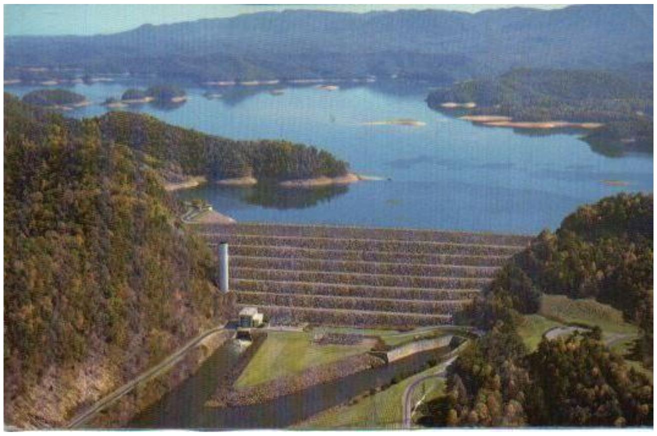
Field Trip to South Holston River Dam
376 South View Dam Dr., Bristol, Tenn. 37602 (36.523804, -82.110076)



Within a kilometer around the South Holston Dam, the South Holston River undergoes dramatic changes. Above the dam, there is a large, calm, deep lake. Water from the bottom of the lake passes through the dam generating electricity, becoming a fast moving river again. Farther downstream, the water is agitated as it passes over a smaller weir dam. Farther down still, the water passes over a cascade. Two teams will analyze and document the changes in the water, and the animals that live in it over this short stretch of the river. A third team will document how these analyses are conducted, and also capture the 'unquantifiable' changes along the river.

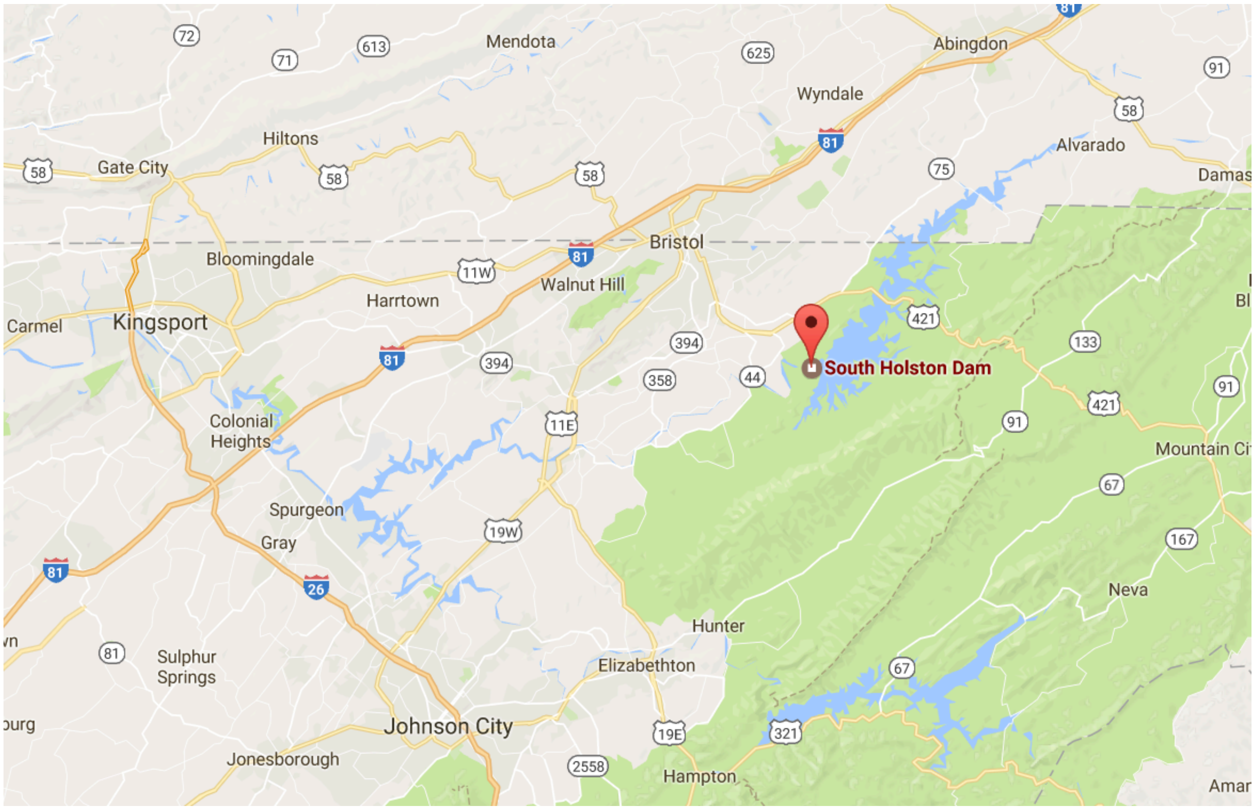
Chemistry-Focus
Deliverables: Graphs and descriptions of changes in water temperature, dissolved oxygen, pH, turbidity.

Biology- Focus
Deliverables: Graphs and descriptions of changes in aquatic macroinvertebrates living in the water.

ELA- Focus
Deliverables: A video documentary of the effects of the dam on the river, poetry and prose capturing the unquantifiable effects of the dam on the river.

Note: This document provides more information than you will need for the field trip (i.e. you do not need to bring it with you). However, you might find it useful to adapt it for your own classes. Data sheets and instruction will be provided on site.
Plan to meet at Site #2 at 9:15 am, Friday 2-June-2017.

The site: South Holston Dam, Bristol, TN.




Site #4
Center of Joy

Site #1

Site #2
Investigation Home

Site #3

Chemistry Focus

Dissolved Oxygen

One of the most important aspects of living aquatic systems is dissolved oxygen (DO). Dissolved oxygen is affected by many parameters. Important parameters that determine DO content are temperature, salinity, pressure, and abundance of aquatic plants, amount of oxygen-consuming materials and organisms present, and the amount of natural aeration form contact with the atmosphere.

DO is inversely related to temperature, i.e., when temperature reduces, DO concentration increases. Salinity is also inversely related to DO. Salinity is mostly a problem in saltwater ecosystems were evaporation of water can increase the salt concentration. DO is directly related to pressure. For example, at sea level the DO concentration is greater than at higher elevation due to the increase in atmospheric pressure with the decrease in elevation.

Through photosynthesis, plants consume carbon dioxide and produce oxygen. Plants also consume oxygen when they create energy the same way animals do. Generally, plants produce more oxygen than they use which is a great benefit to animal life. Photosynthesis occurs only when sunlight is present. Therefore, DO level is highest at sunset and lowest at sunrise. Occasionally, cloudy days can deplete DO concentrations to dangerous levels. During winter, when lakes are frozen and snow accumulates, little to no light reaches plants growing in water. As a result, some plants and fish may die due to the decrease in DO. When plants and animals die, microbes that decompose these dead tissues also consume oxygen.

The atmosphere contains about 20.95% oxygen by volume. Because atmospheric gases contact water sources, the gas dissolve into the water. In places where water is moving, such as a stream of river, water is generally saturated with oxygen. In lakes where water is hardly moving, oxygen is not at the saturation level. The concentration of oxygen in water saturated with air at 1 am and 25 ˚C can be calculated by Henry's law. Considering that dry air is 20.95 % O_2 by volume and correcting for the partial pressure due to water (0.0313 atm at 25 ˚C), the partial pressure is:

$P(O_2) = (1.000 \text{ atm} – 0.0313 \text{ atm})(0.2095) = 0.2029 \text{ atm}$

Using Henry's law and converting to mg/L, the concentration of DO is 8.32 ppm for saturation.

Turbidity

Turbidity is the cloudiness or haziness of a fluid caused by suspended solids that are usually invisible to the naked eye. The measurement of Turbidity is an important test when trying to determine the quality of water. It is an aggregate optical property of the water and does not identify individual substances; it just says something is there.

Water always contains suspended solids that consist of many different particles of varying sizes. Some of the particles are large enough and heavy enough to eventually settle to the bottom of a container if a sample is left standing (these are the settleable solids). The smaller particles will only settle slowly, if at all (these are the colloidal solids). It's these particles that cause the water to look turbid.

Organisms like phytoplankton can contribute to turbidity in open water. Erosion and effluent from highly urbanized zones contribute to the turbidity of waters in those areas. Construction, mining and agriculture, disturb the soil and can lead to raised levels of sediment which run off into waterways during storms. Storm water from paved surfaces like roads, bridges and parking lots also contribute to turbidity.

In drinking water the higher the level of turbidity, the higher the chance that those using it could develop gastrointestinal diseases. Contaminants like viruses and pathogenic bacteria can attach themselves to the suspended solids. These solids then interfere with disinfection.

High turbidity levels can reduce the amount of light reaching lower depths in bodies of water like rivers, lakes and reservoirs, which inhibits growth of some forms of aquatic plants and can negatively affect species that are dependent on them, like fish and shellfish. High turbidity levels will also hinder a fish's ability to absorb dissolved oxygen. This condition has been observed and documented throughout the Chesapeake Bay in the Mid-Atlantic region of the USA.

The most common measurement for turbidity in the United States are the Nephelometric Turbidity Units (**NTU**).

There are several ways you can check turbidity in water, the most direct being a measure of attenuation, or reduction in strength, of a light source as it passes through a water sample. An older system was called the Jackson Candle method, with units expressed as **JTU** or Jackson Turbidity Units. It used a candle flame viewed through a clear column filled with water. The length of water that the candle could be seen through related to the turbidity in the water sample. With the advent of electronic meter technology this method is no longer used.

The particles suspended in the water will scatter a light beam focused on them. The scattered light is then measured at various angles from the incident light path. This is now accepted as a more precise measure of turbidity. To measure turbidity this way use a nephelometer, such as the LaMotte 2020we. *Nephele* is the Greek word for "cloud"; *metric* means "measure." *Nephelometric,* therefore, means "measuring cloudiness." Most nephelometers measure the scattered light at 90°. If more light is able to reach the detector it means there are many small particles scattering the source beam, less light reaching the detector means fewer particles. Nephelometric Turbidity Units (**NTU**) are the units of measurement used by a nephelometer meeting EPA design criteria. The amount of light scattered is influenced by many aspects of the particles like color, shape, and reflectivity. Because of this, and the fact heavier particles may settle quickly and may not contribute to the turbidity reading, the relationship between turbidity and total suspended solids (TSS) can change depending on the location that the test sample was collected.

Measuring turbidity in environmental applications, such as the oceans, rivers and lakes, a Secchi disk can be used. This is a black and white disk that is lowered into the water until it can no longer be seen. At that depth (called Secchi depth) the correlating number is recorded as a measure of the clarity in the water. The advantage in using this device in open waters is the ability to measure turbidity at various depths where multiple turbidity layers are present. This device is also easy to use and relatively inexpensive.

Reference: Wikipedia.com

The Determination of Water hardness

Introduction:

"Natural" water as it flows through rivers, out of springs, or from your water tap contains quantities of dissolved "minerals" matter. The general term for these impurities is hardness. Most hardness is represented by cations such as Ca^{2+}, Mg^{2+}, Fe^{2+}, or Fe^{3+} or by anions such as $CO_3{}^{2-}$, $HCO_3{}^{-}$, $SO_4{}^{2-}$, and Cl^-. Even in the absence of acid pollution, natural waters are usually mildly acidic. Carbon dioxide in the air dissolves in water according to the equation;

$$CO_2\,(g) + H_2O\,(l) ==== H_3O^+\,(aq) + HCO_3{}^-\,(aq) \qquad (1)$$

In addition, decaying organic matter releases acids which dissolve in water. As this acidic water passes over carbonate containing minerals such as limestone ($CaCO_3$) ions are produced in solution.

$$H_3O^+ (aq) + CaCO_3 (s) ===== Ca^{2+} (aq) + HCO_3^- (aq) + H_2O (l) \quad (2)$$

If you add up Reactions 1 and 2, the resulting reaction will be:

$$CO_2 (g) + H_2O (l) + CaCO_3 (s) ==== Ca^{2+} (aq) + 2\ HCO_3^- (aq) \quad (3)$$

Water which contains high concentrations of ions such as Ca^{2+}, Mg^{2+}, and Fe^{2+} is said to be hard water. Hard water is undesirable for several reasons; soaps do not lather well and form an insoluble scum “bathtub ring” in hard water, and deposits may form in water lines which restrict the flow of water. Detergents have largely replaced soaps and avoid the “bathtub” ring problem; however, the other problems are still encountered.

Two types of water hardness can be identified. If the water contains the HCO_3^- ion in combination with Ca^{2+}, Mg^{2+}, or Fe^{2+}, the water is classified as having **temporary hardness**. Temporary hard water can be softened by heating which causes the reaction;

$$Ca^{2+} (aq) + 2\ HCO_3^- (aq) \rightarrow CaCO_3 (s) + CO_2 (g) + H_2O (l)$$

which removes the ions from solution. However, the insoluble $CaCO_3$ deposit forms the scale which plugs pipe lines over long periods of time. **Permanent hardness** results when anions such as SO_4^{2-} or Cl^- are present as the counter ions to the dipositive cations. Heating does not result in reaction so that no softening occurs. Softening, removal of the unwanted ions, must be done by other means. In some waters the total hardness may be due to a combination of both types.

One of the most efficient methods of water softening is **ion exchange**. In this process an ion exchange resin, in the form of small insoluble beads, exchanges the ions in solution for less troublesome ones. Ion exchange resins which exchange cations are called cation exchange resins while anion exchange resins will exchange anions. An ion exchange resin is an insoluble material which has ionic groups covalently bound on its surface. The ionic species attached to a cation exchange resin is $-SO_3^-$. The negatively charged species must have a positive counter ion associated with it in solution and this is the ion which is exchanged. An exchange reaction is shown in the equation;

$$2RZ\text{-}SO_3^-, Na^+ + Ca^{2+} (aq) ===== (RZ\text{-}SO_3^-)_2, Ca^{2+} + 2\ Na^+ (aq)$$

where the Na^+ counter ion on the resin has been exchanged for the Ca^{2+} ion in solution. RZ represents the resin portion of the ion exchange resin. The anion exchange reaction proceeds similarly;

$$RZ\text{-}N(CH_3)_3{}^+, NO_3{}^- + Cl^- (aq) \text{ ====== } RZ\text{-}N(CH_3)_3{}^+, Cl^- + NO_3^- (aq)$$

Thus, if a solution of calcium chloride were passed over the two ion exchange resins shown above, the Ca^{2+} and Cl^- ions would bind to the resin and Na^+ and $NO_3{}^-$ would be released into solution. We would have exchanged calcium chloride for sodium nitrate in solution. The resin may be recharged and reused many times; the above equations are equilibria and if a concentrated solution of $NaNO_3$ is passed over the resin, the equilibira may be reversed according to LeChatalier's Principle to the original form. Alternatively the resins may be converted to any other form by passing the desired solution over the resin. For example, the cation exchange resin may be converted to $RZ\text{-}SO_3{}^-, H^+$ by an acid.

The reactions above represents the use of ion exchange to soften water; the Ca^{2+} ion responsible for causing hardness is cartridge containing the ion exchange resin is replaced periodically and recharged to use again.

The total hardness of water, the total effect of all cations, is measured by a titration procedure using a substance called ethylenediaminetetraacetic acid (abbreviated for unknown historical reasons, H_4Y, or more commonly EDTA). This molecule has four acidic hydrogens and reacts with many dipositive ions in a 1:1 ratio as illustrated by;

$$H_2Y^{2-} + Ca^{2+} \text{ ==== } CaY^{2-} + 2H^+$$

In neutral aqueous solution, two of the acidic hydrogens are neutralized and the H_2Y^{2-} is the primary species in solution. The endpoint is detected by the addition of an indicator, EBT, which forms a red color with Mg^{2+}. At the endpoint, the EDTA reacts with the MgEBT complex and displaces the EBT which is a blue color.

$$HY^{2-} + \underset{\text{RED}}{MgEBT} \text{ ===== } MgY^{2-} + \underset{\text{BLUE}}{HEBT}$$

To insure completion, the titration is performed at pH=10 using an NH_4OH/NH_4Cl buffer.

Water hardness is expressed in ppm (part per million) $CaCO_3$. One ppm corresponds to 1 mg $CaCO_3$ per liter of water sample. No attempt is made to distinguish between the various ions which may be present. From the volume of EDTA used in the titration (to calculate mmol of $CaCO_3$, express the EDTA molarity as mmol/mL);

mmol $CaCO_3$ = mmol EDTA = $(\frac{mmol\ EDTA}{mL})\ x\ (mL\ EDTA)$

the mmols of EDTA and of $CaCO_3$ may be calculated. To obtain the ppm of $CaCO_3$;

ppm $CaCO_3$ = $\frac{mmol\ CaCO_3\ x\ (100\ mg\ CaCO_3\ /\ mmol)}{Volume\ water\ sample\ in\ liters}$

We will determine the total hardness of a water sample in this experiment. We will also show how temporary water may be softened by boiling and how ion exchange is used to soften water.

Water is considered to be soft when the hardness is less than 60 ppm, hard when between 60-120 ppm, and very hard when above 120 ppm.

Experimental Procedure:

Two standard solutions of CaCO3 are provided, their concentrations are 10 and 1000 ppm. You use the Vernier probe to estimate the water hardness. Make sure you rinse the probe in between the standatd and the water samples to avoid cross contamination

pH Measurement

You can quantify the acidity of an aqueous solution by giving the hydronium ion concentration or simply $[H^+]$. But because this concentration value may be very small, the acidity is given in terms of pH. The term pH is defined as:

$$pH = -\log [H^+]$$

Where $[H^+]$ refers to the concentration of H^+ in unit of molarity.

For example: If [H+] = 0.0045 M, the pH is calculated according to the following set up:
PH = -log (0.0045) = - (-2.35) = 2.35
The pH ranges between 0 and 14.
A neutral solution has a pH of 7.00. For an acidic solution, pH is less than 7.00. Similarly, a basic solution has a pH greater than 7.00.
Experimental Procedure:
In order to measure the pH of a solution, we can use a pH probe. Bu the probe must be calibrated before measuring the pH of a solution. Use two different pH 4 and pH 7 standard solutions to calibrate the pH probe.
You would then rinse the probe before you measure the pH of the solution.

Biology Focus

Quantifying Biodiversity

Fig. 1

Photo: Christian Ziegler

Fig. 2

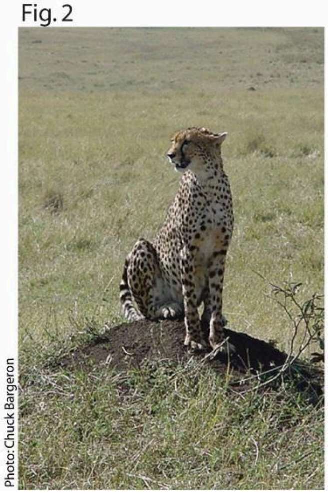


Photo: Chuck Bargeron

Fig. 3

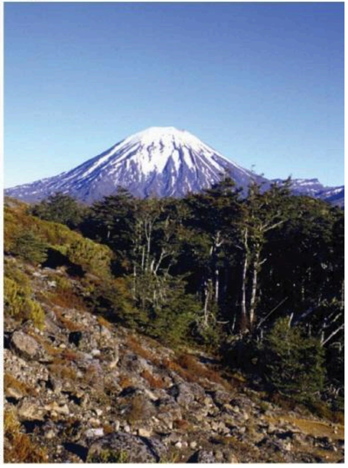


Photo: Peter Lockhart

This lab addresses the challenge of quantifying biodiversity. After reviewing the various levels of biodiversity, we will focus on estimating species diversity. The main exercise involves stream sampling for aquatic invertebrates. A pre-lab exercise simulates the field exercise and introduces several estimates and concepts. A post-lab virtual experiment explores deeper into diversity indices, sampling schemes, and habitat comparisons.

Learning objectives

- Definitions and levels of biodiversity
- Why biodiversity is important
- Design of sampling schemes
- Strengths and limitations of various diversity estimates
- Calculation, analysis, and expression of data

Background

It is common to hear ecologists talking about ***biodiversity***, particularly in terms of conservation biology. It is one of those terms that is used a lot, and is considered to refer to something important, yet, rarely is it clear exactly what is being discussed. In fact, ‘biodiversity’ can refer to many things, and has many specific definitions.

The most common definition of biodiversity refers to the number of different species in a given area or ***species diversity***. The greatest biodiversity by this measure would be the number of different species found in tropical rain forests (Fig. 1) which is estimated to be in the millions. Sometimes biologists refer to the diversity within a particular ***taxon***. For example, the southern Appalachians are the world’s ‘hotspot’ for salamander diversity. There are many indices of species diversity that we will explore later.

Biodiversity, in the broad sense, can also refer to variation within species, or among populations. Many species have populations which can be differentiated by morphology or behavior. Typically this occurs within species with large ***ranges***. Consider for example, the extraordinary differences among human populations across the globe. This variation reflects underlying differences in allele proportions among populations and is called ***genetic diversity***. Genetic diversity is of special concern to endangered species because small populations tend to lose genetic diversity through random genetic drift. Without genetic diversity, populations lose their ability to adapt to changing environments, and are more susceptible to be decimated by disease. In populations with normal genetic diversity there will a range of disease resistance among individuals. An extreme example of a species with low genetic diversity is the cheetah (Fig. 2). Cheetah's are so similar genetically that they can accept skin grafts from unrelated individuals without tissue rejection.

On a larger scale, we can consider ***ecosystem diversity*** (Fig. 3). In this case we are not considering individual species, rather a species assemblage in a particular habitat. Ecosystem diversity is a broad concept, encompassing any level of ecological organization above species (e.g. ***habitat***, ***community***, and ***ecosystem***). An example of a major threat to ecosystem diversity in the US is the loss of wetlands to development. It is not easy to quantify ecosystem diversity, as the edges of things like habitat and communities are hard to define. However, it can be argued that the most natural way to preserve all levels of biodiversity is to protect as much and as varied habitat as possible, and then let nature take care of the rest.

Measures of biodiversity

Abundance- This is not actually a measure of biodiversity *per se*, rather it is a count (or estimate) of all individuals present. Usually abundance refers to a certain species, but it can refer to all the individuals of all species present.

Species richness- This is the simplest measure of biodiversity being the tally of all the species in the area or community in question. While potentially easy to calculate, this measure is limited in that it lacks information of the relative abundance of the various species.

Community Dominance Index **(CDI)-** This index reflects how large a proportion of the total species present (in terms of numbers of individuals) is made up of the two most abundant species. It is calculated by the formula:

$$100\frac{y_1 + y_2}{y}$$

Where y_1 and y_2 are the abundances of the two most common species in the sample and y is the total abundance the sample.

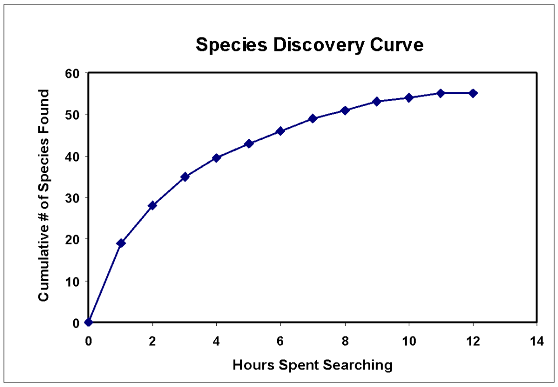
Shannon-Weiner Index **(SWI)-** This index measures how evenly distributed the numbers of the species present in a sample are. Unlike the CDI, this calculates the value from all the species present, not just the top two. It is calculated by the formula:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where p_i is the proportional abundance of the *i*th species (abundance of i / total abundance) and S is the species richness. The higher the index, the more evenly distributed the sample is. The index is maximized if the species are all in equal proportions.

Species Discovery Curve- When sampling for biodiversity, how do you know when you have found all the species? Well, in short, you don't. However, you can get an idea of how many more you *could* find by plotting the cumulative number of species found against some standardized measure of sampling effort (Fig 4).

Fig 4.



The function will be a curve approaching an asymptote of the actual number of species present. The reason it is curved is not (necessarily) because the biologists are getting tired of searching. Rather, it reflects the fact that, as species found accumulate, there is a diminishing probability that the next individual found will be a new species. The curve is also a function of that fact that the most common species are found first, and the rare species are more likely to be missed. From the species discovery curve you can estimate how much more effort it will take to find new species. It allows you to know when you have found most of the species…and decide when it is time to give up.

Jaccard Similarity Index- This measure is used to compare the species assemblages of two areas or habitats. It is used to define how similar two samples are in terms of species present. An example of when it would be useful is in deciding which watersheds to focus on protecting those which will preserve the most biodiversity. If you could only protect two of several, you would choose those with the lowest similarity index. The index is calculated as the number of species two samples have in common, divided by the total number of species represented in both samples.

$$J(A,B) = \frac{A \cap B}{A \cup B}$$

General note on sampling- You might imagine that it would take a long time to identify all the individuals in a sample to species, and it certainly would. Most communities have thousands of different species present, many of which appear quite similar. Fortunately, the biodiversity estimates work as long as you can separate individuals into recognizable groups. For example, you do not need to know what two species of snails actually are, you just need to correctly identify them as one or the other. However, the differences between species can be very subtle, and the better the categorizing, the better the estimates.

Materials

- Clothes and shoes to get in the water (knee deep)
- Seines, sampling nets, or strainers
- Wash cups
- Sorting trays
- Forceps and plastic pipettes
- Data sheets and pencils

Procedures

Working in teams take several samples of the river at each location.

1. One person holds the strainer in place while the other picks up the rocks and brushes them off immediately upstream from the net. Do this for one minute.

2. Take the net to the sorting table and separate the animals into the sorting trays (filled with stream water) by type.

3. Once several samples have been sorted, we will start assigning names to each of the specimen types. Starting with one sample, and then moving to the next, we will create a table of our ‘species’ which will be used to analyze all the samples. We will photograph them for future reference.

4. On site we will sketch a discovered species curve and use it to inform our decision on continued sampling.

5. Before leaving the site, be sure each sample has been properly documented with the numbers of each species found.

Analysis

Use the data you have collected to calculate the following for each sample, and for the combined sample: individual abundance, total abundance, species richness, community dominance index, and the Shannon-Weiner index.

Use software to create a species discovery curve.

If we have time to sample another stream, provide the same analyses. Also, calculate the Jaccard's similarity index. If we do not sample another stream, data will be provided for this.

Questions

1. *Compare the two streams using each of the measures. What species dominate each?*

2. *Given that the second sample was from a stream in the city, what species would be good* ***indicator species*** *for the health of a stream?*

3. *By inspecting your species discovery curve, how many more species might we have found if we kept looking?*

ELA Focus

While at the field site, collect the raw footage (interviews, narration, action shots, etc.) you will use to edit and produce your documentary film. Please, also take some time to capture the ‘unquantifyable’ in prose or poetry.