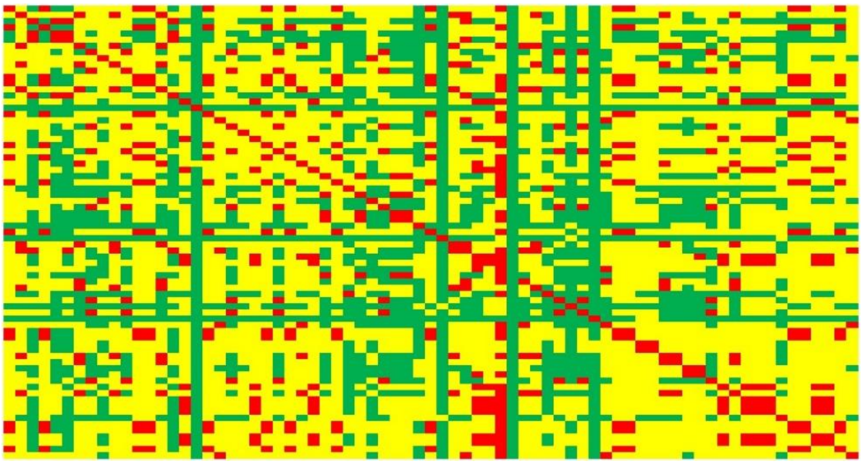


Fig. 4. Jaccard similarity matrix from habitat vertices.

5. Structural Equivalence

Lorrain and White [30] introduced the concept of structural equivalence of individuals in a network. In the network, two vertices are called structural equivalents, if both have exactly the same bonds [31]. The definition shows that two vertices u and v are structural equivalent if $N(u) = N(v)$. The definition causes the two vertices to have the same degree, $d(u) = d(v)$. Structural equivalence will be used for vertices in the network, divided into two parts: structural equivalence for species and habitat vertices.

Structural equivalence has a relationship with Jaccard similarity. A pair of vertices that have precisely the same set of neighbors will have the values $\left|N(v_i) \cap N(v_j)\right| = 1$ and

$\left|N(v_i) \cup N(v_j)\right| = 1$. The ratio of these two values will cause the Jaccard similarity to be 100%. Habitat vertices with a Jaccard similarity percentage of 100% and neighbors with precisely the same species vertices will form clusters or habitat groups. Habitats in the same group are habitats visited by the same species. These species have the potential for interactions between the same and different species.

Based on the structural equivalent definition, the habitat group in the network of species can be grouped into two types. The first group is a special habitat group inhabited by an animal population. The habitat group has a member of a neighboring habitat with the same species vertex. The second is the shared habitat group inhabited by an animal community. The habitat group has the smallest two habitat vertices of two degrees, each of which is neighboring a group of the same species. The species vertices in the species network can be divided into two types, namely, the vertex of non-equivalent species with other species of species called selective species and several species vertices that are structurally equivalent to community or can be called a group of inclusive species.

Table 5. Potential interactions of species in habitat groups based on structural equivalence

Habitat name	Number of habitats	Species name	Potential interaction	Habitat grouping
K008, K011, K021, K025, K035, K051, K053, K065	8	Pig-tailed macaque	Territory	Some special habitats inhabited by one animal population
K030, K033, K036, K037, K047	5	Barking deer	Territory	
K032, K050	2	Wild boar and barking deer	Competition	Some same habitats inhabited by an animal community
K009, K034	2	Pig-tailed macaque and mouse deer	Competition	
K001, K004, K012, K013, K019, K024, K027, K031, K039, K056, K057, K072, K073, K078	14	Pig-tailed macaque and barking deer	Competition	
K003, K006, K015	3	Wild boar, mouse deer, and pig-tailed macaque	Competition	
K020, K079	2	Wild boar, barking deer, and pig-tailed macaque	Competition	
K059, K060	2	Pig-tailed macaque, wild goat, and barking deer	Competition	
K002, K010, K041, K049	4	Pig-tailed macaque, mouse deer, and barking deer	Competition	
K023, K029, K045, K066, K068, K070, K074, K075, K079	9	Pig-tailed macaque, barking deer, and clouded leopard	Competition and predator-prey	
K007, K014, K061, K067	4	Pig-tailed macaque, mouse deer, barking deer, and golden cat	Competition and predator-prey	

Figure 2 shows the potential interaction in several habitats as shown in Table 5. Three possible interactions occur in KSNP: territory, competition, and predator-prey. The relationship interaction is defined as territory if a habitat is visited by only one type of animal. The competition occurs if the animals in the area have the same type of need, such as food or space. Predator-prey occurs when a habitat is visited by an animal that has the potential to become a predator, and another animal becomes prey. Two habitat groups can potentially become a territory of one species or colony. The first colony is the pig-tailed macaque colony in eight habitats, namely, K008, K011, K021, K025, K035, K051, K053, and K065. The second colony is the barking deer colony in five habitats, namely, K030, K033, K036, K037, and K047.

The potential for competition occurs in 42 habitat vertices contained in nine habitat groups. The competition that might occur is between omnivorous and herbivorous animals such as wild boar and barking deer, between two omnivorous animals such as wild boar and pig-tailed macaque, or between two herbivorous animals such as mouse deer and barking deer. The potential for interaction predator-prey occurs when a habitat has been seen by carnivorous animals with herbivorous animals such as clouded leopard and barking deer or carnivorous animals with omnivorous animals such as clouded leopard and pig-tailed macaque.

The species vertices all have different neighbors so there is no structural equivalent. It shows that all animals are classified as selective animals. These traits arise because each animal has structural differences in visiting habitat. There are no structural equivalents of the species recorded in the Bungo area. Figure 3 shows that each species point does not have precisely the same neighbors and no different species have high Jaccard similarity. The results differ from Fig. 4, which shows that many habitat vertices have a high percentage of Jaccard similarity. These habitat vertices can be structurally equivalent.

6. Pearson Correlation Coefficient

Pearson's correlation coefficient (PCC) is used to see which is more dominant between similarities (positive values) or dissimilarities (negative values) for each pair of species or habitat vertices through the elements of SHM. The formula used to calculate the correlation coefficient for a pair of vertices of the same type v_i and v_j, which is denoted by r_{ij}, is [32]:

$$r_{ij} = \frac{\sum_{k=1}^{r+g}(a_{ik} - \langle a_i \rangle)\left(a_{jk} - \langle a_j \rangle\right)}{\sqrt{\sum_{k=1}^{r+g}(a_{ik} - \langle a_i \rangle)^2}\sqrt{\sum_{k=1}^{r+g}\left(a_{jk} - \langle a_j \rangle\right)^2}}$$

where $\langle a_i \rangle$ is the average of all elements in i-th column. Next, a PCC matrix is made for each species vertex and habitat vertex. The green color in the PCC matrix indicates a positive correlation value, which means that the two vertices have more of the same neighbors. The correlation value of one indicates that the two vertices are structurally equivalent. The red color in the PCC matrix shows a negative correlation value; this means that the two vertices have more different neighbors. The correlation value -1 indicates that the two vertices do not have the same neighbors.

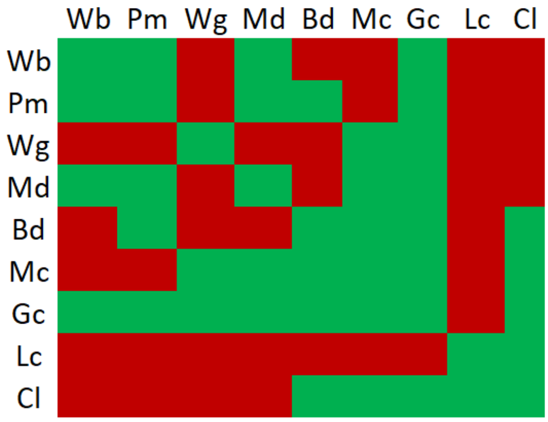


Fig. 5. PCC matrix from species vertices

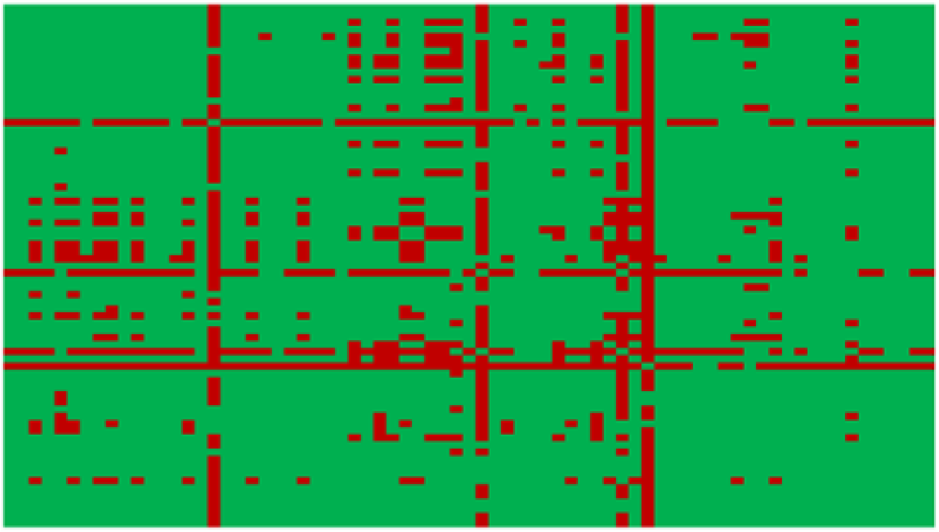


Fig. 6. PCC matrix from species vertices

Based on the sign, the elements in the PCC matrix of the species vertices are 47% negative and 53% positive, as shown in Fig. 5. A pair of species vertices with a positive PCC value indicates that these species have a high potential for visiting the same habitat. Meanwhile, a pair of species vertices with a negative PCC value have a higher potential for visiting habitats that differ from each other or a high potential for not visiting the same habitat.

Meanwhile, the PCC matrix elements for each pair of habitat vertices have 85% positive and 15% negative results, as seen in Fig. 6. A positive PCC value for a pair of habitat vertices indicates that the two habitats have a high potential for being visited by the same species. In contrast, a negative value means that the two habitats have a high potential for being visited by different species.

7. Conclusion

It is very important to manage recording data from camera traps. However, the large amount of data in the form of camera placement locations (habitats) and animals (species) recorded by camera traps is a challenge for ecologists. Representing the relationship between species and habitat in a SHN can facilitate organization and be the basis or foundation for further analysis.

In this study, we construct the network as a SHM. From the matrix, we conducted further research in the form of a similarity test between species and habitat vertices.

The similarity measures discussed in this research are structural equivalence, Jaccard similarity, and PCC. Each of them has specific, unique statistical properties. Based on structural equivalence, 55 habitats are included in one habitat group, while 18 do not have a particular group. These results show that most habitats can form a group of habitats with the same characteristics, namely, being visited by the same species.

Jaccard similarity can determine the tendency of a pair of species to share a habitat with another species or the tendency of a pair of habitats to be visited by the same animals. PCC can determine if a pair of animals visit more of the same or different habitats. The PCC value is used for a pair of habitat vertices to see whether the animals visiting the habitat are the same or different species.

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