

Activity 1

Habitat

Rationale: The data collected for the Habitat Activity will be used for other activities. This lesson also provides opportunities to study the physical characteristics of the Habitat over a continuous period of time.

Objectives

One or more websites, videos, texts, etc should be explored, studied, discussed by the students before this vermiculture activity is started. The students need to have several completed lessons on vermiculture before beginning these activities. The inquiry approach for these activities is best accomplished when the students are already familiar with the task at hand. A successful worm bin should be on hand as an example.

- 1) Measure, record, and analyze the physical constants of the Habitat.
- 2) Collect data on selected variables of the Habitat.
- 3) Record the data in a journal and Data Table 1.
- 4) Record and analyze the data collected over a period of time (Activity 2).
 - a. Rate of change in the mass of vermicompost
 - b. Rate of change in the volume of vermicompost
- 5) Analyze, discuss, and predict future effects on the Habitat.
- 6) Recommend any changes deemed necessary.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F

3.6.7. A,B

3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

4.6.7. A,B,C

Math

2.1.8. A,B,D,G

2.2.8. A,B,F

2.3.8. A,B,D

2.4.8. A,B,D,F

2.5.8. A,B,C,D

2.6.8. A,B,C,E,F

2.7.8. B,C,D

2.8.8. F,G,H,I,J

2.10.8. A,B

2.11.8. A,B

Materials

Worm bin	Graphing calculator (optional)
Scales (bathroom)	Graphical Analysis (software)
Rulers	Breeder worms
Flexible tape measure	

Introduction

The physical characteristics of the Habitat are very important. The students will collect and record the following data in Data Table 1: the amount of space occupied by the bedding, the volume of air above the bedding, the mass of the bedding, and the volume of the bedding. The students, with guidance/coaching, will decide how to collect the data and how often to collect the data.

The change in volume and mass of the bedding will give students an indication of the environmental quality of the Habitat. As these data are collected and analyzed, the students will begin to develop a quantitative record of the health of the Habitat.

Strategies

This activity is best done with minimal guidance if you want students to develop a sense of inquiry. Have each group “brain storm” the possible constants and variables needed. Have each group report to the whole class, providing a short period of time for questions, answers, and advice. Each group should then discuss the information and advice received from their classmates. They should revise and turn in the data table. The data table will then be evaluated and returned to the student/group for revising or to be used by that group. An acceptable data table format must be completed by each group before the next activity period.

Procedure

This will vary from class to class as the groups develop their personal plans for the collection, recording, and analysis of data. A typical procedure is outlined below.

- 1) Record the mass of the empty clean bin (do not forget the lid).
- 2) Record the volume of the bin.
 - a. This will require the use of some geometry and some estimation (corners).
 - b. A height scale in centimeters should be developed and placed on two sides of the bin. This will allow students to quickly determine the height of the bedding (vermicompost).
 - c. The average area (sum of bottom and top area divided by 2) will need to be calculated each time if a commercial bin is used.
 - d. If commercial bins are not used and a rectangular bin has been constructed, the area will remain the same.
- 3) Record the mass of added bedding in the journal and Data Table 1.
- 4) Record the mass of added water in the journal and Data Table 1.

Expectations

The students should be able to:

- 1) set up the Habitat and understand what constants and variables are needed for this project.

Activity 2

Habitat 2

Rationale: This activity looks at the data collected for the past six weeks. Careful analysis of the data will provide a foundation for most of the following activities.

Objectives

- 1) Design an experiment to determine the rate of decomposition.
- 2) Design an experiment to determine the rate of growth of the worms.

PDE Standards

Science and Technology

- 3.1.7 A,B,C
- 3.2.7 A,B,C,D,E,F
- 3.5.7. D
- 3.6.7. A,B
- 3.7.7. A,B,C,D

Environment and Ecology

- 4.1.7. A,B,C
- 4.2.7. A,C
- 4.6.7. A,B,C

Math

- 2.1.8. A,B,D,G
- 2.2.8. A,B,F
- 2.3.8. A,B,D
- 2.4.8. A,B,D,F
- 2.5.8. A,B,C,D
- 2.6.8. A,B,C,E,F
- 2.7.8. B,C,D
- 2.8.8. F,G,H,I,J
- 2.10.8. A,B
- 2.11.8. A,B

Materials

Bin
Scale (Bin)
Balance (worms)
25-mL graduated cylinders

Introduction

The Habitat will be a contained space of many metabolic activities. The worms' food "garbage" will begin to decay microbially and the worms will also break down the food by carrying on normal metabolic activities. These metabolic activities are easy to measure and analyze. In regards to burying the food many vermiculture experts suggest that a feeding grid should be established and strictly adhered to; others suggest the food should be mixed thoroughly in the entire top layer (2 to 3 cm thick). One

method should be selected and continued for the course of the experiment. This Activity needs to be started with breeder worms, not bedding worms.

Strategies

Before this activity is started have students determine what variables would be best suited to determine the quality of the Habitat. Discuss the activities the worms carry on each day and how best to measure these variables. As stated before, these activities are intended to be used with the inquiry approach to learning science. Students should discuss the biological and chemical activities taking place in the bin. Some teachers have a bin filled with bedding and make it into a hot-compost heap to compare with data collected from the worm bin. For the following experiments, the data collected will act as a “control,” comparing the new data to the average of the previous data or the recorded trends. Many real science experiments do not have controls.

Procedure

The procedures will vary from class to class, but basically the students need to select a specified number of variables to study and decide how to best collect the data. If only one large worm bin is available, each group should pick/designate a different set of variables. The best method is to have a small bin for each group and each group will have one or more variables common to all groups and a few specific variables. The following are a list of possible variables that can be studied. This list is by no means complete.

- 1) Mass of food added
- 2) Mass of run off water
- 3) Mass of vermicompost
- 4) Mass of worms
- 5) Number of worms
- 6) Average mass of the worms
- 7) Temperature
- 8) Relative humidity
- 9) pH of vermicompost
- 10) pH of run-off water
- 11) Amount of $\text{CO}_2(g)$ above the vermicompost
- 12) Amount of $\text{O}_2(g)$ above the vermicompost
- 13) Length of individual worms
- 14) Density of the compost
- 15) Aversion to light

Actual lesson plans for most of the above will follow, as well as additional activities. It is imperative that students design as much of the experiment as possible, with guidance.

Typical students' ideas

- 1) Sort, weigh, and count the worms every week and chart their growth.
- 2) Weigh the vermicompost and determine the rate of decay.
- 3) Count the number of worms and chart the increase in the population.

Middle School Activities for Vermiculture

- 4) Compare the mass of the food added to the change in mass of the worms and vermicompost.
- 5) Determine the amount of heat produced by the vermicompost and lost to the environment (a possible project though too complicated for MS).

Expectations

The students will be able to develop:

- 1) a sense of how real scientific experimentation occurs.
- 2) a sense of what are variables and constants.
- 3) a workable method for collecting data on selected variables.
- 4) several drafts of the experimental procedures.
- 5) several tables for recording data.
- 6) an understanding of dependent and independent variables.

Activity 3

Worm Growth

Rationale: Much of the success of the Habitat will depend upon continued optimal environmental conditions for the worms. The most important measure would be the increase in worm mass. The change in mass of the worms can be used with other variables, such as a decrease in mass or volume of vermicompost.

Objectives

- 1) Design a method for collecting all of the worms.
- 2) Develop an understanding about the connection between environmental variables and change in the mass of worms.
- 3) Develop an understanding about which environmental variables may be causing changes in worm mass.
- 4) Develop a sense of how to determine which variable(s) is causing the change in mass.
- 5) Develop an understanding of the accuracy and precision needed for the correct measurement of the variables.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F

3.6.7. A,B

3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

4.6.7. A,B,C

Math

2.1.8. A,B,D,G

2.2.8. A,B,F

2.3.8. A,B,D

2.4.8. A,B,D,F

2.5.8. A,B,C,D

2.6.8. A,B,C,E,F

2.7.8. B,C,D

2.8.8. F,G,H,I,J

2.11.8. A,B

Materials

Bin

Balance (centigram)

Light source

Protective gloves

1-L plastic food container

White poster board, nonabsorbent

Introduction

The best way to determine the health of the Habitat is to analyze the growth data. One of the best procedures is to measure the total mass of the worms at selected intervals. This requires a careful removal of the worms from the vermicompost. The worms should be decomposing the garbage/food, metabolizing the food as stored energy, and converting it to body mass, eggs, and new worms. However, if environmental conditions in the Habitat are not ideal or only near ideal, a slight increase in mass may occur, but new worms will be in very short supply.

Strategies

The standard deviation and variance can be omitted. However, the calculator can calculate both and students can experience using the results without a complete understanding of the mathematics involved. One of the overarching concepts of this and future activities is to determine the environmental conditions that influence the growth of worms. The easiest procedure is to weigh the worms every week -- after the Habitat is well established. Under certain conditions the worms will grow well and their numbers as well as their total mass will increase. These changes in mass can be compared to the recorded conditions in the Habitat. Of course, if the class has more than one habitat each Habitat can be used for selected variables. Use one or more Table 1s to record the mass and the environmental variable(s) conditions for each Habitat. Try not to crush or destroy any of the small 3 – 4 mm cocoons. Each cocoon contains 1 – 3 small eggs that can hatch into small worms.

Procedure

- 1) Remove about $\frac{1}{2}$ of a liter of vermicompost and place it in a pile on a white poster board. Repeat this with the remaining vermicompost.
- 2) Shine a 200 watt light bulb on the piles. Gently remove the outer layers of each pile and place any worms caught into the weighing box. Most of the worms will go the bottom center and you will eventually have them all corralled.
- 3) Tare the weighing box before adding any worms or record the mass of the box in the journal and in Table 1.
- 4) Record the mass of the clean worms in the journal and in Table 1.

Expectations

The students should be able to:

- 1) notice a change in the mass of the worms and the number of new worms (small).
- 2) note the conditions of the vermicompost: dampness, smell, and temperature.
- 3) determine the rate of growth in grams/week and % change/week.
- 4) determine the rate of change by entering the data (mass in List 2 and the time interval in List 1) into the graphing calculator and perform a linear regression on List 1 versus List 2.

Activity 4

Analysis of Worm Growth

Rationale: The data collected are important for the success of the Habitat. The analysis of these data will help determine how to modify the environmental conditions, if necessary.

Objectives

- 1) Analyze the worm growth data by hand.
- 2) Perform a one-variable statistic on the data.
- 3) Compare the hand derived values to the calculated values.
- 4) Determine the mean (average), maximum, minimum, range, variance, and standard deviation.
- 5) Determine which of the above analyses are best for determining the optimum Habitat conditions.

PDE Standards

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

4.3.7. B

4.6.7. A,B,C

Math

2.1.8. A,B,D,G

2.2.8. A,B,F

2.3.8. A,B,D

2.4.8. A,B,D,F

2.5.8. A,B,C,D

2.6.8. A,B,C,E,F

2.7.8. B,C,D

2.8.8. F,G,H,I,J

2.11.8. A,B

Materials

Graphing calculator

Computer

Graphical Analysis (software)

Data from Worm Growth Activity

Introduction

This activity will familiarize the students with the statistics applications on the graphing calculator as well as the meaning and use of several common statistical analyses. The mean or average is the sum of the data collected divided by the number of data points. The range is the difference between the maximum value and the minimum value. The variance is the average of the differences between the measurement and the mean squared.

$$\text{variance} = \frac{\text{sum of the (measurement - average*)}^2}{\text{number of measurements}}$$

The standard deviation is the square root of the variance, $\sqrt{\text{variance}}$.

* This is the average of each group's values.

Strategies

Ideally the students should play a large role in determining the analysis of the data. However, they will need to begin at a fundamental level. The average of the measurements will help them become familiar with analysis of data and the power of a graphing calculator. Have the students calculate the average by hand on the calculator by averaging the mass measurements from Data Table 1 of Worm Growth Activity. These data can be then entered into the appropriate calculator list. Students should complete Data Table 1 for this activity. One variable statistics (1-Var Stats) will give them the calculated mean or average. The students should complete the calculation for the variance and standard deviation. Then they should compare the range to the variance and standard deviation. Have students describe what they observed by writing a short essay. If time permits have them explain and or present their findings.

Procedure

- 1) Enter the change in mass measurements into the calculator and find the average. Record the data in Table 1.
- 2) Enter the same data into List 1. Select STAT, EDIT, "1-var Stats," and then press ENTER. The value after \bar{x} is the average. Compare the average to the measured mass. If different by more than a tenth, consult the teacher.
- 3) Complete the columns in Data Table 1 for variance.
- 4) Take the square root of the variance, $\sqrt{\text{variance}}$.
- 5) Compare to the standard deviation, S_x (found in 1-var Stats).

Expectations

The student should be able to:

- 1) determine the average, range, max and min by hand and compare to the STAT values.
- 2) determine the differences between average measurements, square the values, and find the average - variance.
- 3) take the $\sqrt{\text{variance}}$ - square root of the variance.
- 4) complete Data Table 1 and determine the standard deviation.
- 5) develop an understanding of how the change in mass is a result of the conditions of the Habitat.

Activity 5

Temperature of Vermiculture

Rationale: The temperature of the Habitat is crucial to its success. A data collection system needs to be used to collect data on a continuous basis. The easiest method is to use the system that interfaces with the Texas Instruments graphing calculator TI 83/84. The temperature and changes in temperature will affect the success of all of these activities. A constant ($22 \pm 3^{\circ}\text{C}$) temperature is optimum.

Objectives

- 1) Set up a system for collected temperature data.
- 2) Determine the optimum intervals.
- 3) Compare the temperature of the Habitat with the ambient temperature.
- 4) Determine if any insulation is necessary to maintain a constant temperature.
- 5) Learn how to use the DataMate application.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F

3.6.7. A,B

3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

4.6.7. A,B,C

Math

2.1.8. A,B,D,G

2.2.8. A,B,F

2.3.8. A,B,D

2.4.8. A,B,D,F

2.5.8. A,B,C,D

2.6.8. A,B,C,E,F

2.7.8. B,C,D

2.8.8. F,G,H,I,J

2.11.8. A,B

Materials

Class Habitat

Temperature sensor

Graphing calculator

Computer

Graphical Analysis

Introduction

The rate of metabolism is controlled by the temperature of the worms. To some extent this metabolic process produces excess heat energy as well as the composting/decomposition reactions that are also taking place in the Habitat. The ambient temperature of the room affects the rate at which the Habitat loses or gains heat. Too low of a temperature -- the metabolic reactions proceed too slowly; too high of a temperature - - the reactions proceed very fast. To an extent, large variations in temperature may cause the worms to not metabolize correctly, breed and not reproduce, or die. Most worms used for vermiculture metabolize best between 15°C and 25 °C. Most do best at 22°C +/- 3 °C. The Habitat should not sit on a table that gets direct sunlight or in the stream of cool air from an AC vent.

Strategies

Help the students decide on the number of temperature readings to record each day and the interval between the readings. With the CBL2 system, TI 83/84, and temperature sensor, readings can be taken every few minutes for a week at a time. However, the temperature readings will probably only change significantly when the lid is open, worms are counted, at night when the school temperature is lower, the AC turns off and on, and over weekends. To have these readings and to be able to compare them to the changes in worm mass will help determine the optimum temperature. If the optimum temperature cannot be maintained, the Habitat can be put inside a larger box or a larger bin with shredded paper between all sides, bottom, and the top of the worm bin. Too much humidity and/or too much moisture in the vermicompost will also cause large fluctuations in temperature.

Procedure

- 1) Set up the DataMate application to collect data with the appropriate temperature sensors.
- 2) Students should decide on the number of data points (temperature readings) collected per 24 hours, diurnal. 24 or 48 are good starting values. Every ½ hour or every hour for 7 days will be a total of 168 and 336, respectively.
- 3) Set up the CBL2 with three appropriate temperature sensors. One sensor is on the outside of the Habitat and the other two should be placed in the vermicompost at places decided upon by the students.
- 4) Collect the data for a week. Download the data to a computer via Graphical Analysis. Complete a 1-Var Stat on the data for the week.
- 5) Separate out the data by days and complete a 1-Var Stat analysis for each day.
- 6) Using the statistic button to calculate 1-Var Stat on each day and compare to the values for the 1-Var Stat for the week.
- 7) Were any diurnal means (averages) farther from the weekly mean than others? What days were they? What can be done to correct these temperature fluctuations?
- 8) What were the diurnal standard deviations? Compare them to the weekly standard deviations.
- 9) Place the weekly standard deviation in the last cell in the last column.
- 10) Attach a print out of the weekly temperature readings from Graphical Analysis.

Expectations

The students should be able to:

- 1) use the DataMate application and set up more than one sensor.
- 2) make good decisions about the time interval between readings.
- 3) make better decisions about the location of the Habitat and the sensors in or around the Habitat.
- 4) recall how to do a 1-Var Stat and recall the meaning of mean/average, range, and standard deviation.

Data Table 1

Day	Average temp	Range of temp		Standard deviation
		Max	Min	
1				
2				
3				
4				
5				
6				
7				
Average of following values				

Activity 6

Smell of the Habitat

Rationale: The odor or smell of the Habitat is an extremely good indicator of the health of the vermiculture. This seemingly unimportant variable's measurement must be collected and recorded each day. Many times the change in odor will be the first signal that something is environmentally amiss.

Objectives

- 1) Determine an adequate odor scale for each Habitat.
- 2) Discuss and agree upon a set of four to six odor descriptors.
- 3) Realize that it is difficult to easily graph temperature or humidity vs. descriptors.
- 4) Derive a sequential number value for each descriptor.
- 5) Present/explain a system to peers.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F

3.6.7. A,B

3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

4.6.7. A,B,C

Materials

Habitat

Introduction

The odor of the vermicompost is an excellent qualitative measure of Habitat health. The odor associated with garbage may be present for a short time after adding it to the vermicompost and should not be confused with the presence of rotting garbage. If the Habitat is not healthy, the worms will not decompose the garbage in a normal time frame. Also, if the worms are healthy and too much worm food has been added, a garbage odor will be present for a longer period of time than normal. Therefore, the worms cannot keep up with the excess food. This will also occur sometimes after harvesting worms since the same amount of food will be added and there are too few worms to decompose that amount of food.

Strategies

The ideal situation will be to have students with a refined sense of smell volunteer to be in the odor sensor group. It may be difficult for students to not gag at an unhealthy habitat. Some encouragement may be necessary from the teacher. Students with a too refined sense of smell will get carried away with the number of descriptors. Students without a refined sense of smell will not be discerning enough. Have students

Activity 7

Humidity of Habitat

Rationale: The wetness of the vermicompost is one of the variables that will have the most detrimental effect on the growth of the worms. One way to determine the wetness of the Habitat is to monitor the humidity of the air above the vermicompost. A too wet vermicompost will mask the correct earthy odor associated with a healthy Habitat.

Objectives

- 1) Determine the humidity of the air above the vermicompost.
- 2) Use the humidity value area measure of the wetness of the vermicompost.
- 3) Compare the humidity of the air with the actual water content of the vermicompost.
- 4) Compare the relationship between the humidity, water content, and growth of the worms.
- 5) Compare and correlate the smell value associated with Activity 3 with the humidity of the air above the Habitat.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F

3.5.7. D

3.6.7. A,B

3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

4.6.7. A,B,C

Math

2.1.8. A,B,D,G

2.2.8. A,B,F

2.3.8. A,B,D

2.4.8. A,B,D,F

2.5.8. A,B,C,D

2.6.8. A,B,C,E,F

2.7.8. B,C,D

2.8.8. F,G,H,I,J

2.11.8. A,B

Materials

CBL2

Humidity sensor

TI 83/84

Computer

Graphical Analysis

Duct tape

Introduction

The water content of the vermicompost should not exceed 2 to 3 times the mass of the original mass of the shredded paper, 60 – 70% moisture. This may be very difficult to maintain, especially after adding fresh food. When the vermicompost is maintained correctly, the water content of a healthy Habitat will not exceed 60 – 70% of the mass of the worms, castings, and partially decomposed food. If excessive water appears in the bottom of the worm bin the total water content will be too high. To help maintain a healthy vermicompost, monitoring the humidity will prove to be well correlated with the water content of the vermicompost.

Strategies

Have students discuss within their groups how to best monitor the water content of the vermicompost. One of the easiest methods is to physically weigh the vermicompost and monitor any changes. However, whenever samples are collected for weighing, the vermiculture is shocked, which will lead to a day or more of re-habitation. Also the water content will be much higher near the bottom of the vermicompost than at the top. Once the students decide to also use a humidity sensor, the same thought processes that went into establishing a data collection schedule for the temperature measurements should ensue. However, a correlation must be established and weighing samples of vermicompost and comparing those masses to the humidity must be established. Once the relationship has been established very few, if any weighings of vermicompost will need to be done for only water content. However, the lack of an earthy smell to the vermicompost will occur within a few days of excessive humidity readings.

Procedure

- 1) Press the APPS button and select DataMate.
- 2) Set up the CBL2/TI 83/84 to record humidity values.
- 3) Place the humidity sensor near one of the “exiting” air holes in the Habitat.
- 4) Use duct tape to hold the sensor in place.
- 5) Remove all worms, castings, cocoons from several samples, dry under a heat lamp, and weigh the dry compost.
- 6) Determine the average water content of each sample of the vermicompost. Record the mass of the samples in Data Table 1.
- 7) Download the humidity measurements to the computer using Graphical Analysis.
- 8) Fill in Data Table 1 for this activity.
- 9) Determine what sets of humidity measurements should be entered into Data Table 1.
- 10) Determine what humidity values in percent relative humidity correlate to water content.

Activity 8

Counting and Classifying Worms

Rationale: The number of young worms in the vermiculture is a good indication of the health of the Habitat. The number of new hatchlings can be determined by sorting and counting. If the worms were sorted and counted carefully when they arrived or when a new Habitat was started, then the sizes and numbers at any time after that can be compared.

Objectives

- 1) Learn how to sort and size worms.
- 2) Determine how size relates to maturity or age of the worms.
- 3) Sort, count, and record measurements accurately.
- 4) Display the measurements in graphical form.
- 5) Analyze the measurements and use this analysis in later activities.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F

3.6.7. A,B

3.7.7. A,B,C,D

Math

2.1.8. A,B,D,G

2.2.8. A,B,F

2.3.8. A,B,D

2.4.8. A,B,D,F

2.5.8. A,B,C,D

2.6.8. A,B,C,E,F

2.7.8. B,C,D

2.8.8. F,G,H,I,J

2.11.8. A,B

Materials

Habitat worms

Plastic weighing pans

Rulers

Spatulas

Balance, centigram

Introduction

The newly hatched, healthy worm is between 2 – 3.5 cm long and at reproductive maturity averages about 6 – 10 cm, with a maximum of 13 – 14 cm. Under optimum conditions the worms can double in mass every three months. The average incubation period for the worms is between 32 and 73 days, depending on the Habitat's conditions. Healthy, sexually mature worms (*E. fetida* or *E. andrei*) will produce about four cocoons/week. The hatching rate can be anywhere between 70% and 90% with optimum conditions. About 3 – 4 hatchlings/cocoons will survive in a cocoon. This will

yield between 10 to 15 young per week per adult. The average time for *E. fetida* cocoons to hatch is between 1 – 2 ½ months. After hatching it will take 2 - 2 ½ months to reach reproductive maturity; a band or clitellum will appear. Between 3 and 5 months the amount can increase by nearly an order of magnitude. However, the Habitat will have a maximum carrying capacity; this means the mass of the worms can maximally double every 3 – 4 months. If a small amount of worms was started with – 100 grams – the spectacular population explosion is more likely to occur during the first one or two cycles.

Strategies

This activity can be completed earlier if the class habitat was stocked with bed-worms instead of breeder-worms. Students should read articles or find websites devoted to vermiculture to become well versed in the anatomy, physiology, reproduction, and optimum environmental conditions. Then they should decide on a system of classifying the worms. The students should also find pictures of *E. fetida*, *E. andrei*, or the worms used in the Habitat. Pictures showing how to collect, wash, count, weigh, sort, etc. the worms should be readily available to all students. The best classification system is the one the students devise, but usually the teacher must intervene. Data Table 1 is a typical classification system. Of course, this is the activity that is the most invasive and potentially dangerous to the vermiculture. It is imperative the students be very careful and not injure any worms. If any worms are injured they must be separated from the culture; injured/dying/dead worms can potentially have serious effects on the Habitat unless they are replaced.

Procedure

CAREFULLY CAREFULLY!!!!

- 1) Collect all of the worms in a dimly lit place.
- 2) Wash (water temperature the same as the Habitat's) the detritus off of them.
- 3) Place them on paper towels and blot fairly dry just for weighing.
- 4) Weigh the total amount.
- 5) Sort into the devised classes (be sure to keep them moist).
- 6) Record pertinent data in the journal and Data Table 1.

Expectations

The students should be able to:

- 1) make decisions about a classification system.
- 2) develop good methods for handling worms quickly and carefully.
- 3) sort carefully and accurately.

Typical Classification system

Hatchling: 1 – 3 cm

Juvenile: >than 3 cm, but no band (clitellum)

Mature: has band (clitellum)

Activity 9

Carbon Dioxide

Rationale: The amount of carbon dioxide is related directly to the metabolic activity. Thus these measurements are a very good indication of the rate of metabolism; that is, growth and reproduction. The amount of carbon dioxide above ambient values (ca. 400ppm) will be a quantitative measurement of the amount of activity by the worms.

Objectives

- 1) Determine the amount of carbon dioxide produced by the worms.
- 2) Determine if the amount of carbon dioxide produced is related to any of the other measurements.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F

3.6.7. A,B

3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

4.6.7. A,B,C

Math

2.1.8. A,B,D,G

2.2.8. A,B,F

2.3.8. A,B,D

2.4.8. A,B,D,F

2.5.8. A,B,C,D

2.6.8. A,B,C,E,F

2.7.8. B,C,D

2.8.8. F,G,H,I,J

2.11.8. A,B

Materials

Carbon dioxide sensor

CBL2

TI 83/84

Computer

Graphical Analysis

Duct tape

Introduction

The amount of CO₂ produced diurnally will be a valuable indicator of worm growth. The worms carry on cellular respiration 24 hours a day. The nearer the physical conditions in the vermicompost are to the optimum, the greater the amount of cellular respiration. The amount of CO₂ produced above the ambient value under optimum conditions will be related to the mass of the worms. The CO₂ will be produced by the

worms in the vermicompost and it will diffuse rather rapidly to the surface and into the air space above.

Strategies

It would be ideal if the students could be guided into discovering/recalling the above information before this activity is designed. The carbon dioxide sensor uses a laser to excite a photo receptor (detector) – the frequency of the laser light is absorbed by carbon dioxide. Thus the more carbon dioxide in the air, the more the laser light is absorbed; the lower the amount of reference laser light reaching the detector, the greater the amount of CO₂. Once again, the students should determine the time schedule for the data collection.

Procedure

- 1) Press the APPS button and select DataMate.
- 2) Set up the CBL/TI 83/84 for the CO₂ sensor.
- 3) Duct tape the sensor to the bottom of the lid.
- 4) Start the data collection.
- 5) At the end of the collection period, download the data using Graphical Analysis.
- 6) Attach a copy of the data to this activity.
- 7) Enter the CO₂ data into List 1 and add other data sets that will help determine if the amount of CO₂ is related to worm growth.
- 8) Perform several linear regressions with CO₂ measurements and other variable measurements.

Expectations

The students should be able to:

- 1) determine a meaningful time schedule for data collection.
- 2) program the Datamate program with coaching.
- 3) decide how to compare CO₂ measurements to other variables.
- 4) design the Data Table(s), methods, and present/explain the ideas to the class.
(Groups)

Activity 10

Atmospheric O₂ Content of Vermicompost

Rationale: The consumption of atmospheric O₂ is an indication of the health and rate of metabolism in the vermiculture. This is one more metabolic indicator of the overall efficiency of the Habitat.

Objectives

- 1) Determine the rate of O₂.
- 2) Compare the O₂ rate to other metabolic indicators.
- 3) Determine the agreement of the relationship with the actual data points.

PDE Standards

Science and Technology

- 3.1.7. A,B,C
- 3.2.7. A,B,C,D,E,F
- 3.6.7. A,B
- 3.7.7. A,B,C,D

Environment and Ecology

- 4.1.7. A,B,C
- 4.2.7. A,C
- 4.6.7. A,B,C

Math

- 2.1.8. A,B,D,G
- 2.2.8. A,B,F
- 2.3.8. A,B,D
- 2.4.8. A,B,D,F
- 2.5.8. A,B,C,D
- 2.6.8. A,B,C,E,F
- 2.7.8. B,C,D
- 2.8.8. F,G,H,I,J
- 2.11.8. A,B

Materials

CBL2	Oxygen sensor
TI 83/84	Graphical Analysis (software)
Computer	

Introduction

The worms consume O₂ 24 hours a day and produce CO₂ 24 hours a day. The consumption of CO₂ has already been documented in Activity 8 and now the relationship between CO₂ production and O₂ consumption will be documented. The O₂ sensor measures the amount of O₂ in the sample compared to the normal amount of O₂ present in the atmosphere, that is, the sensor will reproduce the normal amount of O₂ as about 19% in the classroom and in an active vermicompost, a reading below the room reading.

Strategies

The students will need very little coaching for this experiment if most of the other inquiry activities have been completed. Students should read about the O₂ sensor and discuss, in groups, how to best design the experiment. A review of metabolism and the composition of the atmosphere may be necessary. The students should be able to determine what other variables, from previous experiments, can be studied to observe any relationships.

Procedure

- 1) Press the APPS button and select DataMate.
- 2) Set up the O₂ sensor for the appropriate sampling length and interval.
- 3) Carefully excavate an indentation in the vermicompost around a 250-mL beaker.
- 4) Mount the O₂ sensor under the bib lid so the detector end of the sensor is in the indentation, BUT not touching any vermicompost. (This is best accomplished with a wire frame resting on the vermicompost.)
- 5) Download the data to the computer and attach a set of the data to this activity.

Optional

- 6) Press the 2nd function key and then the "0" key (catalog).
- 7) Press the 'x⁻¹' key (letter D).
- 8) Scroll down to DiagnosticOn and press enter.
- 9) Perform a linear regression on the two variables in question.
- 10) When the slope is displayed, numerical values for "r" and "r²" will be, also.
- 11) The "r" value will be a number between 0 and 1. The closer the value is to 1, the closer the data points (coordinate pairs) are to the best fit line.
- 12) Draw conclusions from the results.

Expectations

The students should be able to:

- 1) design the experiment.
- 2) design a Data Table.
- 3) set up the experiment.
- 4) program the DataMate application.
- 5) collect the data and analyze the data.
- 6) determine if other variables have a relationship.
- 7) draw conclusions from the results obtained.

Activity 11

Analysis of CO₂ Data

Rationale: The amount of CO₂ produced by the worms can be measured directly and then related to other variables. To some extent non-worm decomposition of the garbage is also taking place and producing CO₂. In a later activity, students can pursue this corrective measure to the CO₂ collected during these simpler measurements.

Objectives

- 1) Make decisions about what variables may have a relationship.
- 2) Enter data into a graphing calculator.
- 3) Select the proper regression.

PDE Standards

Science and Technology

- 3.1.7. A,B,C
- 3.2.7. A,B,C,D,E,F
- 3.6.7. A,B
- 3.7.7. A,B,C,D

Environment and Ecology

- 4.1.7. A,B,C
- 4.2.7. A,C
- 4.6.7. A,B,C

Math

- 2.1.8. A,B,D,G
- 2.2.8. A,B,F
- 2.3.8. A,B,D
- 2.4.8. A,B,D,F
- 2.5.8. A,B,C,D
- 2.6.8. A,B,C,E,F
- 2.7.8. B,C,D
- 2.8.8. F,G,H,I,J
- 2.11.8. A,B

Materials

TI 83/84
Graphical Analysis (software)
Computer

Introduction

Cellular respiration is carried on by all living members of the animal Kingdom. *E. fetida* or *E. andrei*, the red worms used in the vermiculture are typical annelids. The worms carry on cellular respiration by absorbing oxygen through the skin and releasing CO₂ by the same process. The previous activities have taken advantage of these traits and the CO₂ measurements will aid in the study of growth and reproduction (fecundity).

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The amount of CO₂ released, compared to the increase in worm mass, should show a direct relationship.

Strategies

Students will need to review the concept of cellular respiration in animals. The release of CO₂ gas as a by-product of cellular respiration is important for an understanding of how the amount of CO₂ *released* can be related to growth and maintenance. Show the students that a direct relationship exists between the amount of O₂ absorbed through the moist skin of the worms and the amount of CO₂ released.

Procedure

- 1) Use the data from Data Table 1 in Activity 8 for this Activity.
- 2) Enter the selected data into the proper lists.
- 3) Find the range, max, min, and standard deviation for each list.
- 4) Perform a linear regression on selected lists to determine if there is a relationship.
- 5) Record the values in Data Table 1.

Expectations

The students should be able to:

- 1) observe and realize that trends near or on a specific date are important.
- 2) perform a 1-Var Stat on selected data.
- 3) select the variables that have relationships.
- 4) perform a linear regression on selected Lists (variables).

Data Table 1 *(Typical Table)*

Variable	Maximum	Minimum	Range	Standard Deviation	Slope (+/-)

Activity 12

The pH of the Habitat

Rationale: A healthy Habitat should have a pH that is slightly on the acid side. The optimum is pH of 6.5 +/- 0.2. However, it has been determined that *E. fetida* can tolerate a very wide range of pH conditions. Any rapid change towards acidic or alkaline conditions does need to be addressed immediately.

Objectives

- 1) Learn the basics of acids and bases as they relate to vermiculture.
- 2) Observe the pH of household products and food products.
- 3) Understand how these products could change the conditions of the Habitat.
- 4) Apply this understanding to the health of the Habitat.
- 5) Make connections between pH and other conditions.
- 6) Observe how an extreme pH in one area of the Habitat can affect other sections.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F

3.6.7. A,B

3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

4.6.7. A,B,C

Math

2.1.8. A,B,D,G

2.2.8. A,B,F

2.3.8. A,B,D

2.4.8. A,B,D,F

2.5.8. A,B,C,D

2.6.8. A,B,C,E,F

2.7.8. B,C,D

2.8.8. F,G,H,I,J

2.11.8. A,B

Materials

CBL2 and pH sensor

Plant pH meter

Introduction

A plant pH sensor is good for this experiment since it requires less moisture than a Vernier pH sensor does. The Vernier pH sensor needs to be submerged in very wet vermicompost; usually the water content needed for this sensor would be too high for a healthy Habitat. This requires that students add a few grams of vermicompost to a few

mL of distilled water. Usually an extreme condition (pH < 5 or > 8) of the vermicompost indicates rotting, uneaten, and/or excess garbage or dying or dead worms. The real value of the pH measurements is that any rapid changes in pH indicate something unusual. If rapid changes in pH conditions can be observed early and corrected, the worms will be fine. However, it may take several weeks for the vermicompost to return to optimum conditions naturally. Refrain from adding any chemicals to change the pH. A few drops of Universal pH indicator placed in a few grams of vermicompost diluted with a few mL of distilled water can also be used to determine the pH.

Strategies

The best method to introduce pH to students is to select a number of household products: soaps, cleaners, etc, and have students check the pH (hydrogen or hydroxide ions do not need to be introduced). Next have students check the pH of the individual food products added to the Habitat. If students observe and record the pH values of the food products added, they should observe the relationship between changes in pH and food products added, if any. The changes may not occur in the section where the food was added.

Procedure

- 1) Place the plant pH sensor into selected sections of the vermicompost to a depth of 2 or 3 cm. This assumes students have divided the surface into distinct areas for feeding and the feedings are alternated. **OR**
- 2) Collect several samples of vermicompost and place them in separate test tubes.
- 3) Add a small portion of distilled water; just enough to cover the bottom portion of the Vernier pH sensor. Record the pH in the journal and Data Table 1.
- 4) Record the average pH values from steps 1 or 2 and 3 in all Data Tables for other activities that require these measurements.

Expectations

The students should be able to:

- 1) collect pH data and record it accurately.
- 2) appreciate the need for correct pH ranges.
- 3) make connections between certain food and rapid pH changes in a specific section of the vermicompost.
- 4) observe that the pH of one section will effect nearby sections, though to a lesser degree.

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Data Table 1 *(Typical Table)* **pH Values**

Sections	1	2	3	4	5	6	7	8	Average
Date	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX

Activity 13

Worm Behavior

Rationale: The usual species of worms used in vermiculture are considered to be phototropic, that is, they move towards light = positive (+) phototropism or move away from light = negative (-) phototropism. Vermiculture worms move away from BRIGHT light, but may be attracted to dim light. To what extent is the brightness related to the movement of the worms?

Objectives

- 1) Design an experiment that addresses worms' movement towards light.
- 2) Determine the effects, if any, of light on the worms.
- 3) Determine the effect of light intensity on the worms.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F

3.6.7. A,B

3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

Materials

CBL2 and light sensor

TI 83/84

Computer

Graphical Analysis

Ring stand

Test tube clamp

Introduction

If worms are removed from the vermicompost and placed on top of a flat pile of vermicompost, they dive for cover. The students will observe this trait quite quickly – but what is the reason? The worms may be diving for cover for various reasons. The students will need to be coached to devise an experiment to determine the variable(s) that causes this effect.

Strategies

For any inquiry approach to work successfully, the student must observe the behavior for a sufficient period of time. To have students come to class and be expected to develop questions to study, without a large number of observations, is counterproductive. If this Activity is done as a true inquiry approach, the students need to have made and recorded several hours (total for class) of observations. The journal entries from the very first day can be used to record these observations. After the appropriate amount of hours of observations as many reasons as possible for this behavior can be suggested. This activity can be done as the very first experiment. If it

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done as one of the first activities it will have to be planned out for the students and cannot be used as a student developed strategy. If this activity is used later in the program it can be used as a true inquiry approach to a study. It will be assumed that worms move away from light because a light was used to collect and sort the worms. However, it will need to be shown the assumptions are in fact, true. All the variables that may be related to this behavior should be listed and experiments designed to determine which of the possible variables cause the effect.

Procedure

- 1) Break into groups of three or four students.
- 2) In each group make a list of the possible causes.
- 3) Each group makes a presentation.
- 4) The class comes to a consensus.
- 5) Each group selects the variable(s) to be studied by the group.

Expectations

The students should be able to:

- 1) make appropriate observations.
- 2) decide what observations are needed for a specific behavior.
- 3) select appropriate potential causes (variables).
- 4) design several drafts of possible methods to test for cause and effect.
- 5) design an appropriate experiment with coaching.
- 6) design an appropriate data table.

Data Table 1 *(Typical Table)*

Variable	Light	Moisture	Temperature	Noise	?	?
Toward (+)						
Neutral						
Away (-)						

Activity 14

Degree of Avoidance to White Light

Rationale: It was determined that worms avoid bright white light in Activity 12. It is also important to know if the brightness has an effect on the worms. The students, with the aid of a light sensor, can determine if the worms react to differing intensities of light.

Objectives

- 1) Determine the effect of intensity of white light on worms' avoidance behavior.
- 2) Determine the effect of distance on white light intensity.
- 3) Set up an experiment to determine the effect of light intensity on worm avoidance behavior.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F.

3.4.7. B

3.6.7. A,B

3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

4.6.7. A,B,C

Math

2.1.8. A,B,D,G

2.2.8. A,B,F

2.3.8. A,B,D

2.4.8. A,B,D,F

2.5.8. A,B,C,D

2.6.8. A,B,C,E,F

2.7.8. B,C,D

2.8.8. F,G,H,I,J

2.11.8. A,B

Materials

CBL2

TI 83/84

Graphical Analysis

Computer

Ring stand (2)

Stopwatch

White LED

Camera light meter

Vernier light sensor

Ruler

Test tube clamp (2)

Introduction

To be able to accurately determine the effect of light intensity, students need to understand the inverse effect of intensity and distance. The actual effect is called the

inverse square law. If an intensity light reading is taken of a light bulb at a distance of 10.0 cm and then the sensor is moved to 20.0 cm, the intensity will decrease by a factor of $1/4$ the original. If the sensor is then moved from the original 10.0 cm to 30.0 cm, the intensity of the light will decrease by a factor of $1/9$ of the original. If the distance is changed to 40.0 cm, 4 times the original distance of 10.0 cm, the intensity will decrease to $1/16$ of the original.

- 1) double ($2x$) the distance and the intensity will decrease by the inverse of $2 = 1/2$; $(1/2)^2 = 1/4$ as intense.
- 2) Triple the distance ($3x$) and the intensity will decrease by the inverse of $3 = 1/3$; $(1/3)^2 = 1/9$ as intense.
- 3) Quadruple the distance ($4x$) and the intensity will decrease by the inverse of $4 = 1/4$; $(1/4)^2 = 1/16$ as intense.

Strategies

The students should set up the light bulb in a darkened room and measure the light intensity at various distances and record the light intensity. If the distances and the intensities are measured by several groups and averaged, the results should approximate the inverse square law rather well. This will not work with a flashlight. That light is directed out through the lens from the mirror behind the bulb in a compacted stream and does not obey the inverse square law in the same way. If the diameter of the spot of light doubles, then the intensity obeys the inverse square law.

Procedure

Inverse square law

- 1) Darken the room or work in a very dark place.
- 2) Set up the light bulb on a ring stand.
- 3) Set up the light sensor on a ring stand.
- 4) The light bulb and sensor should be at the same height.
- 5) Measure (to the nearest tenth of a cm) the distance from the LED to the front of the sensor.
- 6) Press the APPS button and select the DataMate application. Select and setup the light sensor for "events with entry" or read the intensity in the upper right corner of the TI screen.
- 7) Record the distance and intensity in Data Table 1.

Optional

- 8) Enter the distances in List 1. Overwrite any values that are in List 1.
- 9) Perform a pwr (power) regression on the data. Power refers to the square (2^{nd} power) of the value.

Procedure

Light intensity

- 1) Use the original distance from the previous Data Table 1 and record the distance in Data Table 2.
- 2) Collect 4 mature worms.
- 3) Place a fluffed up sample of vermicompost on a white piece of paper.
- 4) Place the worms on the vermicompost and turn on the light at the same time.

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For a dimly lit room take the intensity reading with the light sensor in the dimly lit room and subtract that reading from all subsequent intensity measurements and record the values in Data Table 1a (alternate).

1. What relationship is observed between the intensity and distance?

Data Table 2 **Time vs. Intensity**

Intensity (ave)				
Time (sec)	XXXX	XXXX	XXXX	XXXX
Group 1				
Group 2				
Group3				
Group 4				
Group 5				
Averages				

1. What relationship is observed between the intensity and distance?
2. What relationship is observed between the intensity and burying time?

Activity 15

Worm Behavior with Light

Rationale: White light will have a negative effect on worm behavior and it is possible that worms may not react to different colors of light. Counting and sorting worms can be frustrating and if the worms do not avoid one or more colors of light that result could be used to the students' advantages.

Objective

- 1) Determine if different colors of light effect worms differently.
- 2) Determine if one color has little or no effect on the worms.
- 3) Determine one or more methods to determine the color with the least negative effect.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F

3.4.7. B

3.6.7. A,B

3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

4.6.7. A,B,C

Math

2.1.8. A,B,D,G

2.2.8. A,B,F

2.3.8. A,B,D

2.4.8. A,B,D,F

2.5.8. A,B,C,D

2.6.8. A,B,C,E,F

2.7.8. B,C,D

2.8.8. F,G,H,I,J

2.11.8. A,B

Materials (depend on students experiments)

CBL2

TI 83/84

Graphical Analysis

Computer

Stopwatch

Various colored LEDs OR

Flashlights and colored cellophane

Light sensor (used camera shop)

Vernier light sensor

Introduction

The students will have determined that worms avoid bright white light in Activity 11. To some extent, moisture should have shown a positive reaction, also. However, in

this activity, the focus is on the color(s) of light that have the least effect. The commonly used worms for vermiculture are most sensitive to blue light and least sensitive to red light.

Strategies

The students should be able to set up the experiment for this activity without a lot of teacher assistance. However, it is a good idea to ask the students if they feel the intensity is the same for each LED or cellophane covered light beam. Or does the intensity affect the results in this activity? The students should decide that it does and they should be able to set up the experiment so the intensities are the same for each color trial.

Procedure

- 1) Set up the equipment for this activity.
- 2) Set up the CBL2 and have the light sensor ready to make an intensity measurement. Use the dimmest LED placed at an appropriate distance.
- 3) Record the intensity in the journal and Data Table 1.
- 4) Place four mature worms on a flat pile of vermicompost and turn on the light at the same time.
- 5) Record the burying time.
- 6) Repeat two more trials.
- 7) Record burying times.
- 8) Replace the original LED with an LED of a different color.
- 9) Adjust the distance to obtain the same intensity as the first LED.
- 10) Repeat two more trials.
- 11) Record the burying times.
- 12) Repeat with all other colors of LEDs.
- 13) Record all measurements in the journal and in Data Table 1.
- 14) Draw conclusions from the results.

Expectations

The students should be able to:

- 1) set up the equipment and discern what data are needed.
- 2) use a calculator to perform basic calculations.
- 3) determine which color of light has the least avoidance effect.
- 4) determine which color of light has the greatest avoidance effect.

Table Data 1 for Group _____

Times (s)	1 st	2 ^d	3 rd	Ave	1 st	2 nd	3 rd	Ave	1 st	2 nd	3 rd	Ave	1 st	2 nd	3 rd	Ave
Violet																
Blue																
Green																
Orange																
Yellow																
Red																

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Data Table 1 *(Typical Table)*

Time vs. Color

Time (s) (Ave)	Violet	Blue	Green	Orange	Yellow	Red
Group 1						
Group 2						
Group 3						
Group 4						
Group 5						
Average						

Activity 16

Response to Light by Age

Rationale: From previous Activities 12, 13, and 14, the phototropic response to light was determined by intensity and by color. A question that remains: Does the response change with age of the worm? If the response is learned, then the older the worm is the quicker it will respond to bright light.

Objectives

- 1) Set up an experiment for response to light by age of the worm.
- 2) Use the previous age classifications to collect data for this question.
- 3) Determine if there is a relationship between age and response time.

PDE Standards

Science and Technology

- 3.1.7. A,B,C
- 3.2.7. A,B,C,D,E,F
- 3.4.7. B
- 3.6.7. A,B
- 3.7.7. A,B,C,D

Environment and Ecology

- 4.1.7. A,B,C
- 4.2.7. A,C
- 4.6.7. A,B,C

Math

- 2.1.8. A,B,D,G
- 2.2.8. A,B,F
- 2.3.8. A,B,D
- 2.4.8. A,B,D,F
- 2.5.8. A,B,C,D
- 2.6.8. A,B,C,E,F
- 2.7.8. B,C,D
- 2.8.8. FG,H,I,J
- 2.11.8. A,B

Materials

Worms sorted by age	Ring stands
Small polystyrene cups with lids	Test tube clamps
Stopwatch	

Introduction

One of the more interesting aspects of worm behavior is whether certain behaviors are learned or instinctual. *Planaria* can be taught to navigate a maze in search of food. The search for food is instinctual, but the navigation of the maze is a learned behavior. Do vermiculture worms learn to avoid light or is it instinctual?

Strategies

The students should quickly design a good experiment to determine the effect of age on the avoidance response to light. The most difficult part of this experiment is finding very young worms and not hurting them.

Procedure

- 1) Set up the equipment to measure burying times.
- 2) Sort worms into the three classifications (hatchlings, juvenile, mature).
- 3) Collect about a ½ dozen of each.
- 4) Place 4 worms on a flat pile of vermicompost.
- 5) Record the burying time in the journal and Data Table 1.
- 6) Compare the class averages for each age classification.
- 7) Draw conclusions from the results.

Expectations

The students should be able to:

- 1) set up the equipment quickly and accurately.
- 2) collect burying times with a minimum of teacher assistance.
- 3) determine if there is an age vs. burying time relationship.
- 4) record measurements for trials in the journal and record the averages in Data Table 1.

Data Table #1

Time (s)	Hatchlings	Juvenile	Mature	Relationship*
Group 1 (ave)				
Group 2 (ave)				
Group 3 (ave)				
Group 4 (ave)				
Group 5 (ave)				
Averages(1- 5)				

* Determine a small whole number relationship (Ex. 31s, 39s, 35s) = 1:1:1 or 40s, 100, 44 = 2:5:2)

Activity 17

Mass of Input vs. Mass of Output

Rationale: The amount of foodstuffs added to the Habitat compared to the mass of runoff water and the increase in the mass of the worms should be related to the health of the Habitat. These data can be used to determine the efficiency of the system.

Objectives

- 1) Enter data from Data Table 1 and 2 from Activity 1 in the graphing calculator or Graphical Analysis.
- 2) Decide what variables are to be compared.
- 3) Decide what causes and effects are present, if any.
- 4) Evaluate the variable data collected and decide if the appropriate variables are being measured.
- 5) Make changes, if necessary.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F

3.6.7. A,B

3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

4.6.7. A,B,C

Math

2.1.8. A,B,D,G

2.2.8. A,B,F

2.3.8. A,B,D

2.4.8. AB,D,F

2.5.8. A,B,C,D

2.6.8. A,B,C,E,F

2.7.8. B,C,D

2.8.8. F,G,H,I,J

2.11.8. A,B

Materials

Data from Activity 1

TI 83/84

Computer

Graphical Analysis (software)

Introduction

The bedding was weighed and 3 times its mass equals the amount of water added to the bedding. This became the original mass of the future vermicompost. Food-

stuffs were added and the average amount of water was generally considered to be about 70% of the mass of the foodstuffs. In a healthy Habitat, the excess water will drain off at the bottom of the bin. Some water evaporates and therefore cannot be measured. The worms will grow, reproduce, and produce more worms. As the Habitat matures and weekly or bi weekly mass data are collected and analyzed, patterns will begin to appear. If the appropriate amount of foodstuffs is added, a relationship will begin to develop between the input amounts and the growth of the worms and excess water that is present.

Strategies

This activity will require more guidance/coaching than more recent activities. The relationships developed in this Activity will enhance the learning and understanding by the students of the micro ecosystem developed in the Habitat. The maximum and minimum of the measurements will give the students some idea of the complexity of the Habitat. The previous activities have given the students confidence in their abilities to solve ecological problems.

Procedure

- 1) Groups observe Data Table 1 and 2 from Activity 1 and propose a method of analysis.
- 2) Groups design an appropriate analysis of data sets.
- 3) Groups present a data analysis design to the class.
- 4) Students reflect on suggestions and redesign the method, if appropriate.
- 5) Groups' data analysis design is given to the teacher for final approval.
- 6) Conclusions are drawn from the results.

Expectations

The students should be able to:

- 1) design appropriate data analysis methods.
- 2) determine the quantitative values.
- 3) link the quantitative aspects of the Habitat with the qualitative conditions.

Middle School Activities for Vermiculture

Data Table 1

Date	Volume of vermi-compost*	Mass of worms	Mass of vermi-compost	Mass of food stuffs	Mass of water added	Mass of excess H₂O	Net gain or loss
							XXXX

*Not used in final "Net gain or loss"

Activity 18

Analysis of Foodstuffs

Rationale: The mass of foodstuff added and the chemical characteristics will help determine the effects of the foodstuffs on the Habitat.

Objectives

- 1) Determine the mass of the groups of foodstuffs.
- 2) Compare the mass of each food group and its chemical properties to the chemical changes of the Habitat.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F

3.6.7. A,B

3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

4.6.7. A,B,C

Materials

Data Tables

Mini bins*

TI 83/84

Mature worms

Graphical Analysis

Computer

* Mini bins can be made from large plastic containers (1 - 2 liters). Add clean wet bedding to the container. Punch holes in the bottom for excess water to drain. Punch larger holes in the side for air to enter (similar to the class habitat) and holes in the lid. These can be used with other group activities.

Introduction

The mass of the foodstuffs added will add considerable water to the Habitat. This amount will be an approximation, but needs to be included in the calculations. The shredded newsprint is fairly self regulating in terms of its water content; that is, excess water can drain off. However, if it is observed that large amounts of high water content foodstuffs have been added in recent weeks, drainage should also be observed. The pH of the foodstuffs should also be recorded to compare to any changes in the pH of the runoff water and any changes in the pH of the vermicompost.

Strategies

This will be one of the easiest activities for the students, requiring very little coaching. The data have been collected on a regular basis and the students have had sufficient practice with discovering existing relationships. The most important coaching aspect is to guide students to correct conclusions from appropriate results.

Middle School Activities for Vermiculture

Considerable coaching will be needed with the use of an approximate value. Final values can include a range of the minimum and maximum amount of water added to the Habitat. At this time in the maintenance of the Habitat, assumptions may be made that are not appropriate. Students will need to do research to obtain the pH of each group of foodstuffs and the water content in order to complete Data Table 1.

Procedure

- 1) Enter the masses, pH, and % water content values in Data Table 1.
- 2) Determine the approximate (range) mass of water added to the Habitat.
- 3) Draw conclusions from the results.

Expectations

The students should be able to:

- 1) condense data from Data Table 1 and 2 in Activity 1 to Data Table 1 in this activity.
- 2) find results and draw appropriate conclusions.
- 3) work with an approximate value in a Data Table.

Data Table 1 *(Typical Table)* **Mass of Foodstuffs Added**

Date	Fruits	Gr. Leafy Vegetables	Solid vegetables	Cereals	Legumes	Tubers

Activity 19

Castings

Rationale: The amount of castings (excreta) is an important measure of the overall health of the Habitat. The mass of the castings is also related to the mass and age of the worms present.

Objectives

- 1) Determine if there are any relationships established between the mass of the castings and the other variables.
- 2) Collect castings in a specific portion of the Habitat.
- 3) Estimate the total mass of castings in the vermicompost.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F

3.6.7. A,B

3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

4.6.7. A,B,C

Math

2.1.8. A,B

2.2.8. A,B,F

2.3.8. A,B,D

2.4.8. A,B,D,F

2.5.8. A,B,C,D

2.6.8. A,B,C,E,F

2.7.8. B,C,D

2.8.8. F,G,H,I,J

2.11.8. A,B

Materials

TI 83/84

Plastic cups

Tweezers

Introduction

The mass of the castings can be measured in several small samples removed from the vermicompost. After the worms are removed, castings and cocoons are visible within the vermicompost. These castings will be a valuable source of enrichment for plants (Wisconsin Fast Plants®) used in later activities. The castings are a result of the worms' digestive processes and the castings are nutrient rich.

Strategies

This is an activity designed for students to collect castings in several small samples of the compost, weigh the castings, and then estimate the total mass of the castings in the Habitat. The students must look at 10 or more 100 mL samples of the vermicompost. These samples must be representative of the whole system. The worms are separated from the vermicompost. The worms and cocoons can also be counted/weighed and these data can be used in future activities. For this immediate activity, only the mass of the castings will be used to predict the total mass of the castings. Students should collect and weigh the castings from the selected samples and determine if they believe the samples are representative of the whole. The castings will be found mostly in the upper strata of the bin, but not exclusively. This depends on the methods of maintenance and bin size. By taking several samples from several specific areas, these representative samples can then be used to predict the total mass of castings. The sections that are used for alternating feedings can be used as well as several layers. The usual method is to have six feeding areas and 3 strata. That will give a total of 18, 3 dimensional sections, similar to rooms in an apartment house. If a 100 mL sample is carefully collected from half of these sections good results will be obtained. Nine or ten 100 mL samples (ca. liter) will be a small, but representative of the entire vermicompost. After the students have weighed the castings in the samples and averaged the values, the total mass of the castings can be predicted mathematically. The number, age, mass of the worms, and the number and mass of the cocoons can also be recorded for future activities and used to predict the total mass and numbers of worms compared to the actual hand-collected values.

Procedure

- 1) Decide on the sections to be sampled.
- 2) Carefully obtain about a 100 mL sample. Record the actual volume in the journal and Data Table 1.
- 3) Count the worms and return them to the vermicompost.
- 4) Count the cocoons and leave them in the sample.
- 5) Remove the castings, weigh, and record the mass.
- 6) Repeat with 8 or 9 more samples.
- 7) Return all the samples to the vermicompost and mix them carefully into the top stratum.
- 8) Complete Data Table 1.
- 9) Draw conclusions from the results.

Expectations

The students should be able to:

- 1) determine a reasonable set of sample locations.
- 2) collect and weigh the castings from the selected samples.
- 3) collect and record data for the worms and cocoons.
- 4) use the TI 83/84 to predict the total mass of the castings.

Data Table 1

Sample	Volume	Castings
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
Average		

Data Table 2

Volume Bin	Volume Average	Castings Average	Total castings*

* The total is the result of the average volume of samples *divided* into the total volume of vermicompost *times* the average mass of the castings.

Data Table 3 (optional)

Sample XXXX	Volume XXXX	cocoons # XXXX	Worm #*			Worms mass		
			Ha	Ju	Ma	Ha	Ju	Ma
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
Average								
Total								

*Ha = hatchlings, Ju = juvenile, Ma = mature

Activity 20

Predictions vs. Actual

Rationale: The counting/weighing to obtain the actual values for the worms, cocoons, and castings is a tedious and potentially harmful activity. To be able to take samples and accurately predict values is an important part of ecological research.

Objectives

- 1) Use collected sample data to predict totals.
- 2) Compare predicted values to actual values.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F

3.6.7. A,B

3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

4.6.7. A,B,C

Math

2.1.8. A,B,D,G

2.2.8. A,B,F

2.3.8. A,B,D

2.4.8. A,B,D,F

2.5.8. A,B,C,D

2.6.8. A,B,C,E,F

2.7.8. B,C,D

2.8.8. F,G,H,I,J

2.11.8. A,B

Materials

Data tables

TI 83/84

Graphical Analysis (software)

Computer

Introduction

One of the most important aspects of science research is to be able to predict future values. This is especially true in situations when the collection of actual measurements is extremely difficult, might perturb the ecological system, or might be too tedious to get accurate values. Certainly two of the above constraints apply to this Habitat. The actual values will be collected one time to compare to predicted values. The amount of castings, worms, and cocoons are important aspects of the vermiculture

and at some time the excess castings and worms must be removed. This is the time to do a complete census.

Strategies

This activity will be very tedious and requires a careful selection of the time when it is done. The best time to do this activity is when the vermiculture needs to be thinned. Removing the excess worms and castings is necessary when the vermiculture matures. As the castings are removed, they can be weighed, and the worms can be sorted, weighed, counted, and recorded. Additional shredded and moistened (three water to one newsprint by mass) newsprint can be added. After the castings have been removed and weighed, the worms sorted, counted and weighed, and the cocoons counted, the values can be compared to the predicted.

Procedure

- 1) Complete the following Data Table 1.
- 2) Compare the predicted values to the actual values.
- 3) Determine the percent error.
- 4) Draw conclusions from the results.

Composite Data Table

Variable	Castings	Hatchlings		Juvenile		Mature		Cocoons
XXXX	XXXX	#	Mass	#	Mass	#	Mass	XXXX
Predicted								
Actual								
Difference								
% error								

Activity 21

Determination of Food Choice by Age

Rationale: The assumption could be made that all ages of worms prefer all types of food. This activity will take one feeding cycle and the worms need to be observed, sorted, and counted several times a day for the full feeding cycle.

Objectives

- 1) Set up an experiment that has actual implications for the vermiculture.
- 2) Analyze the data collected.
- 3) Calculate a food group ratio for hatchlings, juvenile, and mature worms.
- 4) Make recommendations based on the analysis.

PDE Standards

Science and Technology

3.1.7. A,B,C

3.2.7. A,B,C,D,E,F

3.6.7. A,B

3.7.7. A,B,C,D

Environment and Ecology

4.1.7. A,B,C

4.2.7. A,C

4.6.7. A,B,C

Math

2.1.8. A,B,D,G

2.2.8. A,B,F

2.3.8. A,B,D

2.4.8. A,B,D,F

2.5.8. A,B,C,D

2.6.8. A,B,C,E,F

2.7.8. B,C,D

2.8.8. F,G,H,I,J

2.11.8. A,B

Materials

Habitat

Counting boards

Sorting cups

TI 83/84

Introduction

The quantity of different food groups may cause an observable effect on the development of the worms or the reproductive process. It is important to have the best ratio of foodstuffs for the worms. If only sexually mature worms were harvested and placed in breeding bins, the best ratio of the food groups would ensure the best reproduction, largest number of cocoons, the highest number of worms per cocoon, and

the best rate of live hatchings from each cocoon. On the other hand, the type and quantity of the food might make no difference.

Strategies

The overarching concept of this activity is that students realize a very useful set of data are being collected. These data can be useful for larger practitioners of vermiculture. The design of the activity is very straight forward and is focused on a very practical aspect of vermiculture. Very little coaching should be required.

Procedure

- 1) Mix the top two strata of the vermicompost very carefully.
- 2) Remove any unconsumed food.
- 3) Place a reasonable sized piece of each of the food groups in specific locations on the surface of the vermicompost. Leave the center free.
- 4) Replace the lid and wait for a few hours.
- 5) Open the lid and quickly collect, sort, and count the worms according to the age groups.
- 6) Place all the worms together and replace them in the center of the surface of the vermicompost.
- 7) Repeat this sampling process once or twice a day for 10 collections.
- 8) Replenish any consumed food groups after each sampling.
- 9) Record all data in the journal and Data Table 1.
- 10) Draw conclusions from the results.

Expectations

The students should be able to:

- 1) collect, sort, and count the worms without coaching.
- 2) complete the Data Table.
- 3) draw conclusions from the results calculated in the Data Table.
- 4) make predictions of the food group for each age group.

