Unit 4: Applying Biological Data to Graphing Calculator Exercises

The Lesson Plan

The focus of this unit is the use of the graphing calculator to explore how natural and human induced water quality conditions impact biological communities. This lesson will provide insight on how macroinvertebrate communities respond to environmental stresses and the human induced impacts that undermine the integrity of these communities. The examples and exercises in this lesson use the graphing techniques from the previous three units, inserting macro invertebrate data into the analysis. Exercises challenge the students to use this information not only to create graphs using the calculator, but also understand the interconnections between the human community and aquatic communities; how land based activities impact aquatic communities; and how macroinvertebrate communities provide an indication of the effectiveness of our stewardship to local water bodies. Finally, additional activities encourage students to reach beyond their own site to share information within their watershed and community.

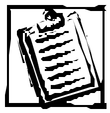
Table of Contents:

Materials Needed:

- A TI-83 Plus S.E. graphing calculator
- A computer
- Internet access

Time Frame: Lesson and Demonstration – 45 minutes
2 Student Exercises – 45 minutes each

Grade Level: Grades 9 thru 12.



Section 1 – The Lesson

Part 1. Overview of Biological Indicators of Water Quality

The ultimate goal of water quality monitoring is to provide ongoing analysis of the river's ability to support the biological aspects of a complex aquatic ecosystem. Water quality monitoring helps to document natural trends and target pollution sources to ensure the integrity of the biological system. Biological monitoring documents directly the impacts of pollution on the biological system. Biological monitoring involves monitoring vegetation, fish tissue and population sampling, and benthic macroinvertebrate communities.

Macroinvertebrate communities are highly sensitive to changes in the environment, and thus, will provide early indication of trends in water quality degradation. These organisms are so sensitive to environmental changes that their breeding and life cycles correspond to seasonal changes in temperatures. When conducting macroinvertebrate monitoring, scientists take three to five replications of the sample (see the *Biomonitoring* units at www.4empowerment.com/en/curricula/science/) to ensure a true representation of the community.

Analyzing macroinvertebrate data and applying the results to water quality conditions is complex and involves various sets of information. The information is applied to an index (set of formulas and equations) that will vary from region to region, based on natural conditions of aquatic systems of the area. Most indices take the following into account:

- Species Richness – indicates the total number of species identified in the monitoring. High number of richness indicates a healthy system.

- Species Diversity – indicates how the individuals are spread across the number of species (using the Shannon Weiner Index in the *Biomonitoring* unit). A higher index number indicates the individuals are spread more evenly between the species, that one species is not dominant with few individuals of other species. A high index indicates a healthy system.

- Species Pollutant Tolerance levels – macroinvertebrate species are divided into three groups based on their tolerance to pollutants; sensitive, somewhat sensitive, and tolerant. More weight is given to sensitive species. Thus, the more sensitive species found at a location, the healthier the system.

A diverse system is the healthiest system. A community that comprises a high number of individuals that are equally divided among pollutant sensitive and tolerant species is a community that will be able to withstand various pollutant impacts. A community that consists of a high number of only one or two types of species is highly susceptible to ecosystem changes, both natural and human induced. The presence of many individuals of pollutant-tolerant species and little to no presence of pollutant-sensitive species can indicate a pollutant-impacted system.

Pollutants that impact macroinvertebrate communities can be divided up into short-term and long- term impacts. Short-term impacts can decimate a community within a just a few hours or days and include sudden high flows and high turbidity, and extreme temperature, pH, dissolved oxygen content changes. These impacts are often associated with flood events or sudden large point source discharge. These sudden changes will cause stress on sensitive organisms; even pollutant tolerant organisms can simply get washed away. However, the impact may be only temporal and, over time, the community will reestablish itself.

Long-term impacts occur with regular pollutant loading that impair overall water quality and impact the integrity of the ecosystem at large. These pollutants may occur in small concentrations, but over the long term, will accumulate in sediment or slowly degrade the water quality to the point that it will no longer support a thriving, diverse community. Such pollutants include:

- **Consistently high organic loading** – while organics are a food source for macroinvertebrate, heavy, consistent loading, especially of fine particles such as silt and clay, can clog gills and smother macroinvertbrate communities. At sites with consistent turbidity, these communities cannot be reestablished.
- **Nutrients and associated algal blooms** –Like organics, algae are a food source for macroinvertebrate; however, consistent, large algal blooms that deplete the water of dissolved oxygen will undermine the ability of the water body to support diverse macroinvertebrate communities.
- **Heavy metals** – even in small concentrations, these pollutants accumulate over time in the sediment and become toxic to macroinvertebrate communities
- **Other chemicals and substances** that change the pH and conductivity of a site will impact the diversity of the macroinvertebrate community.

Special considerations must be taken when conducting water quality indices based on macroinvertebrate data. Short-term impacts such as a flood event or sudden, large discharge from a point source are hard to catch, but the effects can be readily seen. However, the composition of a macroinvertebrate community changes with seasonal changes and long-term analysis should be conducted by comparing community composition within the same season from year to year.

Part 2. Using Biological Data to Obtain a Water Quality Score

The EPA's *Volunteer Stream Monitoring: A Methods Manual* provides a simple index for determining a general water quality score. Using species diversity and giving weight to pollutant tolerant species, the index provides a simple scoring system to rate water quality. Follow the simple steps in the table below to obtain a water quality score to your site (See Example 1).

1. Identify the macroinvertebrates in your sample and assign them letter codes based on their abundance (number of individuals):
   - Rare (R) = 1-9 organisms
   - Common (C) = 10-99 organisms
   - Dominant (D) = 100+ organisms

Group I Sensitive	Group II Somewhat Sensitive	Group III Tolerant
___Water penny larvae	___Beetle larvae	___Aquatic worms
___Hellgrammites	___Clams	___Blackfly larvae
___Mayfly nymphs	___Crane fly larvae	___Leeches
___Gilled snails	___Crayfish	___Midge larvae
___Riffle beetle adult	___Damselfly nymphs	___Snails
___Stonefly nymphs	___Scuds	
___Non net-spinning caddisfly larvae	___Sowbugs	
	___Fishfly larvae	
	___Alderfly larvae	
	___Net-spinning caddisfly larvae	

Note: The tolerance groupings (Group I, II, and III) and the water quality rating categories were developed for streams in the Mid-Atlantic states. A trained biologist familiar with local stream fauna should help determine if these tolerance and water quality rating categories should be modified for your geographic region and program .

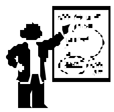
2. To calculate the index value, add the number of letters found in the three Groups above and multiply by the indicated weighting factor.

Group I	Group II	Group III
# of R's ____X 5.0 = ____	# of R's___ X 3.2 = ____	# of R's ___ X 1.2 = ___
# of C's____ X 5.6 = ____	# of C's ___X 3.4 = ____	# of C's ___ X 1.1 = ___
# of D's ____X 5.3 = ____	# of D's ___ X 3.0 = ____	# of D's ___ X 1.0 = ___
Sum of the Index Value for Group I=____	**Sum of the Index Value for Group II=____**	**Sum of the Index Value for Group I=___**

3. To calculate the water quality score for the stream site, add together the index values for each group. The sum of these values equals the water quality score = ___________.

   Compare this score to the following number ranges to determine the quality of your stream site.

> 40	Good
20-40	Fair
<20	Poor



Section 2 – In Class Demonstration: Obtaining a Water Quality Score

Example 1. Obtaining a Water Quality Score

Organize the Data from the macroinvertebrate sampling field sheets into a table:

Species	# of Individuals	% of Total
Stonefly nymphs	10	14
Mayfly nymphs	11	16
Hellgrammites	3	4
Scuds	6	9
Damselfly nymphs	2	3
NS Caddisfly larvae	12	17
Aquatic worms	15	22
Blackfly larvae	10	14
Total	**69**	

Table 1. Macroinvertebre sampling results from Beautiful River 5/3/04

Use the Matrix to obtain a water quality score:

1. Identify the macroinvertebrates in your sample and assign them letter codes based on their abundance (number of individuals):
   - Rare (R) = 1-9 organisms
   - Common (C) = 10-99 organisms
   - Dominant (D) = 100+ organisms

Group I
Sensitive

___Water penny larvae
_R__Hellgrammites
_C_Mayfly nymphs
___Gilled snails
___Riffle beetle adult
_C Stonefly nymphs
___Non net-spinning caddisfly larvae

Group II
Somewhat Sensitive

___Beetle larvae
___Clams
___Crane fly larvae
___Crayfish
_R_Damselfly nymphs
_R_Scuds
___Sowbugs
___Fishfly larvae
___Alderfly larvae
_C_Net-spinning caddisfly larvae

Group III
Tolerant

_C_Aquatic worms
_C_Blackfly larvae
___Leeches
___Midge larvae
___Snails

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Example 1. Obtaining a Water Quality Score (Cont.)

2. To calculate the index value, add the number of letters found in the three Groups above and multiply by the indicated weighting factor.

Group I	Group II	Group III
# of R's _**1**__X 5.0 = _**5.0**_	# of R's_**2**_ X 3.2 = _**6.4**_	# of R's ___ X 1.2 = ___
# of C's__**2**_ X 5.6 = _**11.2**_	# of C's _**1**_X 3.4 = _**3.4**_	# of C's _**2**_ X 1.1 = **2.2**
# of D's ____X 5.3 = ____	# of D's ___ X 3.0 = ____	# of D's ___ X 1.0 = ___
Sum of the Index Value for Group I=_**16.2**__	Sum of the Index Value for Group II=_**9.8**___	Sum of the Index Value for Group III=_**2.2**

3. To calculate the water quality score for the stream site, add together the index values for each group. The sum of these values equals the water quality score = _**28.2=Fair**_____

Section 3: Student Exercises
Applying Biological Data to Water Quality Analysis

Part 1. Apply Biological Information to Water Quality Analysis Using Scatter Plots

Using the methods to correlate water quality parameters in *Unit 1: Applying Graphing Calculators to Water Quality Data* of the graphing calculator curriculum, create a scatter plot following these steps:

1. Calculate a Water Quality Score for each monitoring event conducted using species-specific information.
2. Insert the Water Quality Score into the scatter plot as a ***dependent*** variable (Y) and correlate to these parameters:
   - Turbidity or secchi depth
   - pH
   - Dissolved Oxygen

   Correlate the biological data with water quality data from the same ***sampling date*** or a date just prior to the biological monitoring event date.

After completing the scatter plots, capture the graphs and summarize your findings.

- Which water quality parameters had high correlations with the biological water quality index results (Water Quality Score)?

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Section 3: Student Exercises
Applying Biological Data to Water Quality Analysis

Part 2: Characterize Species Composition Using a Pie Chart

Use the methods outlined in *Unit 2: Applying Graphing Calculators to Garbology Data* of the graphing calculator curriculum to figure percentages and create pie charts for the following information :

- **Percent composition of individuals of each species out of total number of individuals**

Create a Table with the number of individuals of each species and determine the percentage of each, e.g.,

Species	# of Individuals	% of Total
Stonefly nymphs	10	14
Mayfly nymphs	11	16
Hellgrammites	3	4
Scuds	6	9
Damselfly nymphs	2	3
NS Caddisfly larvae	12	17
Aquatic worms	15	23
Blackfly larvae	10	14
Total	**69**	**100%**

Table 1. Macroinvertebre sampling results from Beautiful River 5/3/04

Create a Pie Chart using the graphing calculator showing the percentage of each species.

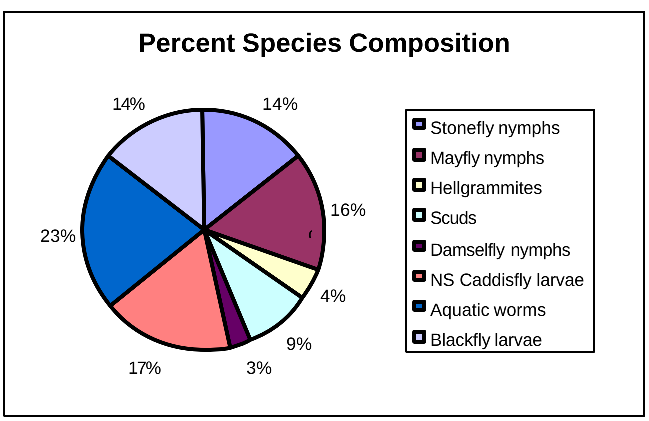

Figure 1. Macroinvertebrate species composition on Beautiful River 5/3/04 (using Excel graphing features.)

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- **Percent composition each Group class make up of total composition**

Obtain the Water Quality Score using the provided worksheet

Create a Table of the resulting index of each group from the water quality score worksheet and determined the percentage each group contributed to the score. E.g.:

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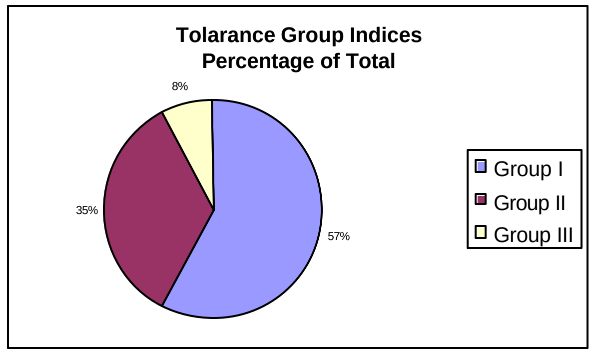
	Index	Percent
Group I	16.2	57
Group II	9.8	35
Group III	2.2	8
Total Score	**28.2**	

Table 2. Percentage of contribution of each group index to the water quality score



Create a Pie Chart using the graphing calculator showing the percentage of each group. E.g.:

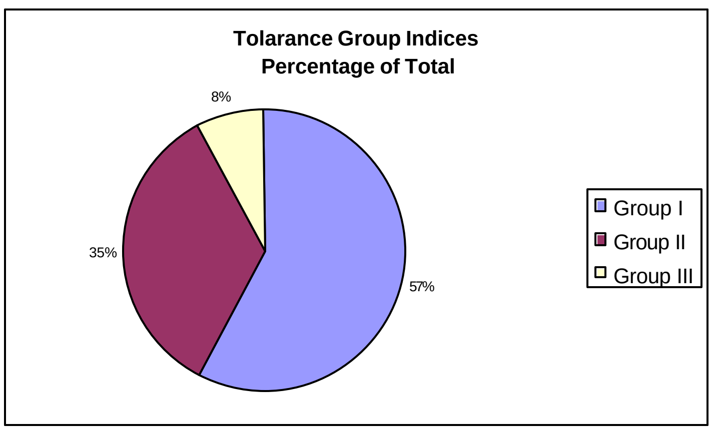


Figure 2. Percentage of contribution of each group index to the water quality score

"Think About It"

Use the pie charts to answer these questions:

- Is the site highly diverse with individual organisms equally distributed among several species? Or does one species dominate the site?
- What tolerance Group dominates the site?
- What does this tell you about the water quality of the site?

Obtaining a Water Quality Score Worksheet

1. Identify the macroinvertebrates in your sample and assign them letter codes based on their abundance (number of individuals):
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# of D's ____X 5.3 = ____	# of D's ___ X 3.0 = ____	# of D's ___ X 1.0 = ___
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3. To calculate the water quality score for the stream site, add together the index values for each group. The sum of these values equals the water quality score = ___________.

   Compare this score to the following number ranges to determine the quality of your stream site.

> 40	Good
20-40	Fair
<20	Poor

Section 3: Student Exercises
Applying Biological Data to Water Quality Analysis

Part 3. Comparing Biological Communities Upstream and Downstream Using Bar Graphs

Using the methods to compare sites in *Unit 3: Applying Graphing Calculators to Water Quality Data* of the graphing calculator curriculum, create a scatter plot following these steps:

1. For each site, calculate a Water Quality Score for each monitoring event conducted using species-specific information.
2. Find the average water quality score for each site.
3. Insert the Water Quality Score into the bar graphs along with these parameters:
   - Turbidity or secchi depth
   - pH
   - Dissolved Oxygen
   - Conductivity
   - Nutrients

After completing the bar graphs, capture the graphs and summarize your findings.

- Are there differences in the macroinvertebrate communities between sites along the river?
- At sites with poor diversity, what are the parameters that may affect the community?
- Are there natural characteristics that make it difficult for communities to become established?
- Are there human activities contributing to poor water quality?
- Determine the land uses and the natural habitat around these sites? How would that make a difference between the communities found at each site?

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Section 4: Long Term Projects

Other Exercises

- Conduct in-depth exercises of season variations in macroinvertebrate communities and correlate parameters that change seasonally with biological data.

"Take Action" Activities

- Organize a Macroinvertebrate Watch with other groups who monitor within your watershed. Coordinate sampling dates based on seasons and analyze differences between the sites.
- Share the information you find with local water resource management agencies. Biological data is very time intensive and scarce. Local agencies appreciate the additional input!