Earthworm (Oligochaeta) Diversity In The Region Of The Ancient Volcano, Nglanggeran, Yogyakarta As A Learning Resource Of Biology Lesson

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WORD COUNT 5032
TIME SUBMITTED 22-DEC-2019 11:50PM
PAPER ID 53232091

Earthworm (Oligochaeta) Diversity In The Region Of The Ancient Volcano, Nglanggeran, Yogyakarta As A Learning Resource Of Biology Lesson

Trikinasih Handayani, Muhammad S. Wibowo, Dwi Sulisworo

Abstract: This research aims to examineearthworm diversity in the region of the Nglanggeran ancientvolcano. Moreover, it also aims to observe the effects of environmental conditions (C/N ratio, soil pH, soil temperature, air temperature, air humidity, and soil moisture) on the diversity of earthworms (Oligochaeta) in the Nglanggeran volcano as well as to examine the potential of the diversity of earthworms (Oligochaeta) inthisvolcanic region as a resource inbiology learning material inhigh schools. The plotting method was used as the sampling method. The worms were collected using the hand-sorting method. The species diversity index of the earthworms was then calculated using the Shannon-Wiener formula and the determination of the effects of environmental abiotic conditions on the diversity index of the earthworms was acquired by processing the data usingthe regression analysis. Lastly, their potential to be used as a source in learning biology in high schools was analyzed. The species of earthworms found in the region of the Nglanggeran ancient Volcano are Eudriluseugeniae, Diplocardiasingularis, and Pheretimacalifornia. The species diversity index of the earthworms found in thisvolcanic region is low with a mean species diversity index (H') of earthworms ranging from 0.10 to 0.15. The lowest H' is seen in sector 4 of study area IV with a value of 0.10. Only one of the environmental abiotic conditions,which is air temperature,does significantly influence the diversity index of the earthworms in thisvolcanic region. Other environmental abiotic conditions namely soil temperature, air humidity, soil moisture, soil pH, and C/N ratio do not significantly influence the diversity index of the earthworms in the Nglanggeran volcanicregion. The analysis of the prospective usage in schools suggests that the results of this study have the potential to be included as a part of biology learning materials in high schools.

Index Terms: earthworm diversity, the ancient volcano of Nglanggeran, learning materials

1. INTRODUCTION

An ecosystem is an ecological system that is formed due to the reciprocal relationship between its biotic components and the environment. Biotic and abiotic components are the important components of the ecosystem [1]. One of the soil faunasfound in the Nglanggeran ancientvolcanicregion is the earthworm. The species compositions and the abundance of earthworms cannot be separatedfrom theenvironmental abiotic conditions. Ecological factors influence the species compositions and diversity of earthworms in an area. The possibility to use the results of this researchas a resource to study biodiversity was also analyzed.

2 RESEARCH METHODOLOGY

This research was carried out in June and July 2016 in the Nglanggeran ancient volcano Yogyakarta. The volcanic region was divided into five areas of studies covering all regions of representative hiking trails, namely:

1. study area I, located around Lookout I
2. study area II, located around Mt. Bagong and Lookout II
3. study area III, located around Campground 1
4. study area IV, located around Campgrounds 2 and 3
5. study area V, located around the summit of the volcano that covers the area of Mt. Gede

Before the data were collected, a preliminary observation was administered in the region of the Nglanggeran ancientvolcano.Then the boundaries of each study area weredetermined using a map from GEGAMAwith a scale of 1: 25,000. Based on the results of this preliminary observation, the overallsize of the study area was specified by taking 10% of the total area of the volcano, which is equal to 48 ha, so that the overall area studied was 4.8 ha.Thisthenwas divided into fivestudy areas of approximately 10,000 m2 each. There were five sectors in each of these study areas so that each sectorwas an area of 2000m2, with a size of 20x100 m. Ten plots of 1x1 m were randomly placed on each sector, from where the numbers of worms and worm eggs were later counted. A 10-cm auger bit was used to obtain the earthworms and to collect soil samples. This drilling process was carried out three times in each plot. The worms wereput in warm water until they were weak, then they were put in a 3-percent formaldehyde solution. The identification of the earthworms was carried out at the laboratory of animal systematics, the faculty of biology, Gadjah Mada University. The C/N ratio analysis was conducted at the laboratory ofagricultural technology research department. The research results were then analyzed to investigate their potential as learning resources by verifying the terms and requirements neededin determiningbiology learning resources. According to Djohar [2], there are six determining factors, namely the clarity of the availability potential of the objects and issues raised, the conformityto learning objectives, the clarity of the subject materials andtargets, the clarity of the information that will be released, the clarity of exploration guidelines, and the clarity of the achievement.

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3 RESULTS AND DISCUSSIONS

3.1 Earthworm Diversity in Each of the Study Area

The research results show that there are variations in the number and species of earthworms in each study area. In study area I, three species of earthworms, namely Pheretima californiа, Diplocardia singularis and Eudrilus eugeniaeare found. This can be seen in the bar graph of Figure 1.

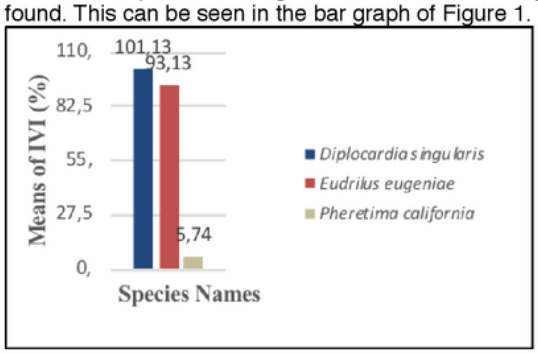

***Figure 1**. The bar graph of earthworm species diversity in study area I*

Research results indicate that the three species of earthworms are also found in study area II. This is shown in the bar graph of Figure 2.

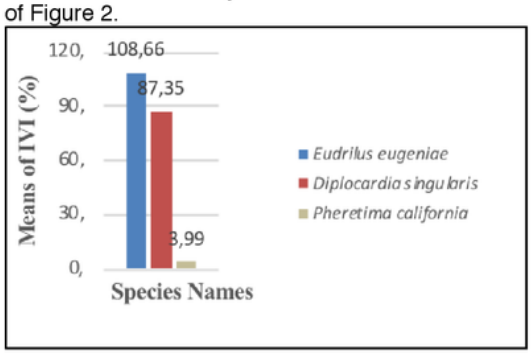

***Figure 2.** The bar graph of earthworm species diversity in study area II*

According to the research results, only two species of earthworms are found in study area III. This can be seen in the bar graph of Figure 3.

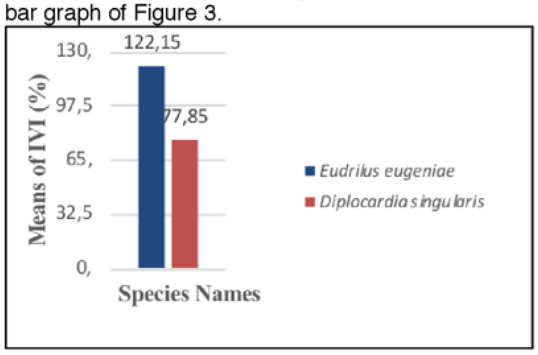

***Figure 3.** The bar graph of earthworm species diversity* in study area III

The bar graph of Figure 4 illustrates the two species of earthworms found in study area IV.

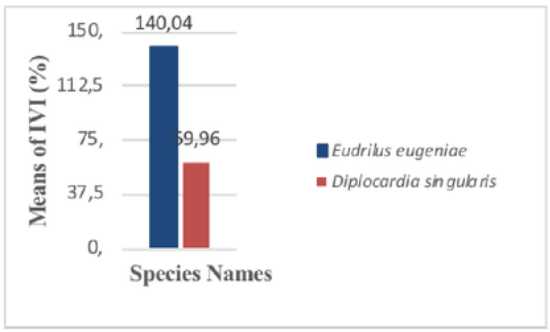

***Figure 4**. The bar graph of earthworm species diversity* in study area IV

The results of research in study area V show that there are also two species of earthworms found. It is illustrated in the bar graph of Figure 5.

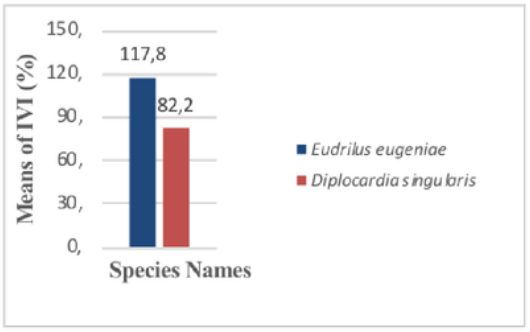

***Figure 5**. The bar graph of earthworm species diversity in study area V*

The results of the research in the five study areas (I, II, III, IV and V) suggest that there are generally three species of earthworms in the region of the Nglanggeran ancient volcano. The three species of earthworms and their average Important Value Index (IVI) in the five study areas are illustrated in Figure 6.

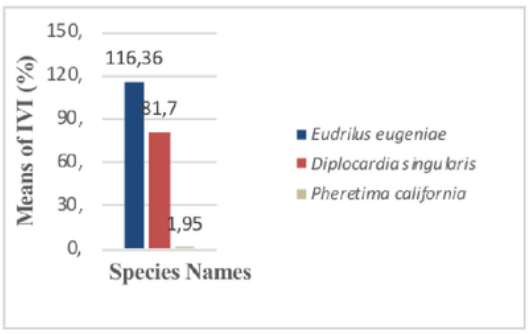

Figure 6. The bar graph of earthworm species diversity in all study areas

3.1.1 The Species Diversity Index of Earthworms

After the data on the diversity were analyzed, it is known that the diversity index in the 25 sectorsof the five study areas is as follows:

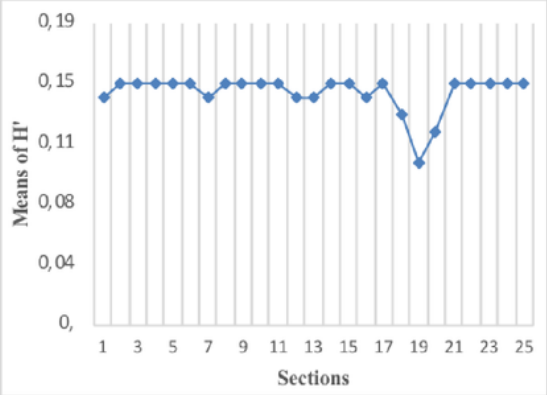

Figure 7. *The graph of means of species diversity index of earthworms in the five study areas*

Earthworms are soil macrofaunasthat play animportant role in the ecosystem. The fact that earthworms are bioindicators of healthy soil cannot be separated from the activities of the earthworms that affectthe structure of the soil, the dynamics of nutrients, water flows, and plant growth. Earthworms are beneficial for the ecosystem since they promote an increase in microbial activities, soil aggregation and infiltration [3]. The importance of earthworms in the ecosystem is viewed in three aspects. First, earthworms are relatively resistant to the direct impacts of agricultural and industrial activities on land and indirectimpacts of air pollution which deposits particles into the soil so that earthworms can be utilized as bioindicators as well as residue bio-monitors. Earthworms are also able to resist the impacts of pesticides, metals or toxic chemical compounds. Second, earthworms consumedead plants, secretions in the form of bodily waste and household waste that are rich in nutrients so earthwormsare useful in handlingtrash, which is a big problem in almost every city. Third, earthworms feed on a mixture of soil and organic matters. When they move, earthworms release mucus that is a source of nutritions for soil microbes so they can be used as bio-fertilizer and soil conditioner in the reforestation and rehabilitation of degraded and nutrient-poor soil, deforested areas, or abandoned mines [4 According to Kainde [5], the Important Value Index of a species isused as an indicator of the role of a species in abiological community. The greater the IVI of a species, the greater the role the species plays. In the five study areas, the IVI of Eudrilus eugeniae is the highest, with an average of 116.36%. Eudrilus eugeniae is a species of earthwormswhich is about 90 to 185 mmlong. It consists of between 140 and 211 segments and has a reddish dorsal surface [4]. Its original habitat is in the west African savanna. However, at present, there are a number of earthworm breeders across the world. In Cuba, India and the Philippines, Eudrilus eugeniaeare often used to produce vermicompostsin organic farming, while in North America and Australia they are bred for commercial usage such as for fish baits. These wormsare also known as 'African Night Crawlers' or 'ANC' [6]. Based on the research conducted by Made [6],Eudrilus eugeniae live in a pH level of 5.6 and 9.2 and an optimal temperature between 23°C and 31.5°C. A growth experiment carried out by Viljoen and Reinecke (Blackmore, 2015) suggests that the juvenilephase of Eudrilus eugeniae survives at a temperature of 12°C up to 30°C, whereas the optimal temperature for growth and reproduction is 25°C. Of all five study areas, the IVI of Eudrilus eugeniaein study area IV is the highest with a value of 140.04%. The high value index of Eudrilus eugeniaein this area indicates that this species plays a big role in thishabitat. Based on its role in the ecosystem, Eudrilus eugeniaeis classified in the epigeic group. Epigeic is a group of soil macrofaunas that live and eat on the ground. The big role of Eudrilus eugeniae in the community is inseparable from the suitable environmental abiotic conditions. The measurement results of the abiotic environmental conditions show that in study area IV, the average air temperature is 28.08°C and the average soil temperature is 25.92°C with an average pH of 6.27. Eudriluseugeniae live in a pH level of 5.6 and 9.2 and a temperature ofbetween 23°C and 31.5°C, with an optimal temperature for reproduction of 25°C. The results of soil temperature measurements show that study area IV provides the optimal temperature forEudrilus eugeniaetoreproduce and the pH level is at a tolerable rangeforthese earthworms so Eudrilus eugeniae dominate study area IV. According to Dominguez [7], at a temperature of 25°C the percentage of cocoons that hatch is 81%. In addition to this, the reproduction age of Eudrilus eugeniae is quite young.Based on research conducted by Reinecke et al. [7],Eudrilus eugeniaebeginsto produce cocoons at the age of 46 days. This is relatively early when compared to other earthworm species such as 6-8 weeks for Eisenia fetida(Hartenstein: Dominguez, 2001), 29-42 weeks forAllolobophora chlorotica, (Satchell: Dominguez, 2001), 10-14 months forMilsonia anomala (Lavelle: Dominguez, 2001) and 12-24 months forBimastos zeteki (Murchie: Dominguez, 2001). Soil moisture is another abiotic component that affects earthworms' habitat. According to Gunadi [8], the optimum soil moisture for worms to grow is 75%. The results of soil moisture measurements indicate that the average soil moisture in study area IV is 55.76%. Moreover, the trees in study area IV have thick leaves. This is proven by the air humidity of 71.4% and air temperature of 28.08°C. According to Hanafiah [4], when the soil is dry, worms move to a wetter place or remain where they are, unmoved. Another species of earthworms that has a high IVI is Diplocardia singularis. In study area I, the average IVI of Diplocardia singularis is 101.13%. According to Garman [9], Diplocardiawidely spreads in America and consists of 40 species. According to Hanafiah [4], the genus Diplocardiahas four main characteristics: (1) the clitella are in front of the 15th segment, (2) the setaefollow the lumbricine pattern, (3) the male pores are in the 18th segment, and (4) the spermathecae are in front of the 19th segment. It is acknowledged that environmental abiotic factors affect earthworms. In study area I, the average air temperature is 26.06°C, the average soil temperature is 24.92°C, the average air humidity is 80.54%, the average soil moisture is 50.72% and the average soil pH is 5.47. The average air and soil temperatures measured in study area I are not in the range of the optimal temperature for the growth of worms, which is 25°C. According to Hanafiah [4], Diplocardia in South America migrates from 10 cm to 40 cm below the ground in January (during winter) and returns to the surface in the spring. In study area I, the results of the measurements of the average air humidity and the average soil moisture are 80.54% and 50.72% respectively. Meanwhile,

the optimum humidity for earthworms to grow is 75% on average. This means that the air humidity and soil moisture in study area I do not support the optimum growth of earthworms. It can be seen from Figure 1 that the highest IVI in study area I is 101.13%. This study area is different than the others in terms of the lower pH in each of its sector. The pH levels in study area I are 5.79 (sector 1), 5.38 (sector 2), 5.47 (sector 3), 5.1 (sector 4), and 5.6 (sector 5). In general, earthworms reproduce in a more basal condition with a pH level ranging from 6 to 7.2. In study area I, the pH level is not in the range of the optimum level for earthworms. In contrast, the earthworm species that has the lowest average IVI of the three existing species is Pheretima california with the highest value of 5.74% (study area I). According to Shun [10], Pheretima california live on the surface and below the ground down to the medium depth. They are brownish-grey worms with a diameter of 5 to 8 mm. Generally, they are found in the piles of cow manure. Hanafiah [4] describes that the clitella of Pheretima california are present in the 11th and 12th segments and the setae follow the perichactine pattern. Shun [10] mentions that the optimum temperature for Pheretima california is 25°C. They live up to six years and it takes them 18 to 20 weeks to grow and become mature. This species of earthworms produces 20 cocoons annually. It takes longer for Pheretima california to mature than for Eudrilus eugeniae which needs about 46 days or approximately six weeks. The IVI of Pheretima california is lower than that of the other two earthworm species found living in the region of the Nglanggeran ancient volcano. The highest average IVI of this species is 5.74%, which is in study area I. The low average IVI of Pheretima california indicates its insignificant role compared to Eudrilus eugeniae or Diplocardia singularis. One of the factors that influence the existence of Pheretima california is the environmental abiotic conditions. Based on the results of the abiotic-condition measurements in study area I, the average air and soil temperatures are 26.06°C and 24.92°C respectively. It is also shown that the air humidity is 80.54%, the soil moisture is 50.72%, and the pH level is 5.47. The temperatures are not ideal for Pheretima california which needs an average temperature of 25°C. Furthermore, soil moisture is also an influential factor. Hanafiah [4] states that Pheretima california prefers damp conditions with high water concentrations and the general optimum soil moisture for earthworms is 75%. In study area I, the soil moisture (50.72%) is much lower than the optimum value. The same condition is also obvious regarding the pH level (5.47) which is lower than the optimum pH level for earthworms in general, which is between 6 and 7.2. Earthworms are also influenced by the C/N ratio. The C/N ratio factors is more likely related to their role as soil macrofaunas. The C/N ratio compares carbon to nitrogen. According to [4], earthworms like to feed on organic matters that contain a low C/N ratio. The C/N ratio of the leaves that fall on the ground in nature is considerably high. Carbon respiration of earthworms slowly changes and lowers the C/N ratio of the organic substances to nearly 20:1 and even lower in the worms' excretion materials. According to Hardjowigeno [11], the C/N ratio is considered low when it ranges between 5 and 10. The C/N ratio of soil is essential for microorganisms that regulate the fertility of soil. Sutanto in Luthfiyah [11] points out that if the C/N ratio is too low, the amount of substance needed and used by microorganisms as their energy sources is not adequate. As a result, in order to ensure their survival, microorganisms compete with the vegetation to fulfill their needs for nitrogen. The C/N ratio of lower than 20 indicates that nitrogen is experiencing mineralization [12]. Handayanto [3] confirms that organic matters that contain a high level of nitrogen and polyphenol increase the population of earthworms. Polyphenol which is present in leaf litters also influences earthworms. If the leaf litters contain a high level of polyphenol, earthworms will not decompose them. Polyphenol is an essential substance in determining the speed of the decomposition of leaf litters. Polyphenol reactswith nitrogen in leaf litters to produce a substance resistant to decomposition. The examples of plants that contain high levels of polyphenol include Acacia auriculiformis (>4%) and Albizia samanl (<4%) (Rindyastuti, 2010). These two types of vegetation are found in the region of the Nglanggeran ancient volcano. The small number of earthworm species found in the Nglanggeran ancient volcanic region and the lack of variety in the earthworm species in each study area influence the species diversity index of earthworms (Oligochaeta) in the Nglanggeran volcanic region. This is represented in the low diversity index. According to Price [13], the number of species and the abundance of species in a biological community are the parameters that determine the diversity index of an ecosystem. Besides species numbers and species abundance, species evenness also contributes to the diversity index. Hardjosuwarno [11] defines that the diversity is a value representing species richness (the number of species) and species evenness. The research results show that the diversity index in study area IV is the lowest with a value of 0.10 (sector 19). In this study area there are two different earthworm species present, namely Eudrilus eugeniae and Diplocardia singularis. The low diversity index in sector 19 of study area IV is possibly due to the environmental abiotic conditions that are not supportive. The results of the abiotic-component measurements in sector 4 of study area IV show that the air temperature is 35°C, the soil temperature is 27°C, the air humidity is 58%, the soil moisture is 50% and the pH level is 5.8. In comparison, the diversity index in the other study areas is more than 0.10 each. Three earthworm species are found in study areas I and II whereas two earthworm species are found in study areas III and IV. The diversity index affects the stability of an ecosystem. Odum [14] states that the diversity is identical to the ecosystem stability. The higher the diversity index of an ecosystem, the more stable the ecosystem is. The different diversity index in each study area is related to different environmental conditions in each study area. The low diversity index may also be caused by the domination of a species in a study area. In other words, there is a considerably high number of a particular species compared to the number of other species in the study area. The results of the regression analysis on the measurements of the abiotic factors suggest that only one of the abiotic environmental conditions, namely air temperature does have an effect on the species diversity index of the earthworms in the region of the Nglanggeran ancient volcano with a significant value of 0.042, which is lower than the alpha value (0.05). Meanwhile, other factors namely soil temperature, air humidity, soil moisture, pH level, and C/N ratio do not have considerable effects on the species diversity index since they result in significant values higher than the alpha value.

3.2 Education Aspects

The results of research on the species diversity of earthworms in the Nglanggeran ancient volcanic region were analyzed

further to see whether or not they were eligible for learning materials. There are six aspects that need to be assessed to verify the potentiality of a material as a resource to learn biology. According to Djohar [2], the six criteria required are the clarity of the availability potential of the objects and the issues raised, the conformity to the learning objectives, the clarity of the subject materials and targets, the clarity of the information that will later be exposed, the clarity of the exploration guidelines and the clarity of the achievement. Research results are considered to have the potential of learning resources when the objects and issues are available. In this research, the objects that were observed were the earthworms in the Nglanggeran ancient volcanic region. The results show that the available objects are the three species of earthworms consisted of two families namely Acanthodrilidae and Megascolecidae. There are two species from the family Acanthodrilidae, namely Diplocardia singularis and Eudrilus eugeniae while the family Megascolecidae is only represented by one species, which is Pheretima california. The issue raised in these research results is the species diversity of earthworms from the subclass Oligochaeta in the Nglanggeran ancient volcanic region. The results describe the different characteristics of different earthworms found that can be used as examples of the species diversity of the earthworms for students. The learning objectives of the biodiversity subject refer to the basic competency section 3.7 of the 2013 curriculum, which is to define the diversity in genes, species and ecosystem through observations. The learning objectives of the biodiversity subject are as follows: 1) Students are able to mention the different species of earthworms in the Nglanggeran ancient volcanic region, 2) Students are able to explain the concept of the species diversity of earthworms in this volcano. These objectives are covered in the research results. The research results in the species diversity of earthworms in the Nglanggeran volcano is said to have the potential of learning resources if they have clear subject materials and targets. The subject material is biodiversity and the targets are grade-X high school students. The research results contain the subject material needed which is the species diversity of earthworms in the Nglanggeran volcano. The clear material and targets of these research results fulfill one of the criteria of learning resources. The research results give information about the species diversity of earthworms in the region of the Nglanggeran ancient volcano. This is actual information obtained from the research location. The species diversity index of the earthworms in the Nglanggeran volcanic region is considered low. There are three species of earthworms found, namely Eudrilus eugeniae which has the highest average IVI of 116.36%, Diplocardia singularis with the average IVI of 81.70% and Pheretima california with the average IVI of 1.95%. This information can be used as a concept of learning material in the species diversity considering the findings of three earthworm species in the Nglanggeran ancient volcanic region. To reveal needed information, clear procedures of research are required during the exploration process. Based on the research results, the exploration guidelines involve clear procedures including setting the location of the study, selecting the object of the study, specifying the equipment and materials of the study, deciding research methodology and data analysis and drawing a conclusion. The research results can be implemented in schools to fulfill the requirement of biodiversity materials of basic competency sector 3.7 after also considering students' capabilities and the limited time. The clarity of achievement based on the results of the study is achieving the aims of learning biodiversity materials. The expected learning outputs are as follows.

a. Cognitive Skills

Cognitive aspects are related to the ability of the brain to respond to learning processes that involve memorizing, understanding, implementing, analyzing, evaluating and conducting. The expected cognitive-skill achievements are as follows:

1) Students are able to explain the concept of the species diversity of the earthworms.
2) Students are able to identify the examples of the species diversity of the earthworms.
3) Students are able to explain biological terms such as the scientific names of the earthworms, which are the focus of the research.

b. Affective Skills

Affective aspects are related to the results of students' learning processes which are reflected in their behaviors. The expected affective-skill achievements include:

1) Students are able to cooperate within their groups and are active in observation activities.
2) Students are able to accept different ideas during discussion sessions.
3) Students are able to learn to be responsible and to tolerate others during group activities.
4) Students are able to learn to be honest, careful, and discipline during observation activities.

c. Psychomotor Skills

Psychomotor aspects are related to the skills of students in gaining learning experience. The expected psychomotor-skill achievements are:

1) Students are able to operate research appliances.
2) Students are able to organize research results and make observation tables.

Considering all the requirements, the results of this research have the potential of learning resources for biology subject.The next step in the potential analysis is examining the process and the product of the research. The research process includes all activities conducted during research. The research results in facts that are generalized as concepts of materials and become the research product. Primack (Mumpuni, 2014) explains that learning materials which contain the conditions of the local area make a significant contribution to biodiversity conservations. One method used to introduce biodiversity conservations is the usage of local content and dialect in the learning material. According to Ramadoss and Moli [15], in India the implementation of local biodiversity in the learning process and its conversion for the continuing development have the potential of long-lasting impacts on students' behaviors and on shaping positive attitudes towards their future.

4 CONCLUSION

There are three species of earthworms found in the region of the Nglanggeran ancient volcano, which are Eudrilus eugeniae, Diplocardia singularis and Pheretima california. The

species diversity index of earthworms in this volcanic region is regarded low with the average diversity index (H') ranging between 0.10 and 0.15. The lowest H' is recorded in sector 4 of study area IV. One of the abiotic factors, which is air temperature, has a significant influence on the diversity index of earthworms in the Nglanggeran volcanic region. Meanwhile, the effects of other abiotic factors namely soil temperature, air humidity, soil moisture, soil pH level and C/N ratio on the diversity index of earthworms in this region are insignificant. The results of the potential analysis indicate that the results of the research on the species diversity of earthworms in the Nglanggeran volcanic region has the potential of learning resources for biology subject in high schools.

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