THINKING AND ACTING LIKE A SCIENTIST

TEACHER'S GUIDE

Fishing for Energy

What percentage of available energy is transferred between trophic levels in an ecosystem?

GRADES 9–12

Life Science

VAN ANDEL EDUCATION INSTITUTE

VAEI.ORG

INQUIRY-BASED SCIENCE

Fishing for Energy

Life Science

Grade Level/ Content	9–12/Life Science
Lesson Summary	In this lesson, students will discover the 10% rule by analyzing energy transfer within an aquatic ecosystem.
Estimated Time	2, 45-minute class period
Materials	Paper and pencil, Investigation Plan, Data Sheet, journal
Secondary Resources	Marine Bio: Trophic Structure YouTube Video: Food Chain in the Everglades Nature Education: Food Web: Concept and Applications Annenberg Lerner: Energy Flow Through Ecosystems
NGSS Connection	**HS-LS2-4** Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.
Learning Objectives	• Students will identify that producers store energy as biomass at the base of food webs. • Students will analyze energy data to discover that energy transfer between trophic levels is inefficient. • Students will calculate energy transfers between trophic levels.

What percentage of available energy is transferred between trophic levels in an ecosystem?

Why are there so many more insects than bears? Top predators are rare compared with organisms at lower trophic levels. A major reason is that energy transfer between trophic levels is inefficient. Consumers have less energy available to them than do producers. Only about 10% of the total energy available at one trophic level is transferred to the next level. In this lesson, students focus on the flow of energy within ecosystems by modeling energy transfer within an aquatic ecosystem. They will also analyze ecosystem energy data from a sample ecosystem to quantify how inefficient energy transfer is within ecosystems.

Investigation is based on the Van Andel Education Institute (VAEI) Instructional Model for Inquiry-Based Science. In all investigations:

Students don't know the "answer" they are supposed to get.

Students play a driving role in determining the process for learning.

Teachers and students construct meaning together by journaling.

Students are working as hard as the teacher.

Part 1

INVESTIGATION SETUP

Computers with Internet access will be necessary for students to conduct organism research and any related investigation into the Silver Springs, Florida ecosystem.

- Paper and pencils or markers to create an Energy flow diagram
- Investigation Plan
- Data Sheet

Part 2

INVESTIGATION FACILITATION

Question

Introduce the investigation question.

What percentage of available energy is transferred between trophic levels in an ecosystem?

CURIOSITY

Show an image of a lake ecosystem, such as the one from Ecosystem.org. Do not include food web arrows or labels in the image. Encourage students to ask questions about the image. Ask them which organisms serve as producers. Have them choose an organism and describe to fellow students how that organism obtains its energy to survive.

Personal Knowledge

Students capture what they already know about energy transfer between trophic levels.

- Find out what students already know about energy, trophic levels, and ecosystems.
- Have each student draw a basic food web from an ecosystem of their choice from memory.
- Challenge them to include at least five different organisms and three or more trophic levels.
- Encourage them to include as many relevant terms in the model as they can remember, such as consumer or herbivore.
- Have students share and discuss their food web with another classmate.

RISK-TAKING

Drawing a quick model based on previous knowledge may be intimidating to some students. Reassure them that there is no single, correct way to represent a food web, and that any misunderstandings will be clarified during the investigation.

Prediction

Students communicate an expected outcome, based on prior knowledge.

- Students consider what they know about energy transfer between trophic levels.
- Students present the prediction as *I predict* _________ *because* _________.

Investigation Plan

Students review a plan to research and collect data to understand energy flow through an ecosystem.

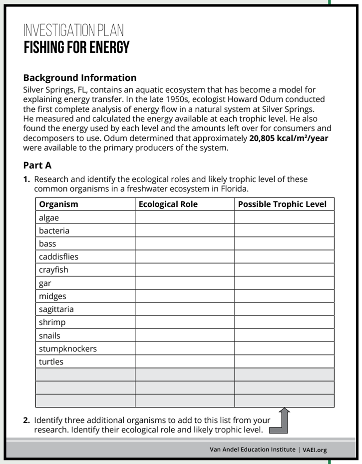
- Divide the students into groups of 2 or 3.
- Review the Investigation Plan and answer any student questions.
- Students will read about an aquatic ecosystem at Silver Springs, FL that has been analyzed to quantify energy transfer concepts within ecosystems.

COLLABORATION

Encourage students to work together to research and compare the ecological roles of the 15 species. They should also collaborate on the identification of possible trophic levels for each organism type. This information will be used to inform how students represent their food web.

CRITICAL THINKING

Use the Fair Test checklist to help students think critically about the investigation plan. Help them understand that a good investigation plan must include a test that is repeatable, generates quality data, and minimizes error. The more critically students think about their investigation plan, the more confident they will be in their results.


INVESTIGATION PLAN

FISHING FOR ENERGY

Background Information

Silver Springs, FL, contains an aquatic ecosystem that has become a model for explaining energy transfer. In the late 1950s, ecologist Howard Odum conducted the first complete analysis of energy flow in a natural system at Silver Springs. He measured and calculated the energy available at each trophic level. He also found the energy used by each level and the amounts left over for consumers and decomposers to use. Odum determined that approximately **20,805 kcal/m²/year** were available to the primary producers of the system.

Part A

1. Research and identify the ecological roles and likely trophic level of these common organisms in a freshwater ecosystem in Florida.

Organism	Ecological Role	Possible Trophic Level
algae		
bacteria		
bass		
caddisflies		
crayfish		
gar		
midges		
sagittaria		
shrimp		
snails		
stumpknockers		
turtles		

2. Identify three additional organisms to add to this list from your research. Identify their ecological role and likely trophic level.

Van Andel Education Institute | VAEI.org

Investigation Plan

Observation

Students record energy data from a provided data set about Silver Springs.

Part A

- For Part A, students will utilize Internet resources to identify the ecological roles and likely trophic level of 12 organisms from a Florida freshwater ecosystem. They are also asked to include 3 additional organisms that could live in this ecosystem during their research.
- If interested, students can research the Silver Springs area and look up additional information about its environment or the groundbreaking ecological research conducted by Howard Odum and his fellow scientists.

Part B

- When students finish with Part A, provide students with the total available and stored energy in each trophic level, the energy used and lost by each level, and leftover energy available to decomposers. Highlight how this data is recorded as a measurement of energy per square meter every year (kcal/m²/year).
- As a whole class, take the time to ask students to identify any initial impressions of the dataset. Also, encourage students to ask clarification questions to ensure that they understand how these columns are related to each other.
- This dataset was built from data found in a study by Howard Odum and the figure found here.

Silver Springs Dataset: All values in kcal/m²/year.

Trophic Level	Available energy	Energy used and lost	Energy stored for consumers	Energy for decomposers
Producers	20,805	13,187	7,618	4250
Primary Consumers	3,368	2,265	1,103	720
Secondary Consumers	383	272	111	90
Tertiary Consumers	21	16	5	5
Decomposers	5065	5065		

(Based on data from: Howard T. Odum, "Trophic Structure and Productivity of Silver Springs, Florida," *Ecological Monographs* 27, no. 1 (1957): 106–107)

Part 3

INVESTIGATION ANALYSIS AND DEVELOPMENT OF CLAIM

Data Analysis

Students make sense of their data by organizing it and representing it visually.

- Instruct the students to analyze the data for patterns and use it to inform their model. They may wish to use the Data Analysis prompt as a guide.
- Have students **evaluate** their data for trustworthiness.
- Then, have them analyze their data to find patterns and trends. They will **organize** the data and/or **represent** it visually in an energy flow diagram to construct meaning.
- Have students **interpret** what the identified patterns or trends mean.
  - Challenge students to calculate the amount of energy transferred to each successive trophic level as well as across all four trophic levels. *(This analysis will be the basis of the 10% rule (average) for your students to communicate in their explanation.)*
  - Challenge the students to figure out what happens to all 20,805 kcal available in this ecosystem. *(The numbers add up so that each kcal is exactly accounted for.)*
- Ensure they have enough data that it can be used as evidence to support a claim.

CREATIVE THINKING

Encourage student groups to brainstorm and identify a variety of ways to organize and communicate their energy flow diagram. A hand drawing, Sankey diagram, digital presentation, or spreadsheet are all great ways to communicate the information while emphasizing one aspect of the data that is of particular interest to each student group.

Secondary Knowledge

Students use secondary sources to understand how energy flows through an ecosystem.

- Use these resources (or your own) to develop students' understanding of energy flow within ecosystems.
  Marine Bio: Trophic Structure
  YouTube Video: Food Chain in the Everglades
  Nature Education: Food Web: Concept and Applications
  Annenberg Lerner: Energy Flow Through Ecosystems
- After reviewing these resources, students should understand that energy from the sun is captured by producers. Energy transfer is inefficient, so energy is lost during transfers from one trophic level to another. They should also understand the connection to decreasing numbers of individual organisms of any given type in higher trophic levels.

CONSTRUCTION OF MEANING

This will confirm the concepts that students discovered in their investigation. In addition, it will remind the students of the larger context. Each organism needs energy to survive, and this energy is originally captured by autotrophs from sunlight.

Explanation

Students write a claim and provide evidence and reasoning to support it.

- Have students use what they've discovered to write an explanation that answers their investigation question. Students may wish to use the Explanation prompt as a guide. Have them write their explanation in their journal.
- Have students develop a **Claim** to answer the question: How can energy transfer between trophic levels be modeled?
- Then, have them add **Evidence** (the analyzed data) to support their claim.
- Finally, have them add **Reasoning** to their claim. Reasoning should include the information obtained from this investigation as well as science principles they have learned.

Claim

We claim that on average, approximately 11% of total available energy is transferred between trophic levels.

Evidence

The evidence that supports our claim is our analysis of the Silver Springs dataset. This analysis showed that the amount of available energy decreases with each trophic level. Our analysis also shows that a total of 16.1% was transferred from producers to primary consumers, 11.3% was transferred from primary consumers to secondary consumers, and 5.4% was transferred from secondary consumers to tertiary consumers.

Reasoning

Investigation: We analyzed a data set to generate evidence from our investigation. The dataset (keep consistent with other uses) was based on an actual scientific study conducted at Silver Springs in Florida.

Science: We learned from readings and class discussion that ecosystem energy initially comes from the sun and is captured by producers. A small percentage of that energy is stored as biomass and can be transferred when a consumer eats the producer. Each trophic level loses some energy through a variety of biochemical processes, so less energy is available at higher trophic levels.

- Once the explanation is written, have 2 or 3 student groups that utilized a different approach for their energy flow diagram discuss their results using a Present and Defend.

Evaluation

Students reflect on the investigation.

Discuss the following questions.

- How confident are you in your analysis?
- How might you design your energy flow diagram differently if you could use any possible materials and have unlimited time?
- What question would you like to pursue next?

Part 4

INVESTIGATION ASSESSMENT AND EXTENSION

Application

Students demonstrate understanding of energy transfer within an ecosystem by applying their learning in multiple contexts.

- Have students apply their learning by considering human eating habits. Which eating habit is more energy efficient: Veganism, vegetarianism, or meat-eating? Have them explain their answer.
- Students can apply their knowledge of food webs by learning about how removing a single organism can affect an entire ecosystem. CBS News: Keystone Species
- Students may think that because producers are the base of an ecosystem's energy pyramid, the more producers, the better! Here students can learn about how the rapid growth of producers can devastate an aquatic food web. BBC: Eutrophication

Assessment

Students demonstrate understanding of trophic levels in ecosystems.

Evaluate student explanations based on how well they:

- identify that producers store energy as biomass at the base of food webs.
- analyze energy data to discover that energy transfer between trophic levels is inefficient.
- calculate energy transfers between trophic levels.

For additional lessons or to customize this lesson, go to www.nexgeninquiry.org.

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INVESTIGATION PLAN
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sagittaria		
shrimp		
snails		
stumpknockers		
turtles		

2. Identify three additional organisms to add to this list from your research. Identify their ecological role and likely trophic level.

FISHING FOR ENERGY

Part B

3. Record the Silver Springs ecosystem dataset labels and values shared by your teacher in the provided table or within your journal.

Trophic Level				
Producers				
Primary Consumers				
Secondary Consumers				
Tertiary Consumers				
Decomposers				

Silver Springs dataset: All values in kcal/m^2/year.

(Based on data from: Howard T. Odum, “Trophic Structure and Productivity of Silver Springs, Florida,” *Ecological Monographs* 27, no. 1 (1957): 106–107)

Part C

4. Analyze the provided energy data to look for patterns or trends to communicate in your explanation and energy flow diagram.

5. Organize your list of organisms, ecological roles, and trophic levels for display in an energy flow diagram. Ensure that you include a way to quantify energy flow values from your data analysis.