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Diversity of Stingless Bees Based on Principal Component Analysis in Halmahera Island, Indonesia

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Abstract: *Tetragonula* is one of stingless bees genus widely spread in Indo-Pacific with various species, including Indonesia. This genus is also found in West Halmahera, but it does not have a unique character as the marker, so it is difficult to identify. The best way to identify is by measuring the body part from each individual. This research was conducted to analyze morphometry to know the diversity of stingless bee in West Halmahera. Three hundred thirty-two (332) stingless bees from 51 colonies of three different species were used, namely *Tetragonula clypearis*, 40 colonies (252 bees), *T. sapiens*, 10 colonies (72 bees), and *T. biroi*, one colony (eight bees). Morphometry of stingless bees were analyzed based on principal component analysis (PCA), visualized into scree plot, score plot, loading plot and biplot. The results showed that only two principal components (PCs) on eigenvalue have a score more than one with the total proportions are 85.8%. All the species were not correlated because they appeared in different quadrants. Morphometry variables have a positive correlation with *T. sapiens*, but negative correlation with *T. clypearies*, while *T. biroi* has a weak correlation with the variables of *T. sapiens*. *T. sapiens* can only be found in the highlands, *T. clypearis* is mostly found in medium elevations but can also be found in highlands, while *T. biroi* can only be found in lowlands.

Key words: Morphometry, *Tetragonula*, elevation, Halmahera Island.

1. Introduction

Tetragonula is one of stingless bees genus widely spread in Indo-Pacific with various species [1], including Indonesia. Kahono *et al.* [2] reported that Indonesia has 12 species of *Tetragonula*, i.e., *T. biroi* in Papua, *T. clypearis* in Ambon, *T. drescheri* in Sumatera, Jawa in Borneo, *T. fuscobalteata* in Sumatera, Borneo and Sulawesi, *T. geissleri* in Borneo, *T. laeviceps* in Sumatera, Jawa, Borneo, Sulawesi and Ambon, *T. melanocephala* in Borneo, *T. melina* in Sumatera and Borneo, *T. minangkabau* in Sumatera, *T. reepeni* in Sumatera, *T. sapiens* in Mollucas and Papua, and *T. sarawakensis* in Borneo.

This genus does not have a unique character as the marker, so it is difficult to identify. The best way to identify is by measuring the body part from each individual [1]. Morphology is about the shape and structure of the organism [3]. Morphology can explain the differences in population, genus or species quantitatively by measuring parts of the body [4]. Morphometry is a method used for species identification based on the measurement of body parts [5]. Determination genus and species for stingless bees also used the measurement of body parts. Previous research conducted measurements of various body characters in *Tetragonula*, i.e., body length (BL), wing length including tegula, head width (HW), wing venation (M-Cu), tibia length (TL), head length, range ocelli area, range of ocello-ocular, hind tibia width, basitarsus length, basitarsus width and number of hamuli [1, 6].

Analysis of morphometric could be done using principal component analysis (PCA). Ruttner [7] for

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the first time used PCA to explain the discriminant of M-Cu in various species of Apidae with two parameters, wing length and wing width. *Apis dorsata* has a larger wing than *A. mellifera* but has the same size with *A. armbrusteri.* Research done by Tej *et al.* [6] on stingless bees also used PCA for 14 body characters. The result shows that, levels of diversity are 54% (first principal component (PC 1)), 29.3% (second principal component (PC 2)), 6.2% (third principal component (PC 3)), with various discriminant characters: fore wing length, hind TL, behind tarsus length, HW, fore wing width, antennal length and bifurication between veins M and Cu.

Stingless bees are also found in West Halmahera Regency, North Moluccas Province, Indonesia, which are originated from *Tetragonula* genus. Morphometry was the method used to identify the morphology characteristic of each species found in West Halmahera. The objective of this research was to analyze morphometry to know the diversity of stingless bee in West Halmahera based on PCA.

2. Materials and Methods

2.1 Study Site

This research was conducted in West Halmahera Regency, North Moluccas Province, Indonesia, with survey method to find the nest of *Tetragonula* in nature and marker by global position system (GPS) (Fig. 1).

2.2 Materials

The materials used in this research are worker bees of *Tetragonula.* It is about 332 bees from 51 colonies found in West Halmahera Regency consisted of three different species, namely *T. clypearis*, 40 colonies (252 bees), *T. sapiens*, 10 colonies (72 bees) and *T. biroi*, one colony (eight bees).

Fig. 1 Map of West Halmahera Regency.

2.3 Measurement of Morphometry

Morphometry measurements were carried out on 10 parts of the body that considered to represent the characteristics of *Tetragonula* found in West Halmahera, Indonesia. The 10 measurements are BL, eye length (EL), eye width (EW), Gena area width (GAW), HW, eye range (ER), antenna range (AR), labrum width (LW), M-Cu and TL.

2.4 Data Analysis

Stingless bees diversity analysis uses PCA to reduce 14 variables, consisting of 10 morphometric measurement variables, one elevation variable and three categories of dummy variables, namely species categorical variables. Dummy variables are qualitative variables that are quantified so that they can be analyzed by quantitative analysis methods.

The score of dummy variables (D) are 0 or 1. Categories of dummy variables in this research:

D_1 = 1, if *T. clypearis*; 0, if not *T. clypearis.*

D_2 = 1, if *T. sapiens*; 0, if not *T. sapiens.*

D_3 = 1, if *T. biroi*; 0, if not *T. biroi.*

Data processing was carried out using Minitab 16. The selection of the main components is done by looking at the eigenvalue and cumulative proportion of eigenvalue of more than 80%. Principal component (PC) selection is useful for finding the highest value of the eigenvector variable which is the main variable. The mathematic models of PCA [8]:

$$Y = a_{11}X_1 + a_{21}X_2 + a_{31}X_3 + \cdots + a_{141}X_{14}$$

where Y = PC ; $X_1 - X_{14}$ = variable 1, 2, 3, …, 14 of size score; $a_1 - a_{10}$ = vektor eigen 1, 2, 3, …, 14.

3. Results and Discussion

The identification of stingless bees from genus *Tetragonula* in West Halmahera is grouped based on morphometric variables that are considered to represent the characteristics of bees using PCA. PCA can reduce the variables in large numbers to several variables that can be used as a marker of a population. Grouping is based on the diversity of data that produces scree plot, score plots, loading plots and biplots graphs.

Based on the results of the analysis, the eigenvalues indicates two components that have values more than one. The same thing can also be seen in the scree plot graph (Fig. 2). The graph shows the components that

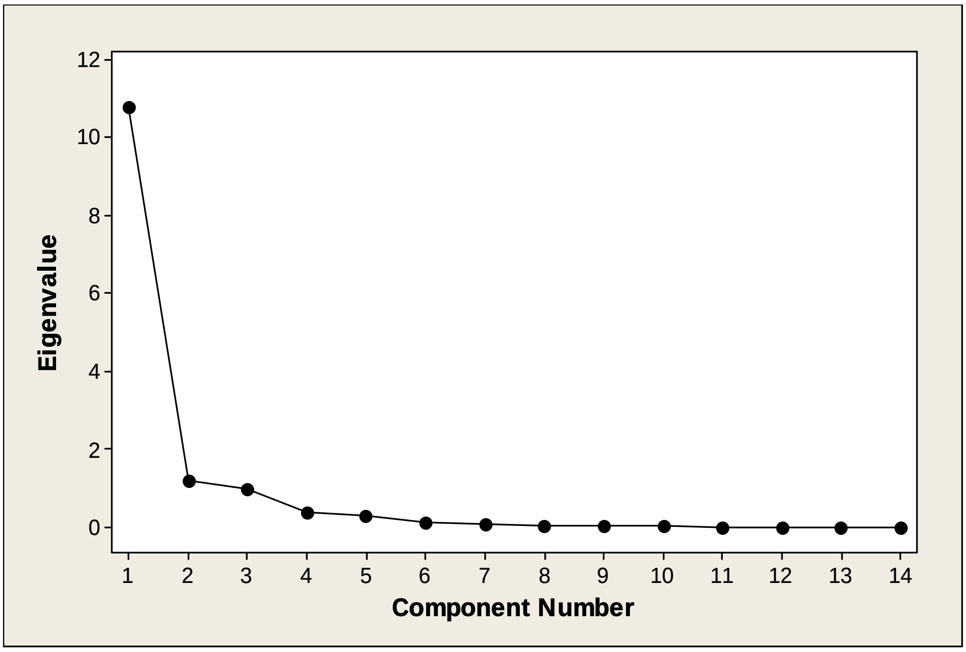

Fig. 2 Scree plot of *Tetragonula*.

must be taken from the two components because they are two points on the graph before the graph shows linear selection. The main component based on the correlation matrix, with only two PCs has produced a total proportion of 85.8%. Eigenvalue and percentage of cumulative morphometry variations of stingless bee in West Halmahera Regency are shown in Table 1.

The results of this study are supported by Nugroho [9], who stated that the use of eigenvalues can be used only on the correlation matrix. This method was suggested by Kaiser in 1960, i.e., if the range of the main components is less than one, it is considered to have a less contribution. Supranto [10] added that the scree plot will show how many components will be used by looking at the point of the eigenvalue that drops dramatically. Jolliffe [8] stated that the determination of the main components can be done at a cumulative diversity value between 70% and 90%. So for this study, the two PCs are able to explain the total diversity of existing data.

The information about the relationship between the samples is represented by PC 1 and PC 2 shown in the scores plot graph. Fig. 3 shows that the stingless bees even though from the same genus, namely *Tetragonula*, but all three have different morphometry. These can be seen at the different positions of each species in different quadrants. *T. sapiens* has a relative correlation in contrast to *T. clypearis* whereas *T. biroi* has no relative correlation to the other two species.

Loading plots provide information about the relationships between morphometric variables of stingless bees (Fig. 4). Visually, it appears that almost all variables have the same vector length, which shows the same diversity or has a high diversity, except GAW and AR with short vector or low diversity. Loading plots also provide information about the relationships between variables. Variables in the same quadrant or region have a positive correlation.

Table 1 Eigenvalue and percentage of cumulative variety.

	PC 1	PC 2
Eigenvalue	10.804	1.206
Propotion	0.772	0.086
Cumulative	0.772	0.858

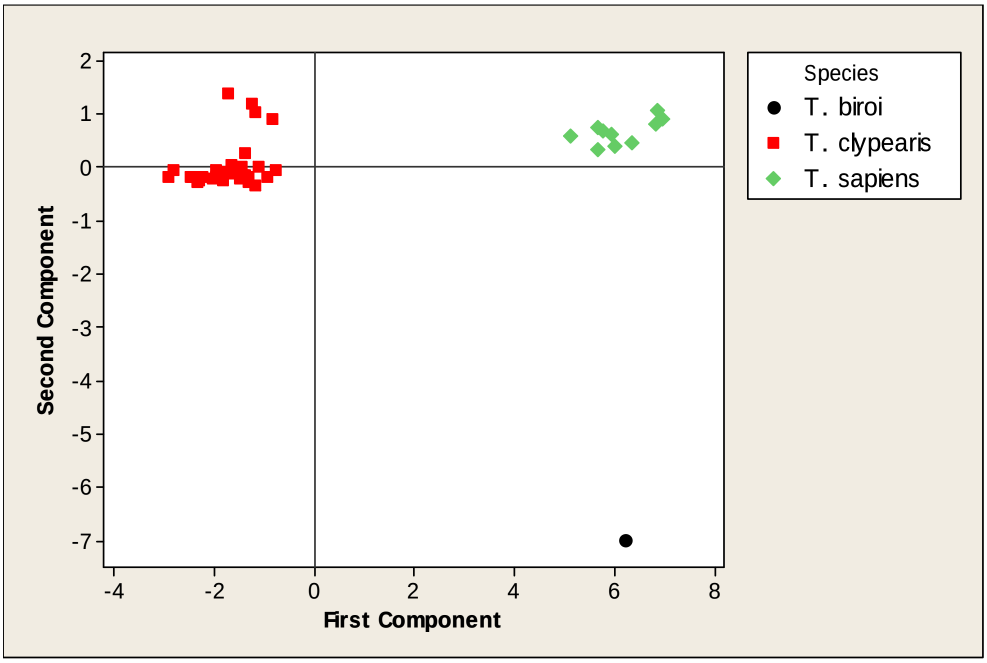

Fig. 3 Score plot of *Tetragonula*.

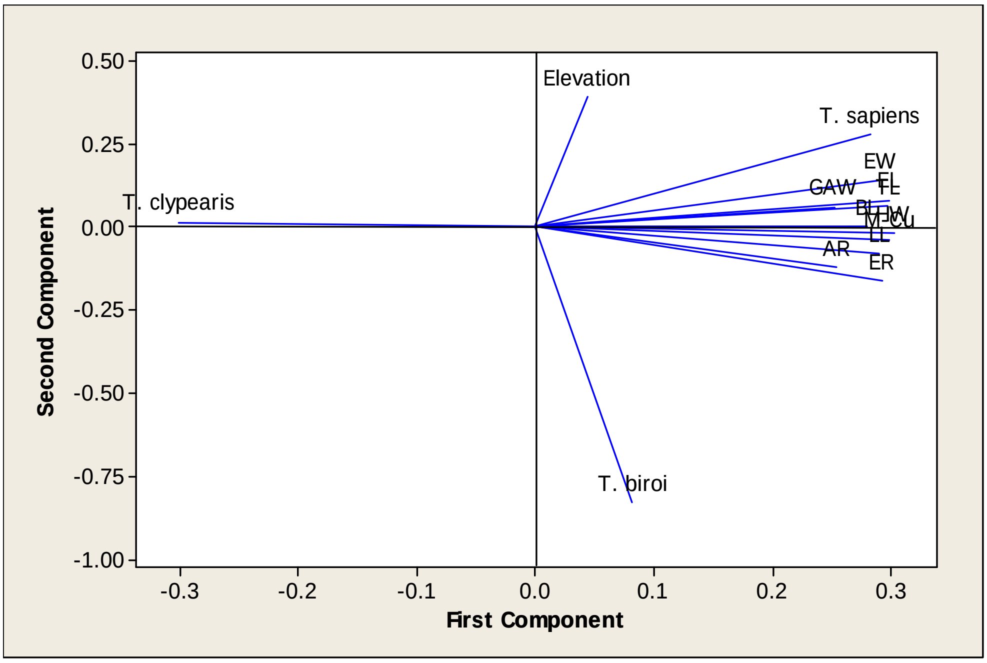

Fig. 4 Loading plot of *Tetragonula*.

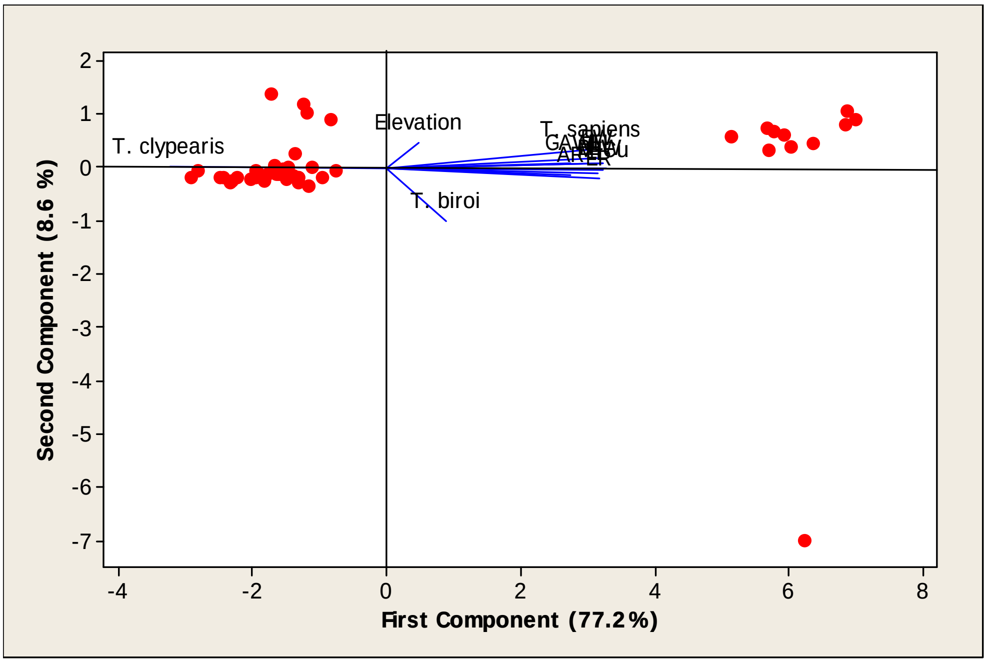

Fig. 5 Biplot of *Tetragonula*.

For example, EW-BL and EW-LW have a positive correlation because it depends on the same quadrant, whereas EW-AR and TL-AR has a negative correlation because it depends on different quadrants.

A score plot graph combined with loading plot will produce a biplot graph. This graph shows the relationship between samples and variables. Fig. 5 shows that morphometry variables are positively correlated with *T. sapiens*, but negatively correlated with *T. clypearis*. *T. biroi* has no relative proximity to the other two species and has a weak positive correlation with morphometric variables on *T. sapiens*. The biplot graph is able to present the data in two dimensions with the values 85.8%, i.e., dimension one

77.2% and dimension two 8.6%.

The distribution of *T. sapiens* is found mostly in the highlands, *T. clypearis* is found in the medium highlands, but some are found in the highlands while *T. biroi* is only found in the lowland. The research doing by Suriawanto [11] supported this research. *T. sapiens* only found above 100-meter above sea level (asl), while *T. biroi* was found at altitude 10-meter asl. The distribution of *T. clypearis* based on elevation has no information yet, but it's the most species found compared to the other species on this research. Heard [12] also found that *T. clypearis* was a widespread Indo-Pacific stingless bee, ranging from Philippines to Northern Australia.

Stingless bees need pollen and nectar for their life and broods from various flowers they visited [12]. Foraging activity of stingless bees is influenced by low humidity and high temperature, which are related to elevation [13]. Spread of plants and insects species, as well as microclimates (temperature, light, intensity and humidity), are influenced by elevation. Species of plants and insects will reduce while the elevation is level up. The abundance of insects is mostly in the region with medium level of elevation, supported by plant abundance [14, 15].

4. Conclusions

PCA reduces the variables and visualized into scree plot, score plot, loading plot and biplot. The analysis shows that eigenvalues indicates two components that have values more than one. It can be seen on scree plot, that the graphs show linear selection after the second component. Two PCs on the correlation matrix can produce a total proportion of 85.8%. Score plot shows that *T. sapiens* has a relative proximity in contrast to *T. clypearis*, whereas *T. biroi* has no relative proximity to the other two species. Loading plots gives the information that almost all variables have high diversity indicates by the length vector, while the short vector indicates the low diversity. Variables in the same quadrant or region have a positive correlation and negative correlation while it appears on different quadrants. Combination between score plot and loading plot, namely biplot shows that morphometry variables are positively correlated with *T. sapiens*, but negatively correlated with *T. clypearis*. *T. biroi* has no relative proximity to the other two species and has a weak positive correlation with morphometric variables on *T. sapiens*. The distribution of *T. sapiens* is found mostly in the highlands, *T. clypearis* is found in the medium highlands, but some are found in the highlands, while *T. biroi* is only found in the lowlands.

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