VA SEA

WE'RE ALL CONNECTED

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Grade Level
Advanced High School (AP/IB)

Subject Area
Environmental Science

VA SEA is a collaborative project between the Chesapeake Bay National Estuarine Research Reserve, the Virginia Institute of Marine Science's Marine Advisory Program, and Virginia Sea Grant. The VA SEA project is made possible through funding from the National Estuarine Research Reserve System Science Collaborative, which supports collaborative research that addresses coastal management problems important to the reserves. The Science Collaborative is funded by the National Oceanic and Atmospheric Administration and managed by the University of Michigan Water Center.

CHESAPEAKE BAY
NATIONAL ESTUARINE
RESEARCH RESERVE
VIRGINIA

VIMS | WILLIAM & MARY
VIRGINIA INSTITUTE OF MARINE SCIENCE

Sea Grant
Virginia

Title: We’re All Connected

Focus: Students will learn about community and ecosystem structure, trophic levels, species diversity, and food webs by participating in a mock-research activity to investigate the impact of human activity.

Grade Level: Advanced Placement (AP) Environmental Science

Learning Standards:

1.1 Introduction to Ecosystems

ERT-1: Ecosystems are the result of biotic and abiotic interactions

ERT-1.A: Explain how the availability of resources influences species interaction

ERT1.A.1: In a predator-prey relationship, the predator is an organism that eats another organism (the prey)

1.9 Trophic Levels

ENG-1: Energy can be converted from one form to another

ENG-1.B: Explain how energy flows and matter cycles through trophic levels

ENG-1.B.3: In terrestrial and near-surface marine communities, energy flows from the sun to producers in the lowest trophic levels and then upward to higher trophic levels

1.11 Food Chains and Food Webs

ENG-1: Energy can be converted from one form to another

ENG-1.D: Describe food chains and food webs, and their constituent members by trophic level.

ENG-1.D.1: A food web is a model of an interlocking pattern of food chains that depicts the flow of energy and nutrients in two or more food chains

ENG-1.D.2: Positive and negative feedback loops can each play a role in food webs, When one species is removed from or added to a specific food web, the rest of the food web can be affected

2.1 Introduction to Biodiversity

ERT-2: Ecosystems have structure and diversity that change over time

ERT-2.A: Explain levels of biodiversity and their importance to ecosystems

ERT-2.A.1: Biodiversity in an ecosystem includes genetic, species, and habitat diversity

ERT-2.A.5: Species richness refers to the number of different species found in an ecosystem

9.10 Human Impacts on Biodiversity

EIN-4: The health of a species is closely tied to its ecosystem, and minor environmental changes can have a large impact

EIN-4.C: Explain how human activities affect biodiversity and strategies to combat the problem

EIN-4.C.2: Habitat fragmentation occurs when large habitats are broken into smaller, isolated areas. Causes of habitat fragmentation include the construction of roads and pipelines, clearing for agriculture or development, and logging

Learning Objectives:

- Students will identify and count organisms found in collection sites, record, and graph their data
    - Students will be able to calculate and describe species richness **(2.1: ERT-2.A.5)**
    - Students will calculate species diversity using Simpson's Diversity Index **(2.1: ERT-2.A.1)**
- Students will develop a hypothesis that will describe how human impact and activity affects ecosystem and community structure **(2.2: ERT-2.C.1)**
- Students will develop and categorize species into a food web **(1.11: ENG-1.D.1 & 1.D.2)**
- Students will identify predator and prey species within food webs **(1.1: ERT1.A.1)**
- Students will assess and identify different variables within the environment, both anthropogenic and natural and explain how these can affect biodiversity **(9.10: EIN-4.C.2)**
- Students will identify and organize organisms into trophic levels **(1.9: ENG-1.B.3)**

Total length of time required for the lesson & activity / Time Required: At least one full class period. Handouts provided can be done in class **or** given as homework. Worksheets need not be assigned if time is short, or worksheet is not beneficial to students' grade level.

Key words/vocabulary:

- **Autotroph** – an organism that can produce its own complex organic compounds, generally through light or inorganic chemical reactions; an organism that can produce its own food

- **Community Structure** – species and their interactions, and relative abundances in a community

- **Diversity** – the variation of organisms that are present in a given ecosystem

- **Diversity Index** – a mathematical measure of species diversity in a given community, eg. Simpson's Diversity Index or Shannon Diversity Index

- **Ecology** – branch of biology that deals with the relations of organisms to one another and to their physical surroundings

- **Ecosystem** – a biological community of interacting organisms and their physical environment

- **Food Chain** – a hierarchical series of organisms each dependent on the next as a source of food; includes producers (autotrophs) and consumers, scavengers, and decomposers (heterotrophs)

- **Food Web** – a representation of feeding relationships within a community that implies a transfer of food energy from its source

- **Habitat** – place or environment where a plant or animal naturally or normally lives and grows

- **Heterotroph** – an organism that takes nutrition from other things; cannot produce its own food

- **Population** – a group of individuals of a single species that live in a particular area or habitat and interact with one another

- **Primary Consumers** – organisms that eat the primary producers, typically herbivores and sometimes omnivores. Primary consumers are found in the second trophic level

- **Primary Producers** – any green plant or microorganism that can convert light or chemical energy into a form of energy that they can use for themselves (autotrophs). Primary producers are found in the first trophic level, at the very bottom of the food chain

- **Relative Species Abundance** – the proportion of individuals of a specific species or type present in a given area, ecosystem, or particular habitat; can also be called species evenness

- **Secondary Consumers** – organisms that that eat the primary consumers, typically carnivores. Secondary consumers are found in the third trophic level

- **Simpson's Diversity Index** – a dominance diversity index that gives more weight to more common (dominant) species; a few rare species will not affect the diversity of the community

- **Species Richness (S)** – the count of the total number of different species within a defined region

- **Species** – a biological classification ranking immediately below the genus or subgenus, comprising related organisms or populations potentially capable of interbreeding to produce fertile offspring

- **Tertiary Consumer** – animals that eat other animals, specifically those that fall within the third trophic level as secondary consumers. Tertiary consumers are found in the fourth trophic level

- **Trophic Level** – The position that an organism occupies in a food chain; ranges from a value of 1 (primary producers) to 5 (marine mammals, humans); typically depicted as a trophic pyramid

- **Quaternary Consumer** – an organism that is at the very top of the food chain and eat organisms found in the lower trophic levels. Quaternary consumers are found in the fifth trophic level

Background Information:

As humans, we continue to increase our **population**, change, and urbanize new environments. We influence the world we live in, whether that be for better or worse. **Urbanization**, and by default, human interaction, have wide-reaching and lasting impacts on **ecosystems**. Urbanization of both land and water can create unavoidable changes within the environment, ultimately influencing **biodiversity**. Changes in these **habitats** can also lead to changes within the **food chain, food web, trophic pyramid,** and **species abundance** and can disrupt **community structure**. As people move into cities and coastal towns to create specific areas for human use, such as docks, marinas, beaches, etc., habitats that were naturally found can become fragmented and broken. Fragmentation can create edge sites, where it is often difficult for species to live in these areas. This can further reduce the potential **biodiversity** and **species richness** within an area.

With humans comes industry: agriculture, specifically, can create water run off filled with pollutants that washes off soil fields. The soil and pollutants are carried into nearby aquatic environments, increasing the risks that are posed to aquatic life and other **heterotrophs**, such as birds, that rely on aquatic organisms in their **food web**. It also reduces how deep light can reach in the water, potentially affecting **autotrophs** such as aquatic plants and phytoplankton (ie. algae) in the area. Any added nutrients that can be found in agricultural and farming sites can pose risks. Chemical fertilizers and manure both contain nutrients such as phosphorous, nitrogen, and potassium that can be washed away into aquatic ecosystems where they can cause phytoplankton blooms. These blooms can be damaging to the natural environment. Phytoplankton blooms can decrease visibility and light penetration into the water column and can potentially kill fish by creating "dead-zones" where there is little to no oxygen.

Student Handouts:

1. Key Words/Vocabulary
2. We're all Connected (by what we eat!)
3. Record keeping sheet with bead species key
4. We're All Connected – Calculating Simpson's Diversity Index
5. We're All Connected – Calculating Simpson's Diversity Index Equation Table
6. We're All Connected – Critical Thinking

Note: An answer key is not provided for the Simpson's Diversity Index Sheet as answers will vary dependent on the species pulled during the activity. It may be beneficial to have one worksheet submitted per group.

Materials & Supplies:

- Pencil/pen
- “Barriers” (cardboard or other material to separate portions of bead containers. Toilet paper rolls, construction paper, plastic cups, cut up paper plates, rulers, etc. would work)
- Scissors
- 3 small to medium sized bins/containers for beads (this is based upon availability and how spread out/separated you want the beads to be. Something the size of a shoe box would work)
- Adhesive (hot glue, tape, staples, etc.)
- Cloth/paper towels/cardboard to cover the containers and keep contents hidden (does not need to be flush against the top edge of containers)

Figure 1. Example of barrier set up using cut up paper plates, a ruler, and a paper towel roll. Barriers were held in place using tape. This would likely be considered a site of high impact (Site 1).

- 28 green beads (Grass Shrimp)
- 8 grey or white beads (Atlantic Silverside)
- 1 orange bead (Summer Flounder)
- 6 yellow beads (Mummichog)
- 10 brown beads (Mud Crab)
- 10 purple beads (Atlantic Flounder)

Note: Alternatively, other differently shaped objects can be used in place of beads, such as different dried pasta shapes, or different types of dried beans/lentils.

Classroom Set-up:

When pilot tested, set up took ~60 minutes.

Classroom or tables/desks will be divided into three “sample sites”. If the classroom is split into three areas, then there will be three bins for the entire class, and students will rotate in groups to each site. If tables/desks are used, then each group at a table/desk will be given all three sites to work through without rotating. This option would involve increasing the required materials.

A shoebox or small to medium sized bin will be used to represent each sampling site. Each site will need to have decoration(s) that show human activity. To construct barriers, use hot glue or another type of adhesive to secure cardboard pieces like cut out cardboard or paper towel tubes in place. Barriers could be touching each other, the wall, or just be loosely placed as a circle (a cut tube for example). Other items, such as construction paper, pencil holders, rulers, cut paper plates, etc. could also be used to form barriers. The point of the barrier is so that students’ hands may not be able to move freely throughout the bin. This shows that hard barriers can cause habitat fragmentation and other changes to the ecosystem. For an example set up, see **Figure 1**. See the last slide of the PowerPoint for a time-lapse video of Figure 1. Example Set Up.

Photo provided by A.C.Salmoiraghi

Teachers should place the most barriers at Site 1 to indicate high human activity, influence, and/or man-made structures, and none or the least barriers at Site 3 to indicate little to no human activity and influence. Site 2 should have a moderate number of barriers. Teachers should place bead counts for each site as seen in **Figure 2.**

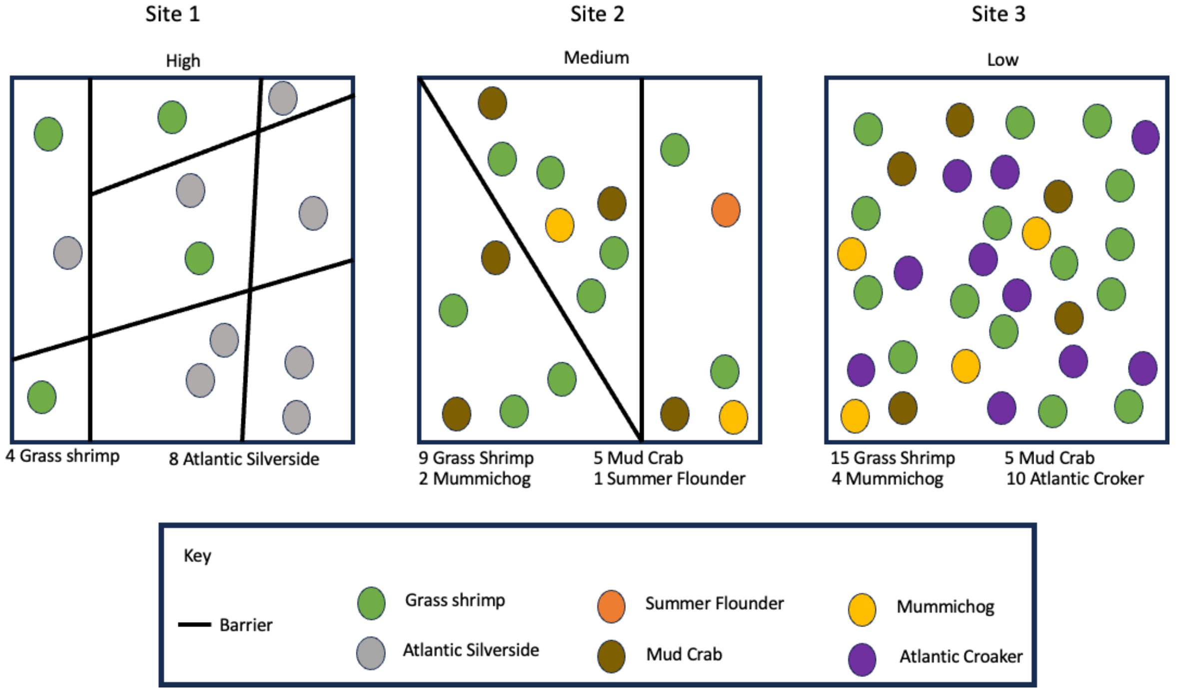

Figure 2. Example of bead placements in each site.

These barriers represent human activity and changes to the environment things such as docks, marinas, beachfront properties, and popular fishing spots. Barriers can also consist of natural rock formations and fallen trees, but these are more likely to be found in areas with less human activity and influence.

Students should not be able to see into the bins, so be sure to cover the tops with cloth or paper towel and instruct students to look away when it is their turn to "fish". Students should not be moving the bins more than necessary. Keep in mind that the barriers are made of cardboard and other material that may be flimsy and may come apart as students use them. Teachers may have to repair the site barriers with tape or glue between classes.

Procedure:
At each site:

1. Student 1 will “cast” a hook by placing their hand into the bin without removing the cover. Only grab one bead and pull it out. Make sure not to put it back into the bin yet. Keep any beads pulled out to the side.
2. Allow the next student to “cast” their hook, repeating Step 1. until all students have pulled out one bead.
3. At the end of the replicate (all students pulled one bead), record the beads’ colors and identify the species using the Key on Worksheet #3 – Record Keeping Sheet.
4. Without looking under the cover, place all beads back into the bin for that site at random. Repeat Steps 1 – 3. two more times (1 time for each replicate, 3 times total).

Engagement:
Students will be expected to work in small groups at each site to develop species richness, calculate a Simpson Diversity Index, and construct a plausible food web and trophic level pyramid using the organisms sampled at each site.

Explanation/Elaboration
Discuss: (1) students’ results as a class; (2) whether their hypotheses were supported or unsupported, and potential reasons why that might be; (3) the constructed food webs and trophic pyramids.

Evaluation
Students will be evaluated on participation in the classroom activity, completion of the data table, and completion and/or accuracy of three post-activity assignments (Worksheets #2 , #4, and #6).

Student Worksheets/Handouts
See following pages

Name:

Key words/vocabulary for students:

- **Autotroph** – an organism that can produce its own complex organic compounds, generally through light or inorganic chemical reactions; an organism that can produce its own food
- **Community Structure** – species and their interactions, and relative abundances in a community
- **Diversity** – the variation of organisms that are present in a given ecosystem
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- **Ecology** – branch of biology that deals with the relations of organisms to one another and to their physical surroundings
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- **Food Web** – a representation of feeding relationships within a community that implies a transfer of food energy from its source
- **Habitat** – place or environment where a plant or animal naturally or normally lives and grows
- **Heterotroph** – an organism that takes nutrition from other things; cannot produce its own food
- **Population** – a group of individuals of a single species that live in a particular area or habitat and interact with one another
- **Primary Consumers** – organisms that eat the primary producers, typically herbivores and sometimes omnivores. Primary consumers are found in the second trophic level
- **Primary Producers** – any green plant or microorganism that can convert light or chemical energy into a form of energy that they can use for themselves (autotrophs). Primary producers are found in the first trophic level, at the very bottom of the food chain
- **Relative Species Abundance** – the proportion of individuals of a specific species or type present in a given area, ecosystem, or particular habitat; can also be called species evenness

- **Secondary Consumers** – organisms that that eat the primary consumers, typically carnivores. Secondary consumers are found in the third trophic level

- **Simpson's Diversity Index** – a dominance diversity index that gives more weight to more common (dominant) species; a few rare species will not affect the diversity of the community 1

- **Species Richness (S)** – the count of the total number of different species within a defined region

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- **Quaternary Consumer** – an organism that is at the very top of the food chain and eat organisms found in the lower trophic levels. Quaternary consumers are found in the fifth trophic level

Name:

We’re All Connected (by what we eat!)

Suppose that you went out to eat at a seafood restaurant. You decided that you wanted to order the night’s special, Atlantic striped bass. You enjoyed your delicious meal and left with a full stomach. Before being eaten by you, that fish ate a crab, and that crab ate some oysters, and those oysters fed on some phytoplankton, and those phytoplankton were able to produce their own energy through photosynthesis. This is an example of a food chain.

You ⟵ Striped Bass ⟵ Crab ⟵ Oyster ⟵ Phytoplankton

Each ecosystem has many food chains within it, with many species being part of multiple food chains. You’re not the only thing that would eat striped bass, striped bass aren’t the only things that eat crab, and so on. **<u>Food webs</u>** consist of all the food chains within a single ecosystem. What food chains are available within a specific ecosystem may vary based on time of the year, time of day, and location.

On the back of this sheet, construct a <u>food web</u> and <u>trophic pyramid</u> using the given information:

Atlantic Croaker: a fish commonly around 9 inches long. Feeds on small fish, crustaceans, plankton, and decaying plant/animal matter

Summer Flounder: a fish commonly around 15 – 37 inches long. Feeds on small fish and crustaceans (like crabs, lobsters, & shrimp)

Mummichog: a fish commonly around 5 – 7 inches long. Feeds on small invertebrates (like marine worms), crustaceans (like crabs, lobsters, & shrimp)

Mud Crab: a crab that is commonly 6 inches wide or larger. Feeds on a variety of prey, such as small fish and crustaceans (like crabs, lobsters, & shrimp)

Grass Shrimp: a shrimp that is commonly 1.5 inches long. Feeds on decaying plant/animal matter, algae, and plankton

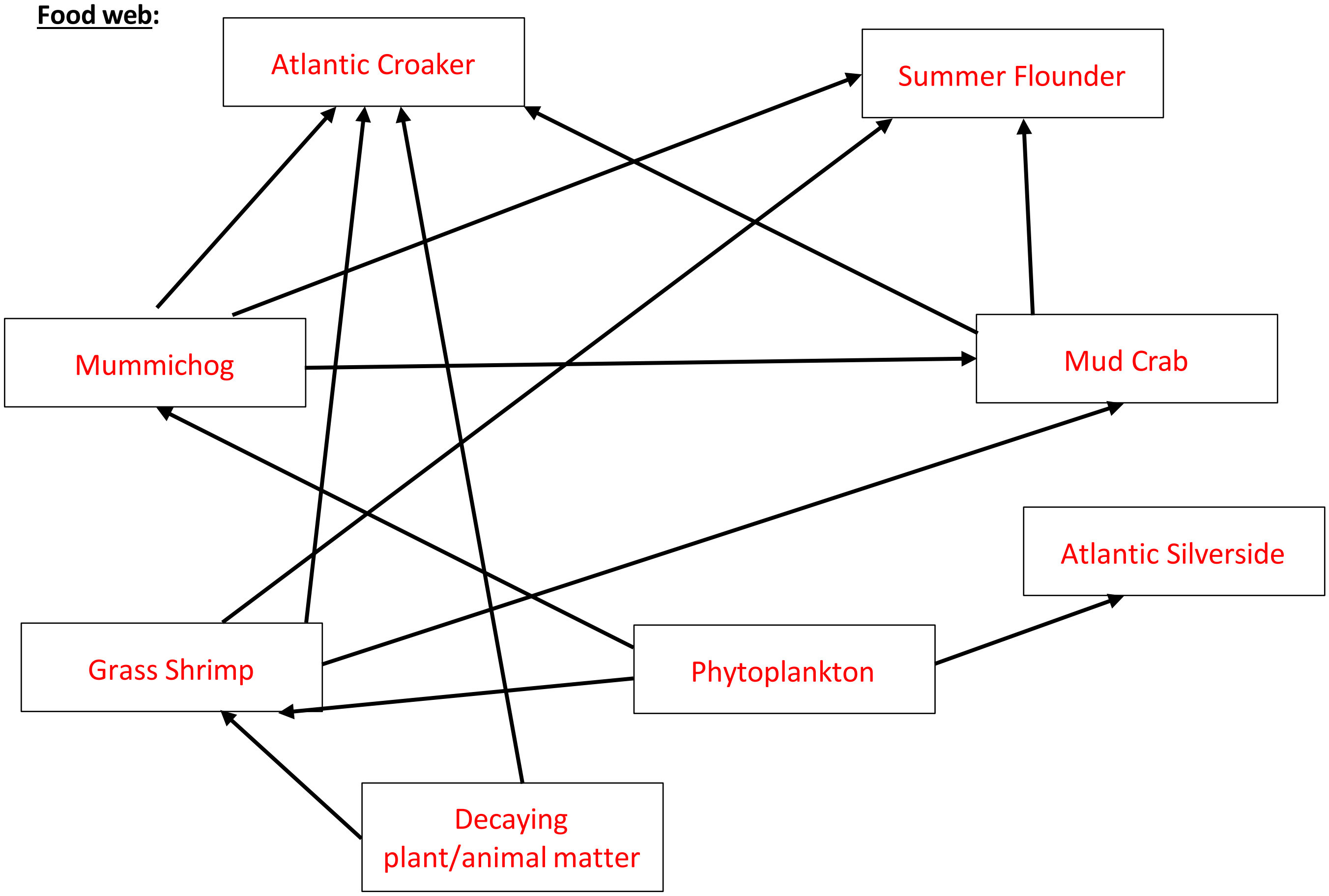
Atlantic Silverside: a fish that is commonly 3 - 4 inches long. Feeds on plankton and small crustaceans (like crabs, lobsters, and shrimp)

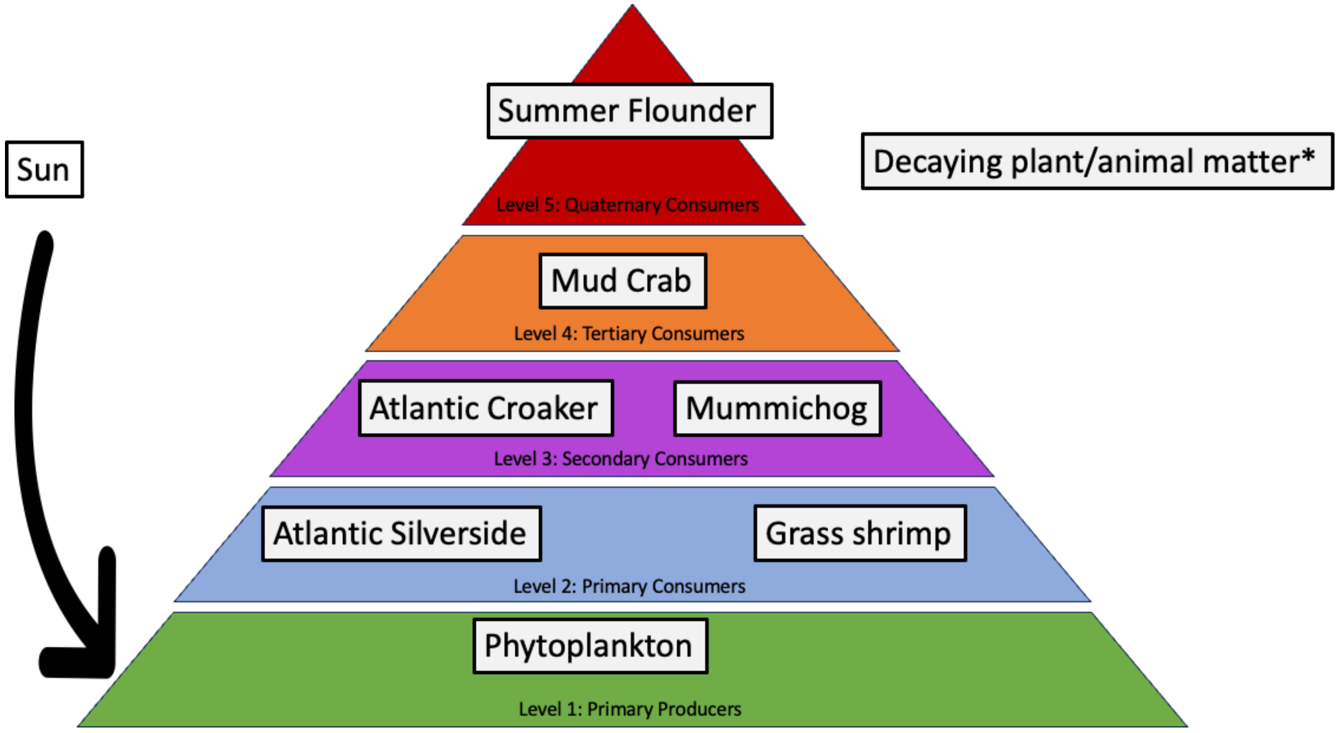
Phytoplankton: very small photosynthetic organisms, usually require a microscope to see

Remember: Arrows should show the transfer of energy

ANSWER KEY: We're All Connected (by what we eat!)

<u>Food web</u>:





Record Keeping Sheet

Name:

Date:

Site	Replicate	Species #1 Bead Color Student 1	Species # 2 Bead Color Student 2	Species # 3 Bead Color Student 3	Species # 4 Bead Color Student 4	Species # 5 Bead Color Student 5	Species # 6 Bead Color Student 6
1	1						
	2						
	3						
2	1						
	2						
	3						
3	1						
	2						
	3						

Key

Green - Grass shrimp
Grey - Atlantic Silverside
Orange - Summer Flounder
Yellow - Mummichog
Purple - Atlantic Croaker
Brown - Mud Crab

Name:

Date:

We're All Connected – Calculating Simpson's Diversity Index

Diversity indices, such as the Simpson's Diversity Index, are mathematical measures of species diversity in a given community. The Simpson's Diversity Index is a dominance index. So, Simpson's Diversity Index considers the number of species present, as well as the relative abundance of each species, which means that a few rare species with little abundance will not affect overall diversity. In other words, it measures how likely it is that two individuals that are randomly selected from a sample set will belong to the same species.

↑ species and ↑ evenness = ↑ diversity

In this activity, we will be focusing on the Simpson's Diversity Index:

The equation for Simpson's Diversity Index is: $DD = 1 - \sum(nn \div NN)^2$

Where… n = the number of individuals of that species

N = the **total** number of **all individuals**

∑ = the sum of the calculations

Another way at looking at it is: 1 – the sum of each number of individuals of one species (n), divided by the total number of individuals found (N) raised to the power of two.

For example, if:

N = 27

11 crabs (n_1)

14 striped bass (n_2)

2 shrimp (n_3)

Then… $DD = 1 - (11 \div 27)^2 + (14 \div 27)^2 + (2 \div 27)^2$

$$DD = 1 - (0.407)^2 + (0.519)^2 + (0.074)^2$$

$$DD = 1 - 0.166 + 0.269 + 0.005$$

$$DD = 1 - 0.44$$

$$DD = 0.56$$

Note: the value of D ranges between 0 and 1 and cannot be negative.

Using the data you collected from the sampling activity, calculate diversity using the Simpson's Diversity Index for each site using the provided table.

Answer the following questions:

a. Rank the sites based on species diversity in decreasing order:

b. Did this surprise you? Why or why not?

We’re All Connected – Calculating Simpson’s Diversity Index Equation Table

Site	Organism	Number of individuals (n)	n/N =	$(n/N)^2$ =	$1 - \sum(n/N)^2$ =
1					
	Total species =	Total N =		Sum of all $(n/N)^2$ =	Total Diversity = 1 -
2					
	Total species =	Total N =		Sum of all $(n/N)^2$ =	Total Diversity = 1 -
3					
	Total species =	Total N =		Sum of all $(n/N)^2$ =	Total Diversity = 1 -

Name:

Date:

Name:

Date:

We're All Connected – Critical Thinking

1. If one species is removed from a food web, how do you think that can affect the rest of the organisms within the web? Give an example.

2. Do you think that organisms are stationary or "stuck" in their trophic levels? Why or why not?

3. If we are creating habitat fragments, do you think that this can influence the original food web in that area? Why or why not?

4. Is it better to have a number closer to 0 or 1 for Simpson's Diversity Index. Why?

5. Suppose you catch many different species (S = 9) in Site A, but only one individual of each species (n = 9). In Site B, you catch not as many different species (S = 3), but you catch a lot of individuals (n = 12, suppose 4 individuals to each species).
    a. Which species has the higher relative species abundance?
    b. Which has higher species richness?

We're All Connected – Critical Thinking

1. If one species is removed from a food web, how do you think that can affect the rest of the organisms within the web? Give an example.

It could limit food availability up towards the upper trophic level if a species is a specific prey item of a predator. It could increase the number of organisms within that trophic level – which could be both good or bad. If you take out a berry bush from a food web, a bear might not be as affected as it could also eat salmon, but something like a smaller rodent (squirrel, chipmunk, etc) might have a harder time of finding food. This could potentially impact birds of prey in the food web and limit their food availability, potentially leading to a decrease in the population size.

2. Do you think that organisms are stationary or "stuck" in their trophic levels? Why or why not?

No – organisms can move between trophic levels depending on the ecosystem and other organisms within those systems.

3. If we are creating habitat fragments, do you think that this can influence the original food web in that area? Why or why not?

It could potentially influence the original food web in the area because it is breaking apart the habitat. This could mean that certain plants or prey items may no longer be present in an area and are instead isolated in a small spot, away from other things. This could potentially lead to population increase for the plant or prey items as there may be a lack of predators and other organisms that eat them, but it might also lead to decrease as their habitat may no longer be suited for their survival. Likewise, if the predators lose their prey items, they would either have to adapt to different food options, or face a population decline as food becomes scarce.

4. Is it better to have a number closer to 0 or 1 for Simpson's Diversity Index. Why?

Better to have a number closer to 1. Simpson's diversity index is a probability measure that measures the likelihood of two individuals being selected that are the same species in an area with less diversity. This might seem counterintuitive as in probability statistics, 1 means that the likelihood of two individuals being selected is definite (which means less diversity overall), and 0 would mean that there is an infinite amount of diversity. To remedy this, the probability (D) is subtracted from 1. This will then flip the values so that the larger value now indicates greater diversity, and a lower value would mean less.

5. Suppose you catch many different species (S = 9) in Site A, but only one individual of each species (n = 9). In Site B, you catch not as many different species (S = 3), but you catch a lot of individuals (n = 12, suppose 4 individuals to each species).
    a. Which species has the higher relative species abundance?

Higher relative species abundance: Site B

b. Which has higher species richness?

Higher species richness: Site A

Relative species abundance = total # of one specific species/total # of different species present

Site A: RSA = 1/9 = 0.11, S = 9

Site B: RSA = 4/12 = 0.33, S = 3

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