# WHEN BLUE IS GREEN

## Sustainable Blue Food Systems Driven by Integrated Aquaponics

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# WHEN BLUE IS GREEN

**When Blue is Green (BiG)** is a five-year project led by Purdue University and funded with a $10 million grant from the U.S. Department of Agriculture. The BiG project aims to advance aquaponics through integration with microalgae cultivation, anaerobic digestion and biorefinery processes for zero-waste food production.

The project's goal is to develop a zero-waste, grid-independent and economically viable food production system to facilitate increased regional production of nutritious and affordable blue foods with a minimal environmental footprint.

## CREDITS

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# OVERVIEW

A team of researchers is working to increase the availability of blue foods (seafood) in the U.S. About 90% of seafood consumed in the U.S. currently comes from abroad, resulting in a $17 billion trade deficit.

Aquaponics (growing seafood and plants together) can produce an array of nutritious blue foods and specialty crops. This emerging food production system faces intertwined technical, economic and environmental challenges that are barriers to its wide adoption.

Members of this research team bring expertise in the following disciplines: agricultural and biological engineering, agricultural economics, aquaponics, civil engineering, education, environmental and ecological engineering, Extension, food science, forestry and natural resources, and nutrition.

We are testing the hypotheses that integrating aquaponics with microalgae cultivation, anaerobic digestion and biorefining can fully utilize nutrients, produce energy and high-value bioproducts, and reduce waste and negative environmental impacts. We are also integrating research with Extension (for producers) and education (for high school students) to increase adoption of aquaponics and consumer interest in blue foods.

The U.S. Department of Agriculture supports this project under award number 2023-68012-39001.

# PROJECT OBJECTIVES

- Identify barriers and opportunities for blue foods and aquaponics.
- Build a novel, integrated aquaponics food production system.
- Develop sustainability metrics for system assessment and management.
- Support aquaponics and blue food industry and market development.
- Create blue food-related education materials.

# CURRICULUM TARGET AUDIENCE

Students in grades 9-12 studying agriculture, biology, environmental science and food science. Teachers may choose from 11 activities best suited for their classrooms or students.

The first activity, *What are Blue Foods?,* is an overview of our project and goals. The rest of the activities are listed in alphabetical order. All include Next Generation Science Standards (NGSS) and Agriculture, Food, and Natural Resources (AFNR) standards.

Note: Topics reflect the work promised to our funder (USDA) and are based on the expertise of the researchers. They are not developed for any particular subject but are intended to be used if they enhance your curriculum and in the order you wish.

The learning activities and page numbers for them are listed under Contents. You will find *Teacher Resources*, PowerPoint slides, and student worksheets. The PowerPoint slides are available at the project Learning Resources page click on the Learning Resources tab at https://purdue.ag/big-project, and may be altered as needed for your students. This page also includes short videos (BiG Snippets) of our project.

Check out this video, Aquaponics System Tour: When Blue is Green Project at Purdue University:


Or https://purdue.ag/big-project

# BiG CURRICULUM TOPICS & STANDARDS

| Activity | Topic | Subject | NGSS | AFNR Content Standards |
|---|---|---|---|---|
| **What are Blue Foods?** | Aquaponics & grant intro. | Ag; Econ; Science | ▪ Stnds: HS-LS2-7, HS-ETS1-1<br>▪ Core: HS-LS2-7 | ▪ FPP.04.02<br>▪ FPP.04.03 |
| **Let's Get Started** | Aquaponic system set-up with goldfish and basil. | Ag; Science | ▪ Stnds: HS-LS2-5, HS-LS2-7, HS-ETS1-4<br>▪ Core: HS-LS2-5 | ▪ CRP.11.01 & 12.01<br>▪ ESS.01.02 & 03.04, & 03.05<br>▪ FPP 01.02 & 02.01 & 02.02<br>▪ NRS.03.01 & 04.03<br>▪ PS.01.01 & 01.02 & 01.04 & 03.01 - 03.05 & 04.01 |
| **Comparing the Financial and Environmental Costs of Food Production** | Food production supply chain intro. | Economics | ▪ Stnds: HS-ETS1-1 | ▪ ABS.01.01 & ABS.01.03<br>▪ NRS.02.04<br>▪ CRP.12.01 |
| **Flow Rates, Why They Matter** | How pollution is affected by flow rates. | Engineering; Math | ▪ Stnds: HS-LS-6, HS-ETS1-4<br>▪ Core: HS-LS2-4, HS-LS2-7, HS-LS2-5, HS-LS2-6 | ▪ ESS.01.02<br>▪ ESS.03.02<br>▪ ESS.03.03 |
| **Food Safety in the Kitchen** | Safe food handling. | Food Science | None | None |
| **Comparing the Nutritional Value of Different Foods** | Value of reading food labels. | Food Science, Science | None | None |
| **Plant and Fish Nutrition** | Important nutrients for plants and animals. | Ag; Science | ▪ Stnds: HS-LS2-5<br>▪ Core: HS-LS2-7, HS-LS2-7 | ▪ ESS.03.04 |
| **The Systems Approach to Aquaponics** | Importance of a systems approach. | Engineering; Math | ▪ Stnds: HS-LS2-4, HS-LS-6,HS-ETS1-3<br>▪ Core: HS-LS2-7 | ▪ CRP.11.01<br>▪ CRP.12.01 (optional) |
| **Wastewater Recycling** | Reducing nutrients and contaminants in aquaponics systems. | Engineering; Math | ▪ Stnds: HS-LS2-5, HS-LS2-7<br>▪ Core: HS-LS2-4, HS-LS2-5 | ▪ ESS.04.01<br>▪ ESS.04.02 |
| **Water Quality and Aquaponics** | Taking WQ measurements. | Engineering; Math; Science | ▪ Stnds: HS-ETS1-1 | ▪ ESS.01.02<br>▪ ESS.02.02<br>▪ ESS.03.03 |
| **Zero Waste, Grid Independent, and Economically Viable Aquaponics System** | What is a zero waste, grid independent, and economically viable aquaponics system? | Economics; Science | ▪ Stnds: HS-LS-6, HS-LS2-7, HS-ETS1-3 | |

# AG STANDARDS

- ABS.01.01. Apply economic principles to plan and manage inputs and outputs in an AFNR business.
- ABS.01.03. Develop and apply skills to manage an AFNR business in an efficient, legal and ethical manner.
- CRP.11.01. Research, select and use new technologies, tools and applications to maximize productivity in the workplace and community.
- CRP.12.01. Contribute to team-oriented projects and builds consensus to accomplish results using cultural global competence in the workplace and community.
- CRP.12.01. Contribute to team-oriented projects and builds consensus to accomplish results using cultural global competence in the workplace and community.
- ESS.01.02. Properly utilize scientific instruments in environmental monitoring situations (e.g., laboratory equipment, environmental monitoring instruments, etc.).
- ESS.03.04. Apply microbiology principles to environmental sustainability systems.
- ESS.03.05. Apply ecology principles to environmental sustainability systems.
- ESS.04.01. Develop systems of sustainability management for all categories of solid waste in environmental sustainability systems.
- ESS.04.02. Sustainably manage solid waste in environmental service systems.
- FPP 01.02. Apply food safety and quality assurance procedures in the harvesting, handling and processing of food products.
- FPP.02.02. Apply principles of microbiology and chemistry to develop food products to provide a safe, wholesome, and nutritious food supply for local and global food systems.
- FPP.04.02. Evaluate the significance and implications of changes and trends in the food products and processing industry in the local and global food systems.
- FPP.04.03. Identify the purpose of industry organizations, groups and regulatory agencies that influence the local and global food systems.
- NRS.02.04. Examine and explain how economics affects the use of natural resources.
- NRS.03.01. Sustainably produce, harvest, process and use natural resource products.
- NRS.04.03. Prevent or manage introduction of ecologically harmful species in a particular region.
- PS.01.01. Determine the influence of environmental factors on plant growth.
- PS.01.02. Prepare and adjust growing media for use in plant systems.
- PS.01.04. Develop and implement a nutrient management and/or fertilizer plan for specific plants or crops.
- PS.03.01. Demonstrate plant propagation techniques in plant system activities.
- PS.03.02. Develop and implement a management plan for plant production.
- PS.03.04. Apply principles and practices of sustainable agriculture to plant production.
- PS.03.05. Harvest crops according to industry standards.
- PS.04.01. Evaluate, identify, and prepare plants to enhance an environment.

Ag students wishing to focus on Education, Communication and Leadership Career Pathway are encouraged to use one or more of the activities with younger students to meet the following performance indicators.

- ECL.02.01. Develop and deliver a workshop or lesson using a variety of methods and best practices in instruction and facilitation.
- ECL.02.02. Evaluate facilitation or presentation strategies that encourage appropriate social interactions, embrace diversity, promote equity and build a positive learning environment that is welcoming to all individuals.
- ECL.03.01. Identify the methods and characteristics of effective verbal, nonverbal, written and visual communication.
- ECL.04.01. Develop a communications plan that includes purpose, target audience, message, medium and outcome evaluation.
- ECL.04.02. Identify, apply and demonstrate communication skills and methods per the communications plan.

**Teachers recommended we add the Environmental Standards so they have been added at the end of this document, pg. 64.**

# WHEN BLUE IS GREEN

| Activity | Page |
| --- | --- |
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Most of these activities are intended for a 50-60 minute class period (or after school project) and will take an hour of teacher prep time. Note that the Let's Get Started! activity takes much longer for system set up and maintenance. The plants and fish will need to be monitored throughout their life.

# What are Blue Foods?

**Contributing author:** Jen-Yi Huang, associate professor, department of food science

**Student objective:** Students learn what blue foods are and why they are important.

**Next Generation Science Standards**
- NGSS Standards: HS-LS2-7, HS-ETS1-1
- Disciplinary Core Ideas and Crosscutting Concepts: HS-LS2-7

**AFNR Content Standards**
- FPP.04.02. Evaluate the significance and implications of changes and trends in the food products and processing industry in the local and global food systems.
- FPP.04.03. Identify the purpose of industry organizations, groups and regulatory agencies that influence the local and global food systems.

> ***Note:*** This activity requires students to track their food intake (or that of a study subject) after estimating it in class. They will collect data for a week, so you may go through the PowerPoint with students and begin another activity, returning to the final calculations after they have collected their data.

**Materials/supplies**
- What are Blue Foods.pptx
- Food Inventory worksheet, pg. 12 (two per student)
- Internet access

**Activity 1. What Do You Eat?**
**Direct instruction: Students calculate their foodprint to see how their food choices affect the environment.**
What are Blue Foods.pptx
- Introduction, slides 1-3.
- Youth list all the food they remember eating over the last week.
- Discussion, suggested questions:
  - Did you remember to include after-school snacks?
  - Did you include any after-dinner snacks?
- Instruct students to estimate their food environmental foodprint by using the Harvard Foodprint calculator: https://harvard-foodprint-calculator.github.io/

> ***Note:*** Consider compiling class data but note that some students may not wish to share their food diaries for personal and/or financial reasons (for example, if their family uses food stamps).

- Discussion, suggested question: Were you surprised by the total?

> ***Note:*** Youth should compare the impact of different food choices. They should not discuss counting calories or choosing not to eat which could encourage an eating disorder. If you feel this might be a possibility we recommend:
> - Discussing the importance of proper nutrition and using Activity 3 (*Comparing the Nutritional Value of Different Foods*) as a companion activity.
> - The Center for Disease Control (CDC) article: Benefits of Healthy Eating https://www.cdc.gov/nutrition/resources-publications/benefits-of-healthy-eating.html

- Assignment: (Note that this takes a lot of time so students may complain and it may not fit your schedule.)
  - Optional: slides 4-5
  - Students keep track of what they or a study subject eat for a week.
- One week later: Students use the Harvard foodprint calculator to calculate their food footprint.
  - Ask students to compare their actual food footprint with the one they estimated previously.
- Discussion (slide 5, optional):
  - Compare your first Food Inventories and Food Footprints.
  - Did you have a lower food environmental footprint in week 2? Why or why not?
  - How accurate do you think your first food inventory was?
  - What are the major contributors to your food footprint?
    - Eating a plant-based diet, rather than one with a lot of meat and dairy, can help fight climate change, according to a report by the UN's Intergovernmental Panel on Climate Change (IPCC). According to the IPCC, the West's high consumption of meat and dairy is fueling global warming. (https://www.bbc.com/news/science-environment-49238749).
    - Some students may not agree with the IPCC conclusion because of their family's eating patterns or personal preferences. However, they might accept that eating more vegetables and fewer processed foods may improve health over the long run.
  - How do your personal choices for food and other products affect the environment?
    - Youth may also wish to discuss how transportation modes, clothing, use of electronics, leisure activities, personal-care products and other lifestyle choices impact the environment.

**Assessment**

- Teacher's analysis of the knowledge their students gained
- Quiz or discussion questions

**Glossary**

**Aquaculture:** Cultivation of aquatic animals or plants for food.

Aquaponics: The combination of recirculating aquaculture and hydroponics.

**Food miles:** The distance traveled from where food is grown to where it is consumed.

**Foodprint:** The environmental result of everything it takes to get your food from the farm to your plate.

**Supplemental information**

> ***Note:*** Although this information is provided for the teacher, you may use it as supplemental reading for higher-ability classes or students. You may also assign any of the additional resources listed at the end of this document.

The food production, processing and distribution system is one of humankind's greatest achievements. However, humanity still struggles with malnutrition and the environmental degradation associated with food production systems. Planning for the future requires a transformation of current food systems, as detailed here: The role of seafood in sustainable diets (Environ. Res. Lett. 17 (2022) 035003). The authors concluded: Foods sourced from plants as well as bivalve and carp aquaculture and small pelagic fisheries tended to have the lowest environmental impact given their nutrient richness to meet dietary requirements across a diversity of nutrients. https://iopscience.iop.org/article/10.1088/1748-9326/ac3954

The BiG research team noted, in their grant application, that blue foods, as a critical source of nutrition, can improve human health by: reducing micronutrient (e.g., vitamin A, calcium, iron, etc.) deficiencies and providing a critical source of omega-3 fatty acids that can reduce the risk of diet-related non-communicable diseases; and displacing the consumption of red and processed meats — a characteristic of the nutrition transition that often accompanies the Westernization of food systems — that can cause adverse health outcomes.

Aquaculture and capture fisheries also generally produce fewer greenhouse gas emissions and use less land than farming red meats, and many aquaculture industries outperform commercial production of chicken, the most efficient major terrestrial animal-source food. The *Blue Food Assessment*, an international joint initiative aiming to build healthy, equitable and sustainable food systems, indicates that a blue food solution requires subnational efforts to increase both production and consumption. See https://bluefood.earth/what-we-do/.

Some students, particularly those who raise livestock at home, may disagree that a diet composed primarily of red and processed meats is less healthy that other diets. You may explain that adding a variety of foods and removing or reducing processed meats is considered healthier eating. You can note that reducing portion sizes of red meats from the 6-10 ounces that is often consumed to 3-4 ounces is also important for our overall health.

"Meat, including fish and shellfish, represents a valuable constituent of most balanced diets. Consumption of different types of meat and fish has been associated with both beneficial and adverse health effects. While white meats and fish are generally associated with positive health outcomes, red and especially processed meats have been associated with colorectal cancer and other diseases." (Ref: Biomarkers of meat and seafood intake: an extensive literature review, Springer Nature, Volume 14, article 35, 2019, https://link.springer.com/article/10.1186/s12263-019-0656-4).

Youth may have heard of the environmental costs of farming practices and efforts to reduce negative impacts by using minimum tillage or no-till practices and reducing or eliminating pesticide use. Calculating the environmental footprint of the food they eat helps youth understand how their choices matter and allows them to consider the environmental impact of transporting the foods they eat.

While current global food systems produce sufficient calories to keep pace with U.S. population growth, many Americans consume nutrient-poor diets that contribute to increased incidence of diet-related obesity and chronic diseases, a concern echoed in the Food and Agriculture Organization of the United Nations (https://www.fao.org/home/en) most recent State of Food Security and Nutrition in the World report. A reorientation of U.S. agricultural priorities — away from simply producing greater quantities of food and toward the production of a diverse range of nutritious foods using resilient and sustainable methods — is critical.

> ***Support for materials and supplies*** –
> Your local PTA/PTO may support your students.
> You can also look for small grant programs, like Donors Choose Teacher Sign-up | DonorsChoose, industry partners (e.g. Kroger, Seafood distributors, ...), and community groups.

### *AQUAPONICS*

Aquaponics combines hydroponics and recirculating aquaculture systems (RAS) to grow aquatic animals and plants in a system linked by water flows and nutrient exchanges. As an integrated system that utilizes the natural ecological interactions between animals and plants, aquaponics offers the benefits of controlled environment agriculture to intensify production.

Technical challenges, however, jeopardize the stability, reproducibility and scalability of aquaponics. Businesses are concerned about the startup process and maintaining water quality. Up to 20% of nutrient-rich aquaponics wastewater, which is composed of ammonia, nitrites, nitrates, phosphates and organic carbon, must be discharged daily to maintain water quality, leading to potential environmental impacts.

Before discharging to a waterway, large-scale farms need to clean the wastewater to a level that satisfies the National Pollutant Discharge Elimination System permit from the Environmental Protection Agency (EPA). This generates additional maintenance costs. In contrast, small farms do not need discharge permits — so may be fouling the environment. These technical and economic barriers make only a few U.S. aquaponics producers commercially successful. Reforming current aquaponics through a novel systems approach is needed to increase producer financial stability and reduce perceived risks.

Blue foods — those derived from aquatic animals, plants or algae, and used interchangeably with "seafood" hereafter — can provide more nutritional benefits and be produced more sustainably than land-based foods. As described in several papers in *Nature*, blue foods have the potential to address malnutrition, lower environmental impacts of food systems and generate better livelihoods. Each of these benefits aligns with UN Sustainable Development Goals and USDA Strategic Goals, Science Blueprint, and Agriculture Innovation Agenda. The Voluntary Guidelines on Food Systems and Nutrition of the Committee on World Food Security also call for a national food and nutrition policy to transform food systems by prioritizing blue foods.

About 90% of seafood consumed in the U.S. comes from abroad, resulting in a $17 billion trade deficit and long supply chains that generate significant "food miles." These long supply chains are further challenged by volatile markets, fluctuating fuel costs, changing consumer demands, the global pandemic and armed conflicts around the world.

With 90% of global wild fish stocks being overfished or fished at capacity, expanded seafood production must come from aquaculture. An expanded form of aquaculture is increasingly popular with stakeholders and at multiple scales, from hobbyist to commercial.

### *FOR MORE INFORMATION*

- *The role of seafood in sustainable and healthy diets*. The EAT-Lancet Commission report through a blue lens. J Zachary Koehn et al 2022 Environ. Res. Lett. 17 035003 https://iopscience.iop.org/article/10.1088/1748-9326/ac3954
- *Global Food-Miles Account For Nearly 20% of Total Food-Systems Emissions*, https://www.nature.com/articles/s43016-022-00531-w
- Research (PDF files available on the BiG Teacher Resource website, https://purdue.ag/big-project, Select Learning Resources)
  - » *Changing dietary patterns is necessary to improve the sustainability of Western diets from a One Health perspective.*
  - » *Environmental footprints of Mediterranean versus Western dietary patterns: beyond the health benefits of the Mediterranean diet.*
  - » *Evaluation of environmental performance of dietary patterns in the United States considering food nutrition and satiety.*

# FOOD INVENTORY WORKSHEET

Name:

Date:

Class period:

**List the foods you (or your study subject) ate for one week.**

| Day | Food eaten |
|---|---|
| **Sunday** | Breakfast –<br>Lunch –<br>Dinner –<br>Snacks – |
| **Monday** | Breakfast –<br>Lunch –<br>Dinner –<br>Snacks – |
| **Tuesday** | Breakfast –<br>Lunch –<br>Dinner –<br>Snacks – |
| **Wednesday** | Breakfast –<br>Lunch –<br>Dinner –<br>Snacks – |
| **Thursday** | Breakfast –<br>Lunch –<br>Dinner –<br>Snacks – |
| **Friday** | Breakfast –<br>Lunch –<br>Dinner –<br>Snacks – |
| **Saturday** | Breakfast –<br>Lunch –<br>Dinner –<br>Snacks – |

**Add up the number of servings you ate of the following.**

- Beef
- Chicken
- Pork
- Fish and seafood
- Eggs
- Milk and yogurt
- Cheese
- Beans and legumes
- Fruits
- Vegetables
- Wheat and grains
- Rice
- Fats and oils
- Nuts and seeds

**Calculate your environmental foodprint using the Harvard foodprint calculator website:** https://harvard-foodprint-calculator.github.io/

| | | |
|---|---|---|
| | | |
| **Carbon** | **Nitrogen** | **Water** |

***Note:***
1 kg = 2.2 pounds
1 g = 0.0022 pounds
1 L = 0.264 gallons

# NOTES

# Let's Get Started!

**Contributing authors:** Paul Brown, professor, Department of Forestry And Natural Resources and his graduate student Timothy Rice, senior aquaponics technician

**Student objective:** Students start their own/group aquaponics system.

**Next Generation Science Standards**

- NGSS Standards: HS-LS2-5, HS-LS2-7, HS-ETS1-4
- Disciplinary Core Ideas and Crosscutting Concepts: HS-LS2-5

**AFNR Content Standards**

- CRP.11.01. Research, select and use new technologies, tools and applications to maximize productivity in the workplace and community.
- CRP.12.01. Contribute to team-oriented projects and builds consensus to accomplish results using cultural global competence in the workplace and community.
- ESS.01.02. Properly utilize scientific instruments in environmental monitoring situations (e.g., laboratory equipment, environmental monitoring instruments, etc.).
- ESS.03.04. Apply microbiology principles to environmental sustainability systems.
- ESS.03.05. Apply ecology principles to environmental sustainability systems.
- FPP 01.02. Apply food safety and quality assurance procedures in the harvesting, handling and processing of food products.
- FPP.02.01. Apply principles of nutrition and biology to develop food products that provide a safe, wholesome, and nutritious food supply for local and global food systems.
- FPP.02.02. Apply principles of microbiology and chemistry to develop food products to provide a safe, wholesome, and nutritious food supply for local and global food systems.
- NRS.03.01. Sustainably produce, harvest, process and use natural resource products.
- NRS.04.03. Prevent or manage introduction of ecologically harmful species in a particular region.
- PS.01.01. Determine the influence of environmental factors on plant growth.
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- PS.03.05. Harvest crops according to industry standards.
- PS.04.01. Evaluate, identify, and prepare plants to enhance an environment.

**Research option**

Teams of three to four students complete their own research and design of an aquaculture system for raising goldfish and basil.

- Students create the first design of their system on paper, including a sketch and list of all items their system requires.
- Teacher reviews the design.
- Class discussion of cleaning the tank and when and how to introduce the goldfish and basil.
    - » See slides 4-9 in Getting Started.pptx
- Create the system and collect water quality and plant growth data.
    - » See slide 10 in Getting Started.pptx

**Materials/Supplies**

- Getting Started.pptx
- Materials list: Slide 3 (and page 18)

**Direct instruction. Students set up and maintain an aquaponics system.**

Getting Started.pptx.

- Gravel bed as an alternative to the polystyrene board, slide 4
- How to clean your tank and accessories, slide 5
- Setting up your system, slides 6 and 7
- Adding the goldfish, slide 8
- Feeding your fish, slide 9
- Adding plants, slide 10
- Maintaining your system, slide, 11
    - » Students should keep records of their aquaponics system, including the date; approximate fish size in inches; plant height in inches; and pH, ammonia, and nitrate levels.
    - » They should also record any general observations.
    - » Students may use Data Collection.docx or create their own record sheet in Word or Excel.
- Watching them grow, slide 12
- Goldfish disposal warning, slide 13
- Common aquaponics species, slide 14

**Assessment**

- Teacher's analysis of the knowledge their students gained.
- The health and growth of fish and plants.

**Supplemental information**

Building and maintaining a small aquaponics system as a class project is the best way for youth to learn the principles of aquaponics, waste recycling, and hydroponics. They may even be inspired to build their own system and/or seek a career in aquaculture growing blue foods —seafood derived from aquatic animals, plants, or algae.

Blue foods provide excellent nutritional benefits and can be produced more sustainably than land-based foods. Blue foods have the potential to address malnutrition, lower environmental impacts of food systems and generate employment. But increasing blue food consumption in the U.S. requires increasing the volume of blue foods available to consumers. Additional seafood production must come from ***aquaculture***, since approximately 90% of global wild fish stocks are overfished or fished at capacity. Fish farming is one of the predominant, fast-growing sectors that supply seafood products worldwide.

This activity provides basic instructions for setting up a cost-effective system. Many packaged systems are available online as well. Some considerations and recommendations follow.

- Fish
  - » Density: For small systems, 1 inch of fish per gallon of water is recommended. The ratio of fish to plants is critical in the flow of nutrients. More fish in a tank result in higher feed inputs and higher waste output, yielding a higher flow of nutrients to plants.
  - » Food: Use food that specifically lists the species of fish you are raising. Floating food is best for goldfish and for monitoring how much they eat. Choose a nutritionally complete food available at pet stores, farm stores, some large grocery-plus stores and through online retailers.
  - » Type: Goldfish, a type of carp, are recommended because they can tolerate a relatively wide range of temperatures. However, goldfish are an invasive species. Do not release goldfish to streams, rivers or lakes, because invasive species reproduce rapidly and are hardy, surviving the low oxygen conditions in winter. Goldfish can live to be 25 years old, and once established are not easily removed.
  - » Goldfish and other carps are very hardy and can take a spike in ammonia. Monitor the ammonia levels carefully for the first 3 weeks or so. You should see a spike in ammonia followed by a spike in nitrites before they start to level out.
  - » If ammonia levels get too high you will need to change the water change but it won't be a problem for the goldfish. Most of the problems you get with city water is the chlorine that is added. Off gassing the chlorine or adding a dechlorinate to the water will make it safe for use.
  - » You can speed up the cycling of the system by adding bacteria.
  - » When adding a little water to the system to replace what has evaporated the chlorine in city water should not be a problem for goldfish.

- Plant crop considerations
  - » Recommended crops for small systems: lettuce, basil, Swiss chard and mint. Mint can be invasive, so grow it without other crops.
  - » Basil can be planted roughly twice as densely as lettuces. Brassicas such as kale and broccoli need more space.
  - » Chards and other herbs tend to do well in small systems.
  - » Leafy plant crops versus fruiting plant crops: Leafy greens, such as lettuce, grow relatively easily without extra maintenance in an aquaponics system. They can be planted at densities limited only by the final size of the plant. Fruiting crops have differing nutrient requirements throughout their life cycle.
    - They generally require additional phosphorus potassium and calcium when fruiting.
    - Excessive nitrogen may cause fruiting plants such as tomatoes to continue producing leafy growth without producing fruit.
    - Fruiting crops need to be tended more carefully to produce a good harvest, including pruning and pollination if the system is inaccessible to insects.
    - They tend to have higher nutrient requirements than leafy greens when compared on a square meter footprint.

**Aquaponics system setup**

### CLEAN YOUR TANK

- Wash the tank and any accessories in tap water.
  - » Do not use soap or detergent; they can leave residues that can harm your fish.
- Place the accessories in the tank and fill it to the top with hot water.
- Add as much noniodized salt as will dissolve when you stir it into the hot water.
- Leave the salt water in the tank for one hour.
- Remove the salt water by dipping or siphoning. Never tip a full tank — the water is too heavy and could spring the sides of the tank.
- Rinse the tank and accessories with water.

### SETTING UP YOUR SYSTEM

- Place your tank near a window for natural light but out of direct sunlight and drafts.
  - » Use artificial light (grow lights) if needed. The fish (and plants) need 8-10 hours of light each day.
  - » Temperatures between 65° F and 70° F are best for goldfish.
- Fill your tank with 8-9 gallons of tap water.
  - » Chlorinated water must de-gassed by aerating it with an air stone or dichlorination chemical.
- Add nitrifying bacteria to regulate the nitrogen cycle.
  - » The bacteria convert ammonia produced by fish waste into nitrite.
  - » Add additional bacteria whenever you change the water.
- Place clean gravel and any accessories in the bottom of your tank.
- Place the pump and filter in the tank.
- Allow time for the water to "cycle" before adding fish. Cycling can take two to six weeks.
  - » Aquarium cycling is the process of creating a biologically safe environment for the fish.
  - » Test for ammonia until it is zero.
  - » Cycling the tank makes the water healthier for your fish and plants.

### ADDING THE GOLDFISH

- Purchase 6-7 goldfish for a 10-gallon tank.
  - » Stock about 1 inch of fish per gallon of water.
- Place the plastic bag containing your fish in the tank as soon as possible.
- Leave the fish in the bag for one hour so you don't shock the fish.
  - » The water temperature in the bag will equilibrate with the tank water temperature.
  - » Adding a little aquarium water to the bag every 10-15 minutes can help the goldfish acclimate to the new water. This is not as important for goldfish as it is for less hardy fish.
- Release your fish from the plastic bag after an hour.
- Fish do not like being touched, bright lights or loud noises.

### FEEDING YOUR FISH

- Feed your fish once a day.
- Offer small amounts of food no longer than 5 minutes or until they stop eating, whichever comes first.
  - » The amount of food they want can vary.
  - » Avoid overfeeding; uneaten food degrades your water quality.
- Initial feeding behavior may be aggressive as they are hungry, but it will slow within a few minutes as they consume the amount of food they want.

### ADDING PLANTS

- Purchase and add plants once your fish have acclimated to the tank for a week or two.
  - » Small herb plants may be available in the produce section of grocery stores.
  - » Cuttings from herbs, house plants or flowers may be used.
- Polystyrene foam board
  - » Cut a board about 15" x 8" for a 10-gallon tank.
  - » Cut small openings in the polystyrene for your herbs.
- Place the plants
  - » Remove potted herbs from pots and gently rinse soil off the roots.
  - » Place the herbs or cuttings in the holes in the polystyrene foam board.
- Extra aeration may be needed if the fish have limited access to the surface water due to the polystyrene board.

### MAINTAINING YOUR SYSTEM

Weekly:

- Test your water pH, ammonia and nitrite levels.
    - » Clean more often if contamination levels are high.
    - » Record your data.
- Keep track of fish and plant growth.
- Clean your tank.
    - » Remove leftover food and fish waste with a tube or gravel vac.
    - » Watch for algae growth.
        - ♦ Clean algae off the glass with an aquarium algae scraper.
        - ♦ Adjust the lighting schedule if necessary to limit excessive light exposure.
- Remove 25-30% of the water and replace with cycled water.

### WATCH THEM GROW!

- Monitor and record fish and plant growth.
- Harvest the plants or selected leaves from your herbs as desired.
- Harvest your herbs when they get too large for your tank.

***Note:***

- Goldfish are an invasive species. *Never* release them into the wild.
- From the U.S. Fish and Wildlife Service: "When they are released into the wild, goldfish can grow to the size of a football and weigh up to 4 pounds! These voracious eaters carry parasites, foul the water, and uproot native plants and animals."
- Alternatives for disposal:
    - » Gift to a friend or family member.
    - » Donate to a pet store or aquarium.
    - » Euthanize.

**Materials list and costs.** Materials may be purchased online or at a local pet store or retail store. (Prices are as of January 2025.)

Small (10-gallon) aquariums are often sold as a starter kit and include filter, lighting, thermometer and net for $75-100. If you purchase a starter kit, you still need:

- Aquarium stones or clean pea gravel (rinse carefully) – $5-10 (online merchant)
- Bacteria starter (nitrifying bacteria) – $10-20 (online merchant)
- Gravel vac or siphon tube to clean debris from the stones at the bottom of the aquarium – $15-50 (online merchant)
- Noniodized salt – $2 (grocery store)
- Tank accessories (optional): plants, marbles, figures, buildings –$10-20 (online merchant)
- Water testing kit to check water parameters: pH, ammonia, nitrite – $10-15 (online merchant)

If you do not purchase a starter kit, you may need the following items:

- Air stone or dichlorination chemical if you have chlorinated water – $6-10 for either stone or chemical (online merchant)
- Aquarium tank, 10-gallon – $100 (online merchant)
- Aquarium filter and pump – $15-20 (online merchant)
- Artificial light if you do not have a bright spot to place the tank (but not in direct sunlight) – $10-30 (online merchant)
- Filter and pump; a sponge filter can be used instead of a carbon filter – $15-40 (online merchant)
- Fish net – $5-10 (online merchant)

### AFTER TANK HAS CYCLED

- Goldfish, $1/fish
- Goldfish food, $5-10 (pet store)

### AFTER FISH ARE ESTABLISHED

- Polystyrene foam board, 3/4 inch, 4-foot x 8-foot sheet, $10
    - » A piece about 8 inches x 15 inches is needed for one 10-gallon tank
- Small herb plants, often available in the produce section of grocery stores

***For more information on aquaponics water chemistry see:***

https://www.youtube.com/playlist?

or watch a video on what needs to tested and how to do testing: https://www.youtube.com/watch?v=GfFGcudqC8M.

# DATA COLLECTION WORKSHEET

Name:

Date:

Class period:

**Monitor your aquaponics system every week.** Record the date; approximate length of your fish and plants (in inches); and the pH, ammonia, and nitrate levels. Add your general observations in the last column.

You may use the chart below or make your own in Word or Excel software.

| Date | Fish length (inches) | Plant height (inches) | pH level | Ammonia level | Nitrate level | Observations |
|---|---|---|---|---|---|---|
| | | | | | | |
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# Comparing the Financial and Environmental Costs of Food Production

**Contributing authors:** Kwamena Quagrainie, clinical engagement professor, Department of Agricultural Economics and Department of Forestry and Natural Resources, and Jen-Yi Huang, associate professor, Department of Food Science

**Student objective:** Students are introduced to the food production supply chain and learn about inputs and outputs.

**Next Generation Science Standards**
- NGSS Standards: HS-ETS1-1

**AFNR Content Standards**
- ABS.01.01. Apply economic principles to plan and manage inputs and outputs in an AFNR business.
- ABS.01.03. Develop and apply skills to manage an AFNR business in an efficient, legal and ethical manner.
- NRS.02.04. Examine and explain how economics affects the use of natural resources.
- CRP.12.01. Contribute to team-oriented projects and builds consensus to accomplish results using cultural global competence in the workplace and community.

**Materials/Supplies**
- Financial, Environ Cost.pptx
- Paper and pencils

**Activity: Estimating Costs**
**Direct instruction: Students study financial inputs and outputs.**
Introduce the activity using Financial, Environ Cost.pptx, slides 1-8.
- Ask students to list the financial, environmental and personal costs of raising plants for a Mother's Day plant sale, slide 9.
- Have students work in small groups to combine their lists and estimate costs, slide 10.
- Class discussion, slides 11-12
  - » Note: Exact costs are not as important as understanding all costs and externalities.
  - » Students may not realize how many of the costs the school system absorbs.
  - » Students may not realize that volunteer (unpaid) time is a cost.
  - » Students may forget to include the time teachers and students spend.
  - » Externalities might include reuse or proper disposal of waste water and plant debris; impacts (positive or negative) on local residents; the space needed and, possibly, taken from other projects.
- Aquaponics in the Midwest, slides 13-15.

**Assessment**
- Discussion questions
  - » The questions discuss only the highest estimates. You could also look at the lowest estimates and the average estimate across all groups.
  - » Vote on which estimates for costs, income and profits are most realistic.
  - » Discuss how miscalculating costs can lead to errors. For example, underestimating the costs, time and profit of a new venture (going to college, buying a house, etc.) can cause problems.
  - » Discuss how we can make better estimations by collecting data from knowledgeable sources.
- Teacher's analysis of the knowledge their students gained.

**Glossary**
**Externality:** A cost or benefit caused by one party but financially incurred or received by another. Externalities can be negative or positive. A negative externality is the indirect imposition of a cost by one party on to another.
**Farm to table:** Purchasing and eating locally grown foods.
**Input cost:** The expenses incurred in the production of food, goods or services.
**Integrated system:** The combination of separate systems working together as one cohesive unit.
**Output cost:** The total expense incurred to produce a food product, good or service.

**Supplemental information**
Aquaponics is an integrated food production system (FPS) that integrates aquaculture and plant production systems (often as hydroponics) into a single closed/semi-closed loop system. These systems intensively produce diverse, high-quality seafood and specialty crops in controlled environments, meeting the criteria for climate-smart agriculture set by the Food and Agriculture Organization (FAO) of the United Nations. Despite using less land and water than conventional food production, aquaponics requires high energy input and creates considerable nutrient wastes, leading to high operational and maintenance costs. These costs challenge its economic sustainability, a main barrier to wider adoption.

Although growers are widely interested in the potential of aquaponics, existing gaps in research on animal-plant-microbe co-management, benefit-risk assessment and financing inhibit initial engagement. The overarching goal of the Purdue University-led project is to increase local and regional production of adequate, nutritious and affordable blue foods with a minimal environmental footprint to ultimately diversify U.S. agricultural systems and dietary patterns.

An aquaponics farm's economic viability depends on financial feasibility, taking into account all relevant variables that go into finding feasible and optimal outcomes. BiG researchers will evaluate all capital and operating costs. While there is a basic technological layout for an aquaponics system, different practitioners adapt different operational designs — choices determined largely by available resources and location.

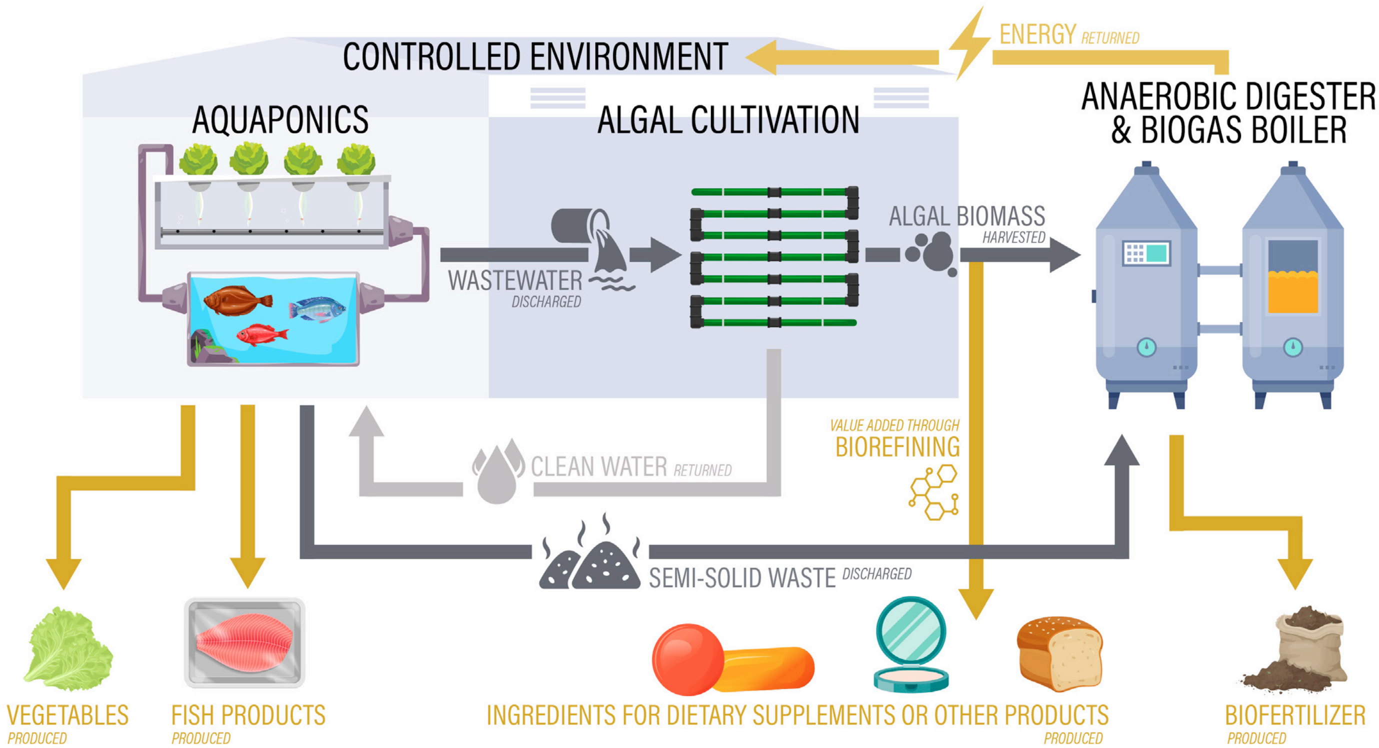
The BiG team will utilize enterprise budgeting with research-derived data collected from the various system designs, and will supplement field data to determine variable choices and optimal scenarios. With the various system designs, economic optimization of the Integrated Aquaponics Food Production System (IAFPS) is necessary to understand key factors that affect profitability. Researchers will use a discounted cash flow analysis with the material, energy and equipment information from our spreadsheet model to determine process economics. The team will fully describe each proposed system in terms of technological designs, biological requirements and economic costs, and assess them in terms of scalability in production and the relative benefits of economies of scale. The profitability analysis will be designed to simulate sensitivities in key variables that have uncertainty associated with them, including costs, prices, germination and survival rates, etc., and assess financial returns from alternative strategies and scenarios. It will help to quantify various factors for scale-up and their economic feasibility to determine whether investments in IAFPS will generate sufficient income to costs.

The modeling procedure has various considerations for fixed (infrastructure, equipment, setup) and variable (energy, labor, seed, feed, water, fingerlings, seedlings) resources with associated costs, biological variables, and outputs with the associated prices, as well as all other costs associated with operating the systems. Biological factors to consider in the analysis include fish stocking density, stocking weight, harvest weight, survival rate, and feeding rate. For plants, factors to consider include space requirement, germination rate and other growth factors. The financial analysis comprises a profitability analysis, investment analysis and sensitivity analysis. Some important financial indicators to be assessed include breakeven analysis, cost-volume-profit analysis, cost-benefit analysis, margin analysis, net present value and internal rate of return.

You may enjoy reading this Purdue news release, *Analysis shows how investing in nature improves the economy while boosting equity*. It discusses research by Thomas Hertel, Distinguished Professor of Agricultural Economics, and others. https://ag.purdue.edu/news/2023/06/analysis-shows-how-investing-in-nature-improves-the-economy-while-boosting-equity.html.



**This activity is most appropriate for upper level high school students. It may be challenging for students who struggle to connect math concepts outside of math class.**


CONTROLLED ENVIRONMENT
ENERGY RETURNED
AQUAPONICS
ALGAL CULTIVATION
ANAEROBIC DIGESTER & BIOGAS BOILER
WASTEWATER DISCHARGED
ALGAL BIOMASS HARVESTED
VALUE ADDED THROUGH BIOREFINING
CLEAN WATER RETURNED
SEMI-SOLID WASTE DISCHARGED
VEGETABLES PRODUCED
FISH PRODUCTS PRODUCED
INGREDIENTS FOR DIETARY SUPPLEMENTS OR OTHER PRODUCTS PRODUCED
BIOFERTILIZER PRODUCED

# NOTES

# Flow Rates, Why They Matter

**Contributing author:** Zhi (George) Zhou, associate professor, Department of Civil Engineering and Environmental and Ecological Engineering

**Objective:** Students learn how flow rate can affect the concentrations of various substances in an aquaponics system.

> *Note:* This activity requires materials to be purchased and an overflow tube installed in one of the buckets before students can do the lab.

### Next Generation Science Standards

- NGSS Standards: HS-LS-6, HS-ETS1-4
- Disciplinary Core Ideas and Crosscutting Concepts: HS-LS2-4, HS-LS2-7, HS-LS2-5, HS-LS2-6

### AFNR Content Standards

- ESS.01.02. Properly utilize scientific instruments in environmental monitoring situations (e.g., laboratory equipment, environmental monitoring instruments, etc.).
- ESS.03.02. Apply soil science and hydrology principles to environmental sustainability systems.
- ESS.03.03. Apply chemistry principles to environmental sustainability systems.

### Materials/Supplies

- Flow Rate Lab, page 27
- Flow Rate Worksheet, pages 28 and 29
- Flow Rate Worksheet Example Answers, page 30
- Supplies (page 27)
- Equipment
  - Two 5-gallon buckets:
  - Small submersible water pump (95 GPH 5W)
  - Digital PH meter + LCD TDS EC water purity PPM filter pen
  - 1/2 inch vinyl tubing, 4-5 inches in length
  - 1/2 inch straight liquid-tight fitting (or glue the tube on the inside and outside of the tank)
  - Table salt
  - Food coloring (optional)

> *Note:* it may be easier to work with a 1/4 inch vinyl tube and fitting. Use an alligator clip to secure the tubing in the higher bucket. See photos under Supplemental Information.

### Setup before working with students

- Bucket 2, freshwater tank. Drill a 1/2-inch hole at about the 3-gallon level (three-fifths the height of the bucket) for overflow. Attach the straight liquid-tight fitting to the bucket so the vinyl tubing can be attached. Or glue the vinyl tubing to bucket 1 so it has an overflow.
- Check that your pump can pump water to bucket 2 when it is on a chair or table. If not, you can use another 5-gallon bucket to set the freshwater tank on.
- See photos under Supplemental information for an sample setup.

### Direct instruction: Students monitor the effects of flow rate on total dissolved solids in water.

Why Flow Rates Matter.pptx

- Introduction: slides 1-3.
- Have students set up and run the experiment, slides 4-7.
- Results and questions – The worksheet can be handed in and/or discussed in class.
  - Flow Rate Worksheet Answers.docx contains suggested answers to the questions for students.
  - Experiment questions are also on slide 8.
  - Answers are on slide 9.

### Assessment

- Teacher's analysis of the knowledge their students gained.
- The worksheet may be handed in and graded.

### Facilitating the activity

This activity requires equipment and setup time. You may need to run the two tests on two different days.

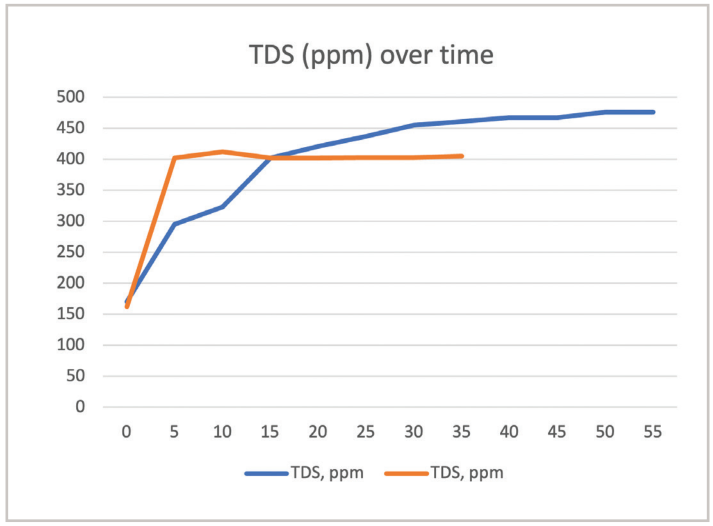
- Make sure the pump works to transfer saltwater to the freshwater tank.
- Monitor the water level to avoid overflow issues in the freshwater tank. If needed, use a larger diameter bulkhead and tubing.
- The food coloring can be a simple monitor of when the concentrations in the freshwater tank stabilize.
- Rinse both tanks before the next experiments to avoid carry-over contamination from previous experiments.

**Supplemental information**

This activity helps students understand how flow rate may affect the concentrations of various chemicals in a hydroponic system. They gain a better knowledge of chemistry of salts dissolved in water, math to calculate changing rates of water quality parameters, regression analysis and report writing. It may also spark an interest in chemistry!

High flow rates in an aquaculture system speed up nutrient and oxygen supply rates, which uses more energy. Low flow rates could result in nutrient and oxygen deficiencies that affect growth rates of fish and plants. High flow rates may be needed with some species of fish to provide enough oxygen to support fish growth. However, organic contaminants may be distributed rapidly to aquaponic systems as nutrients and oxygen under high flow rate conditions. An effective treatment system is needed to remove organic contaminants from the system to avoid inhibiting fish and plant growth.

Using real-time monitoring to optimize the aquaponics system is best, but it is costly. An alternative approach is to determine the optimal concentrations of nutrients and oxygen and maintain a flow rate that keeps them stable in aquaponic systems.




*SAMPLE SETUP:*


*Drill a hole an push the tubing through*


*Add glue around the hole to prevent leaking*


*Start the pump and watch water flow into the upper bucket*


*Wait five (5) minutes before you take your first reading*


*Taking the TDS readings*


*Stacked buckets, showing overlap to catch potential leaks*

**Equipment**

Materials may be purchased online or at a local pet store or large retail store. Prices were checked January 2025.

- 95 GPH 5W small submersible water pump – $10 (large local retailer)
- TDS (total dissolved solids) PPM meter – $4 (large local retailer)
- 3/4 inch polyethylene (or vinyl) tubing, 4-5 feet – $20 for 10 feet or $9 for 5 feet (large local retailer or big box store)
- Two 5-gallon buckets – $10 for two at large local retailer; $2.77 each at big box store
- Noniodized table salt – $2 (grocery store)
- Red food coloring gel (optional) – $2 (large local retailer or grocery store)

**Flow Rate Lab**

You will measure the effect of flow rate on chemical concentrations in a tank, using food instead of chemicals for safety and visibility.

- Bucket 1: This is your contaminated bucket.
  - » Place the tank on the floor.
  - » Place the pump in the tank.
  - » Add 4 gallons of tap water.
  - » Stir in 1 teaspoon of table salt.
  - » Optional: Add a few drops of food coloring.
- Bucket 2: This is your freshwater bucket.
  - » Place on another bucket or chair so it's higher than bucket 1.
  - » Add water to just under the overflow hole.
- Attach the tubing:
  - » From the water pump in bucket 1 to bucket 2. You may need to secure the tube so the water flows into the bucket.
  - » From the overflow fitting in the freshwater tank to the saltwater tank.
- Set the pump flow rate to low.
- Check that the pump is fully immersed in the saltwater.

***Trial 1***

1. Take total dissolved solid (TDS) readings in the freshwater tank (bucket 2), and record on the worksheet before you start your pump (0 minutes).
2. Note the time and start the pump.
3. Measure and record the TDS level in the freshwater tank (bucket 1) every five minutes until there is little/no change in values.
4. Record TDS level in the worksheet
5. Stop when the TDS values level off.

***Trial 2***

1. Empty and rinse both buckets and the vinyl tubing.
2. Refill both buckets as in trial 1
3. Set the pump flow rate to high.
4. Repeat steps 1-5 from trial 1.

Complete the worksheet:

- Graph your TDS readings for both trials.
- Calculate the TDS changing rate: (TDS2 – TDS1)/(t2 – t1)
  - » TDS – Total Dissolved Solids
  - » t – time
- Answer the four questions about this experiment.

***For more information on aquaponics water chemistry see:***

https://www.youtube.com/playlist?

or watch a video on what needs to tested and how to do testing: https://www.youtube.com/watch?v=GfFGcudqC8M.

# FLOW RATE WORKSHEET

Name:

Date:

Class period:

**Record your data.** Bucket #2, freshwater: Dissolved Solids (TDS) readings:

| Pump speed | Slow | Fast |
|---|---|---|
| Time (minutes) | TDS (ppm) | TDS (ppm) |
| 0 | | |
| 5 | | |
| 10 | | |
| 15 | | |
| 20 | | |
| 25 | | |
| 30 | | |
| 35 | | |
| 40 | | |
| 45 | | |
| 50 | | |
| 55 | | |
| 60 | | |

**Chart your data.** Enter the units for the X (time) and the Y-axis on the graph below. Graph your TDS reading on Y-axis against time (X-axis).

**Calculate the TDS change rate:**

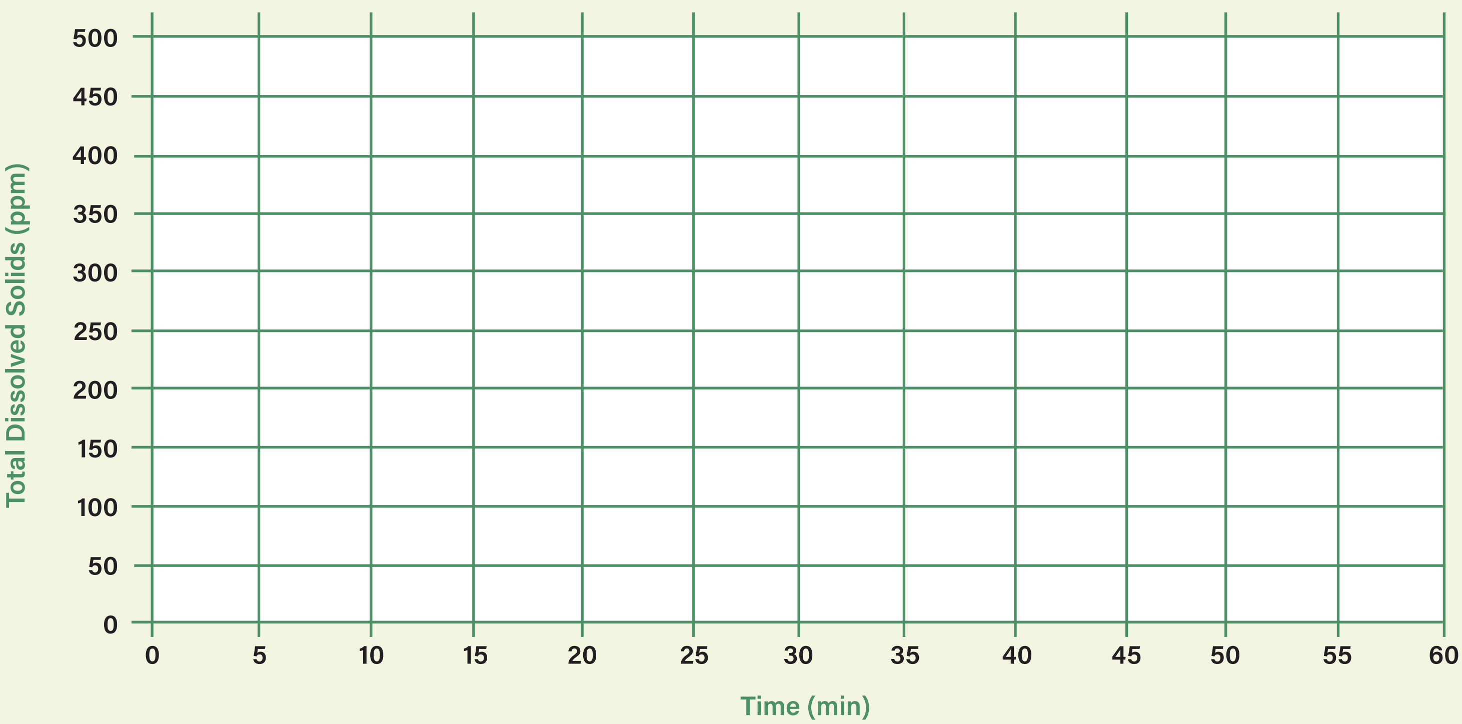
$(TDS2 - TDS1) = (t2 - t1)$

- TDS - Total Dissolved Solids
- t - time

**TDS change Rates:**

At <u>low</u> pump speed ______________________

At <u>high</u> pump speed ______________________



**Questions**

1. How did flow rate impact the TDS? (salt)

2. Based on your understanding of how flow rates impacted TDS (salt), how do you think flow rates impact nutrient and oxygen supplies in an aquaponics system?

3. How do flow rates impact point-source pollution in rivers?

4. How does flow rate or mixing affect water quality in rivers and lakes?

# NOTES

# FLOW RATE WORKSHEET

Name:

Date:

Class period:

**ANSWER KEY**

**Record your data.** Bucket #2, freshwater: Dissolved Solids (TDS) readings:

| Pump speed | Slow | Fast |
|---|---|---|
| **Time (minutes)** | **TDS (ppm)** | **TDS (ppm)** |
| 0 | 170 | 162 |
| 5 | 295 | 402 |
| 10 | 323 | 412 |
| 15 | 402 | 402 |
| 20 | 421 | 402 |
| 25 | 437 | 403 |
| 30 | 455 | 403 |
| 35 | 461 | 403 |
| 40 | 467 | |
| 45 | 467 | |
| 50 | 476 | |
| 55 | 476 | |
| 60 | | |

**Chart your data.** Enter the units for the X (time) and the Y-axis on the graph below. Graph your TDS reading on Y-axis against time (X-axis).

**Calculate the TDS change rate:**

$(TDS2 - TDS1) = (t2 - t1)$

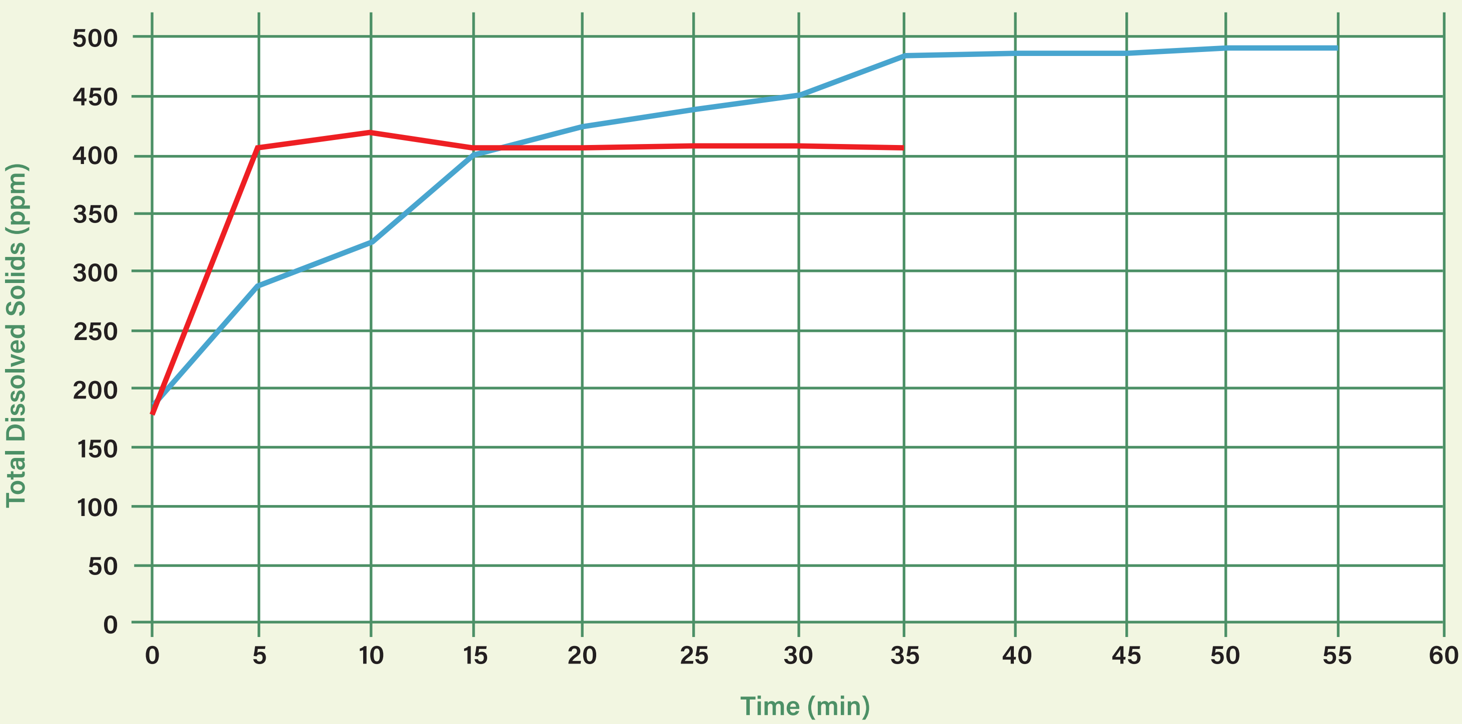
- TDS - Total Dissolved Solids
- t - time

**TDS change Rates:**

At low pump speed **(476-170) / 55 = 5.6 ppm/min**

At high pump speed **(405-162) / 35 = 6.9 ppm/min**

TDS readings should be the same, or nearly so, for both tanks at the end of the experiement.



ANSWER KEY

**Questions**

1. How did flow rate impact the TDS? (salt)

**The TDS rate of change was higher with higher flow rates, showing how flow rate affects how quickly nutrients and/or contaminants mixed with the fresh water.**

2. Based on your understanding of how flow rates impacted TDS (salt), how do you think flow rates impact nutrient and oxygen supplies in an aquaponics system?

**Higher flow rates speed up nutrient and oxygen supplies in an aquaponics system.**

3. How do flow rates impact point-source pollution in rivers?

**Flow rates and mixing are responsible for both the extent and location that point-source pollution moves in streams and rivers.**

4. How does flow rate or mixing affect water quality in rivers and lakes?

**Flow rates affect the volume of water entering a river or lake in a given time. Flow rates contribute to mass transfer efficiency of substances in the water. In other words, higher flows cause quicker mixing of contaminants.**

# Food Safety in the Kitchen

**Contributing authors:** Yaohua (Betty) Feng, associate professor, Department of Food Science, and her graduate students: Tressie Barrett, research assistant, Fanny Gozzi, research assistant

**Student objective:** Students learn (or review) important safe food handling practices.

**Next Generation Science Standards and AFNR Content:** N/A

**Materials/Supplies**

- Food Safety in the Kitchen.pptx

**Direct instruction** (estimated 15 minutes)

PowerPoint: Food Safety in the Kitchen.pptx

- Introduction, slides 1-2.
- Guided practice: Safe food preparation – matching, slides 3-5.
  - Words, Definitions.pdf, available if you wish to print the words and definitions so students can match them individually or in groups.
  - Two sizes of cards are provided.
- Additional information: slides 6-13. Optional YouTube videos:
  - Slide 11. CDC video: Fight Germs. Wash Your Hands! https://www.youtube.com/watch?v=eZw4Ga3jg3E
  - Slide 13. How to wash produce: https://www.youtube.com/watch?v=neJJEwcAC9k
- Observing others: slide 14.
  - Video https://www.youtube.com/watch?v=FaIynhb0twk
    - Or Google, Gordon Ramsay Cooks Mediterranean Sea Bass in Under 10 Minutes | Ramsay in 10
    - 10 minutes, 12 seconds in length
- Class review, slide 15.
  - Each student should share an error they saw in the video. This gets more difficult as errors are noted.
  - Choose a class reporter to write the error on the board or paper.
  - Tally how many students noted each error.
  - After each student has had a chance to note an error, ask if students saw any additional errors.
  - You can play the video again after students have shared the errors they saw, before moving on to slide 16.
- Food Safety Errors, slides 16-18.

***Note:*** This activity includes content adapted from *Safe Food Handling Practices*, part of the *Food Safety Curriculum for Middle and High School Students*, by Betty Feng and Tressie Barrett.
Available free from:

- *The Education Store*, https://edustore.purdue.edu/newsearch.asp. Search Food Safety Curriculum. https://ag.purdue.edu/department/foodsci/fenglab/extension-news.html. See Curriculum under PK-12 Food Safety Education.

**Assessment**

- Teacher's analysis of the knowledge their students gained.
- Number of errors spotted in the video.

**Resources**

- Videos
  - Keep food safe basics (USDA) https://www.fsis.usda.gov/food-safety/safe-food-handling-and-preparation/food-safety-basics/steps-keep-food-safe
  - Cross-contamination: https://www.youtube.com/watch?v=horgGwEAm7s
- Seafood Basics: A Toolkit for Understanding Seafood, Nutrition, Safety and Preparation, and Sourcing. Seafood Preparation and Safety Tips, page 15
  - PDF is available from The Education Store, https://edustore.purdue.edu/newsearch.asp. Search Food Safety.

**References and additional resources**


- *An Outbreak Investigation of Salmonella Typhimurium Illnesses in the United States Linked to Packaged Leafy Greens Produced at a Controlled Environment Agriculture Indoor Hydroponic Operation.* McClure, M., et al., 2021 (2023) *Journal of Food Protection,* Vol. 86 (5) https://doi.org/10.1016/j.jfp.2023.100079.
- *Chicken preparation in the home: an observational study.* Bruhn, Christine M. 5, 2014, Food Protection Trends, Vol. 34, pp. 318-330.
- *Consumer Food Handling Practices Lead to Cross-contamination.* Sneed, Jeannie, et al. 1, s.l.: Food Protection Trends, 2015, Vol. 35, pp. 36-46.
- Cutting boards, cross-contamination: https://www.fsis.usda.gov/food-safety/safe-food-handling-and-preparation/food-safety-basics/cutting-boards#:~:text=Avoid%20Cross%2DContamination&text=However%2C%20consider%20using%20one%20cutting,that%20requires%20no%20further%20cooking
- Fish: safely choose, cook and store: https://extension.umn.edu/preserving-and-preparing/safely-choose-cook-and-store-fish#:~:text=For%20best%20quality%20and%20to,within%20three%20to%2012%20months.%20Fish%20info%20sheet
- *Food worker hand washing practices: an observation study.* Green, Laura R., et al. 10, 2006, Journal of Food Protection, Vol. 69, pp. 2417-2423.
- Handwashing video: www.youtube.com/watch?v=vYwypS-LiaTU
- *Keeping Aquaponics Products Safe*: https://aquaponics.umn.edu/aquaponics-resources
- *Leafy Greens outbreak* 2021: https://www.fda.gov/food/outbreaks-foodborne-illness/factors-potentially-contributing-contamination-packaged-leafy-greens-implicated-outbreak-salmonella
- *Microbial Pathogens in Aquaponics Potentially Hazardous for Human Health. Microorganisms.* 2023. Dinev, T., Velichkova, K., Stoyanova, A., Sirakov, I. Nov 21;11(12):2824. https://doi.org/10.3390/microorganisms11122824
- *Produce Safety in Hydroponic and Aquaponic Operations:* https://www.uvm.edu/extension/necafs/produce-safety-hydroponic-and-aquaponic-operations
- Reusable Grocery Bags, Best Practices: https://www.pubs.ext.vt.edu/FST/fst-476/fst-476.html and https://www.cdph.ca.gov/pubsforms/Documents/fspnu04ReusableBags.pdf
- Seafood Basics: A Toolkit for Understanding Seafood, Nutrition, Safety and Preparation, and Sourcing. See page 15, PDF. Also available from The Education Store, https://edustore.purdue.edu/newsearch.asp. Enter “Food Safety” in the search box.
- Wash your hands with the Happy Birthday song: https://www.youtube.com/watch?v=aGJNspLRdrc

# NOTES

# Comparing the Nutritional Value of Different Foods

**Contributing author:** Andrea Liceaga, professor, Department of Food Science

**Student objective:** Students learn the value of reading food labels.

Before starting this activity, collect food labels from your cafeteria, teachers or students. You need five labels per student or team. Suggestions include labels for fresh vegetables, canned vegetables, fruit, canned soup, chips, cookies, cheese, beef, meat, fruit, chicken, pork, seafood, deli meat, bacon or sausage.

### Materials/Supplies

- Comparing Nutritional Values.pptx
- Comparing Food Nutritional Values worksheet, page 39
- Paper, pencils, highlighter
- Internet access
- Food labels

### Activity 1. Comparing Nutrition Values

**Direct instruction: Students learn the value of reading food labels.**

*Comparing Nutritional Values*.PPT

- Introduction, slides 1-6.
- Assignment, slide 7.
  - » Students may work in teams of two or three.
  - » Discussion questions, slide 8.
- Argument for the increased consumption of blue foods, slides 8-9.
- Assignment, reading about nutrition (sources: FDA and CDC), slide 10.
  - » Assign for class time or as independent practice.
- Additional suggestions for further study, slide 11.

### Independent Practice

*Comparing Nutritional Values*.PPT, slide 11.

### Assessment

- Teacher's analysis of the knowledge their students gained.
- Quiz – FDA Fun Facts Quiz: https://www.accessdata.fda.gov/scripts/interactivenutritionfactslabel/quiz/


### Glossary

**Blue food (seafood):** Edible aquatic organisms, including fish, shellfish and algae from marine and freshwater production systems (aquaculture and fisheries).

**Nutrition facts label:** The label listing calories, carbohydrates, fat, fiber, protein and vitamins per serving of food. Labels make it easier to compare the nutrition of similar products.

**Omega-3 fatty acids:** Essential fatty acids that are important in the human body and may provide health benefits. EPA and DHA, found in certain fish, are the primary ones. ALA (alpha-linolenic acid) is another found in plant sources such as nuts and seeds.

- EPA (eicosapentaenoic acid) is found in cold-water fatty fish such as salmon. It is in fish oil supplements, along with DHA, as part of a healthy diet that helps lower risk of heart disease.
- DHA (docosahexaenoic acid) is an important structural component of skin and the retinas in eyes. Fortifying baby formula with DHA improves vision in infants. DHA is vital for brain development and function in childhood as well as brain function in adults.

**Organic:** Relying on natural substances and physical, mechanical or biologically based farming methods to the fullest extent possible. Produce can be called "organic" if it is certified to have grown on soil where no prohibited substances were applied for three years prior to harvest.

### Supplemental Information

Cardiovascular diseases, largely driven by diet-related factors, are the leading cause of death worldwide. In the U.S., heart disease caused over 700,000 deaths in 2022 (CDC.gov - https://blogs.cdc.gov/niosh-science-blog/category/cardiovascular-disease-2/). Globally, cardiovascular diseases causes 17.9 million deaths each year (World Health Organization - https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)).

The *EAT* Lancet report (https://eatforum.org/content/uploads/2019/11/Seafood_Scoping_Report_EAT-Lancet.pdf) and many dietary guidelines indicate that diets focused on plant-based foods and some fish (e.g., aquaponics products) are among the most healthful and sustainable foods. Aquaponics is an ideal climate-smart form of agriculture for local and regional food production. It can provide high-quality blue foods with shortened supply chains in diverse locations.

- Iron deficiency is the most common form of micronutrient malnutrition globally. In the U.S., one in six women is iron deficient during pregnancy. Iron deficiency rates are higher among non-Hispanic Black and Hispanic women. It is a leading cause of anemia, which during pregnancy can result in poor fetal growth, preterm birth, low birth weight, and increased risk of death for the mother and baby (World Health Organization - https://www.who.int/nutrition/topics/ida/en/).

**Additional Resources**

- *Infant and Toddler Nutrition*, PDF or https://www.cdc.gov/nutrition/infantandtoddlernutrition/
- For high school students, FDA Nutrition Facts Label www.accessdata.fda.gov/scripts/InteractiveNutritionFactsLabel/#intro
- For youth ages 9-13, *FDA Whyville Snack Shack Games,* www.fda.gov/food/nutrition-education-resources-materials/whyville-snack-shack-games
- *Is a Calorie a Calorie? Processed Food, Experiment Gone Wrong*. *Ted Ed* talk by Robert Lustig. https://www.youtube.com/watch?v=nxyxcTZccsE
    - Robert Lustig, MD, professor of pediatrics in the Division of Endocrinology at University of California, San Francisco, and author of Fat Chance: Beating the Odds against Sugar, Processed Food, Obesity, and Disease.
    - This talk notes that all processed foods are made by just 10 companies and describes why processed foods have so little nutrition.
- *Seafood Basics: A Toolkit for Understanding Seafood, Nutrition, Safety and Preparation, and Sourcing.*
    - Available from The Education Store, www.edustore.purdue.edu. Direct link: https://edustore.purdue.edu/item.asp?Item_Number=FNR-634-W

# COMPARING FOOD NUTRITIONAL VALUES WORKSHEET

Name:

Date:

Class period:

**Comparing Food Nutritional Values**

*Instructions*

- Choose five food labels. List each food across the top row.
- Read the label to fill in the amount of each nutrient per serving under each food.
- If no nutrient value is given, put an X.
- Make a note if the unit of measurement on the label is different than the one in the table.
- Use different colored highlighters to mark the highest and lowest values for each nutrient in the table.
    - Mark the highest value in each row in yellow.
    - Mark the lowest value in each row in blue.
    - Highlight the corresponding key (high value and low value) below your table.

**High Value**

**Low Value**

| FOOD NAME | | | | | |
|---|---|---|---|---|---|
| **Nutrient per serving** | | | | | |
| Total fat (g) | | | | | |
| Saturated fat (g) | | | | | |
| Trans fat (g) | | | | | |
| Cholesterol (mg) | | | | | |
| Sodium (mg) | | | | | |
| Total carbohydrate (g) | | | | | |
| Fiber (g) | | | | | |
| Total sugars (g) | | | | | |
| Protein (g) | | | | | |
| Vitamin D (mcg) | | | | | |
| Calcium (mg) | | | | | |
| Iron (mg) | | | | | |
| Potassium (mg) | | | | | |

# Plant and Fish Nutrition

**Contributing authors:** Paul Brown, professor, department of forestry and natural resources and his graduate student Timothy Rice, senior aquaponics technician

**Student objective:** Students learn about important nutrients for plants and animals.

**Next Generation Science Standards**
- NGSS Standards: HS-LS2-5
- Disciplinary Core Ideas and Crosscutting Concepts: HS-LS2-7, HS-LS2-7

**AFNR Content Standards**
- ESS.03.04. Apply microbiology principles to environmental sustainability systems.

**Materials/Supplies**
- Plant and Fish Nutrition.pptx
- Plant and Fish Nutrition puzzle, page 42, answers, page 43
- Pencils
- Optional: Three to five brands of goldfish food

**Direct instruction: Students learn the nutrition that plants and fish need.**
Plant and Fish Nutrition.pptx
- Introduction, slides 1-7.
    - Optional: Goldfish Nutrition, slide 4. Students list and compare the ingredients in different types of goldfish food.
- Puzzle Clues, slide 7, may be left on your screen and/or handed out.
    - Students can work on the puzzle alone or in teams.
- Discussion, suggested questions, slide 8.
- Discussion, suggested answers, slide 11.

**For further study**
This activity introduces the importance of proper nutrition for plants and fish. The plants help remove water contaminants. The amount of contaminants removed will depend on the type of plants and the ratio of plants to fish. If you want to study this relationship further, consider using the hydroponic Kratky system to grow different plants with goldfish.

**Assessment**
- Teacher's analysis of the knowledge their students gained.
- Quiz or Discussion questions

**Supplemental information**
Depending on their species, plants and fish have specific nutritional needs for optimal growth.

***PLANTS***
The U.S. Department of Agriculture's Plant, Soil and Nutrition Research Unit works to improve the security and nutritional quality of plant crop species. It does this through interdisciplinary research that integrates molecular biology and genomics, bioinformatics, genetics, physiology, biochemistry and membrane biophysics. Its major research areas include:

1) Developing better genomic, computational, statistical and molecular genetic tools for facilitating fundamental discovery at the gene/protein levels for use in crop improvement;
2) Food-based solutions to micronutrient malnutrition and other diet-related issues, including developing plant varieties with higher concentrations and/or high bioavailability of critical mineral elements (iron, zinc, calcium, selenium) as well as selected phytonutrients (carotenoids, vitamin C and flavonoids); and
3) Enhancing food security by developing food and biofuel crop plant species that can maintain productivity on acidic, nutrient-depleted and/or metal toxic soils.
    - USDA Plant, Soil and Nutrition Research
    - https://www.ars.usda.gov/northeast-area/ithaca-ny/robert-w-holley-center-for-agriculture-health/plant-soil-and-nutrition-research/

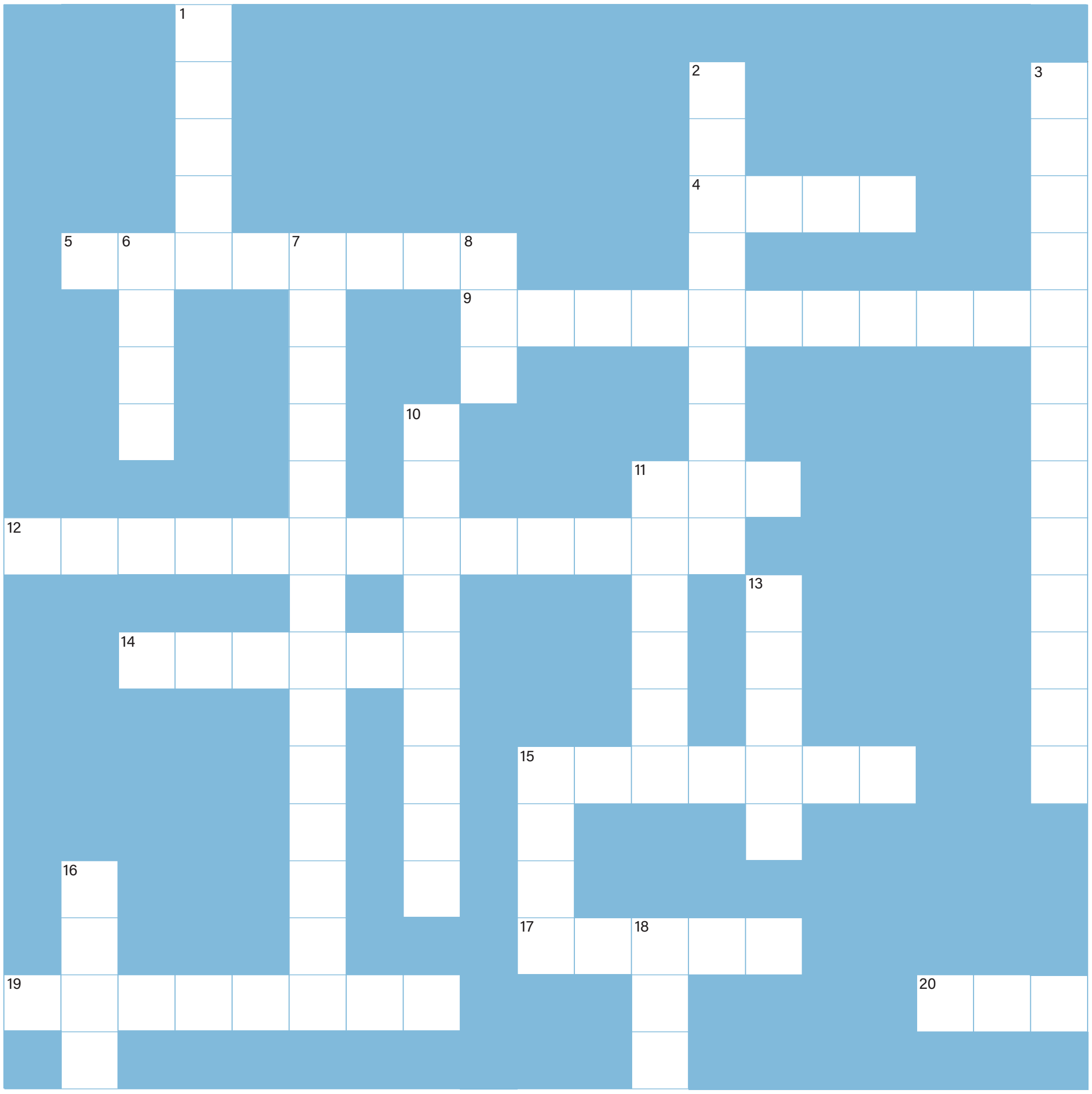
***FISH***
Commercial suppliers provide fish food blends to suit a specific type of fish. Goldfish and tropical fish food often comes in flakes and is widely available. Fish food suppliers provide larger operations with feed that contains vitamins, protein, fiber and fat for the correct nutrient balance.

# PLANT AND FISH NUTRITION PUZZLE

Name:

Date:

Class period:




## Plant and Fish Nutrition Puzzle Clues

**ACROSS**

4 Gold____, a cost-effective animal to begin with in your aquaculture system
5 Fish obtain these from their diet
9 Growing both fish and plants in a system
9 Part of an aquaponics system (with hydroponics)
11 They ruin picnics
12 Essential in relatively large amounts to the growth and health of a living organism
14 Provides nutrition to plants in an aquaponics system
15 A nutrient that animals and plants both need
17 Needed to run the filter
19 Localized death of living tissue
20 Acronym for the When Blue is Green project

**DOWN**

1 Usually grown in soil
2 Not enough of a nutrient
3 Level of nutrient
6 Deficiency causes yellowing of the newer leaves
7 Essential in very small amounts to the growth and health of a living organism
8 How you would feel if your fish die
10 Deficiency that causes yellowing of older leaves
11 Not a plant
13 An herb that can be grown in an aquaculture system
15 Generally produced for sale
16 Input to an aquaculture system.
18 What your friends might say about your aquaponics system

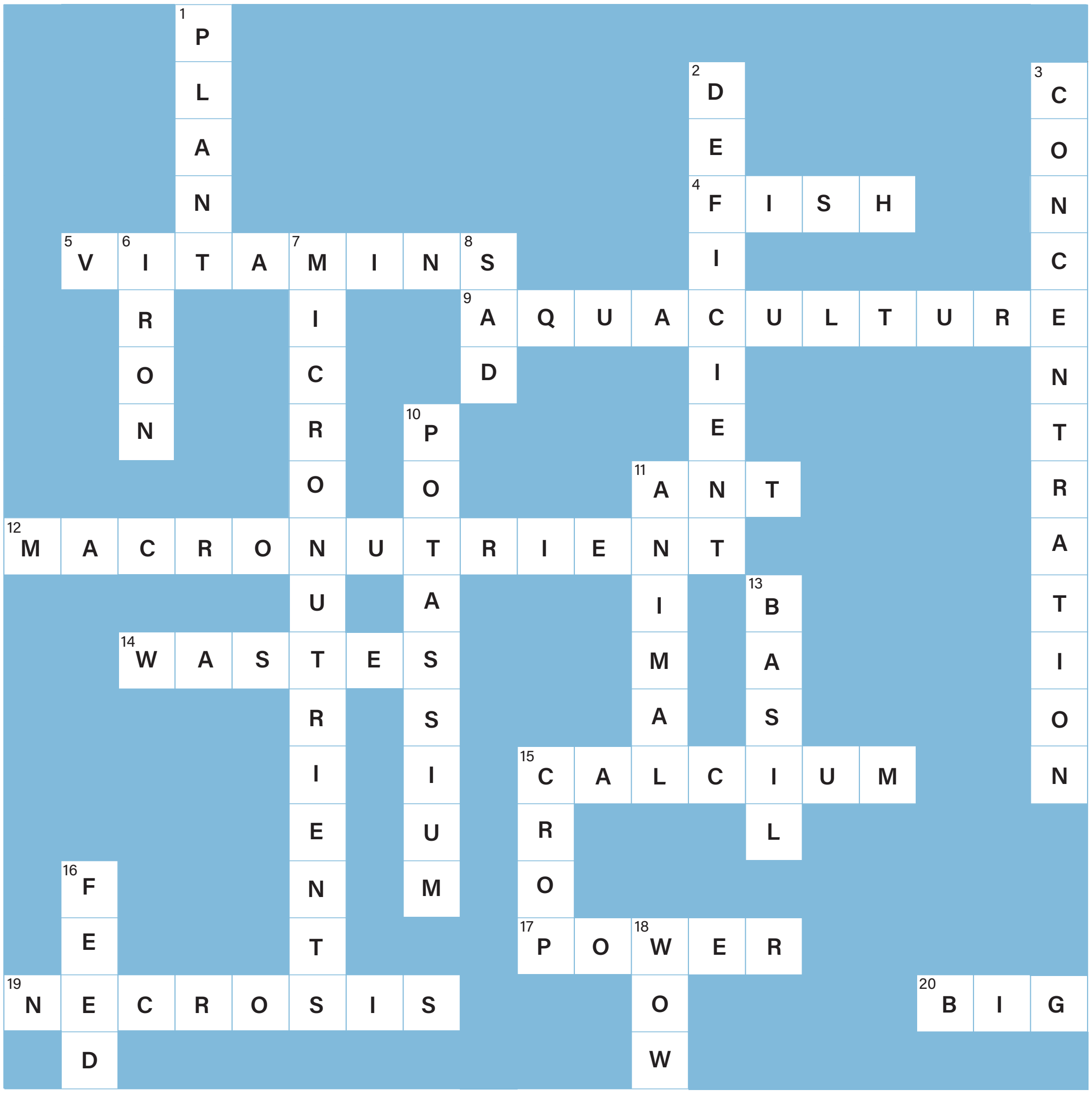
# PLANT AND FISH NUTRITION PUZZLE

Name:

Date:

Class period:

ANSWER KEY



## Plant and Fish Nutrition Puzzle Clues

**ACROSS**

4 Gold_____, a cost-effective animal to begin with in your aquaculture system

5 Fish obtain these from their diet

9 Growing both fish and plants in a system

9 Part of an aquaponics system (with hydroponics)

11 They ruin picnics

12 Essential in <u>relatively</u> large amounts to the growth and health of a living organism

14 Provides nutrition to plants in an aquaponics system

15 A nutrient that animals and plants both need

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10 Deficiency that causes yellowing of older leaves

11 Not a plant

13 An herb that can be grown in an aquaculture system

15 Generally produced for sale

16 Input to an aquaculture system.

18 What your friends might say about your aquaponics system

# The Systems Approach to Aquaponics

**Contributing authors:** Abigail Engelberth, associate professor, Department of Agricultural and Biological Engineering and Jen-Yi Huang, associate professor, Department of Food Science

**Student objective:** Teach students the importance of a systems approach and how it applies to aquaponics.

**Next Generation Science Standards**

- NGSS Standards: HS-LS2-4, HS-LS-6,HS-ETS1-3
- Disciplinary Core Ideas and Crosscutting Concepts: HS-LS2-7

**AFNR Content Standards**

- CRP.11.01. Research, select and use new technologies, tools and applications to maximize productivity in the workplace and community.
- Optional: CRP.12.01. Contribute to team-oriented projects and build consensus to accomplish results using cultural global competence in the workplace and community.

**Materials/Supplies**

- Paper and pencils
- The Systems Approach.pptx
- BiG System Components page 47 (one per team)

**Activity 1. Your School System**

**Direct instruction: Students study the school system to understand the systems approach.** The Systems Approach.pptx

- Introduction, slides 1-4.
- Allow the students to think about the entire school system, individually or in teams of two or three. Slide 5.
    - » You may need to help students get started. Sample answers:
        - A bean seed is an input for a gardener. What is an output? (beans for the table and/or for sale)
        - School system output: educated students. What is an input to this system? (children, teachers)
- Give students time to come up with everything they can think of.
- Compile the inputs and outputs on the blackboard or large adhesive sheets.
- Discussion, suggested questions
    - » Can you think of any other inputs we are missing?
    - » Can you think of any other outputs we are missing?
- Share suggested answers, The Systems Approach.pptx, slides 6-7.
    - » Add to or change the slides as needed.
- Discussion, suggested questions
    - » What would happen if the input building is not provided?
    - » What would happen if the input lunch staff is not provided?
    - » Why are so many inputs required to run a school system?

**Activity 2. The Aquaponics System**

**Direct instruction**

- Introduce the activity using The Systems Approach.pptx, slides 8-11.
- Have students work in teams to read the BiG System Components information. Draw a schematic (on the board or on large adhesive sheets on the wall) that shows how the system components work together. Slide 12.
- The BiG research grant application schematic is on slide 13 (The Systems Approach.pptx) without the component names. This slide is included at the end of this lesson plan, if you want to print it.
- The completed schematic and some pictures of our research pilot plant are in slides 14-15.

***Questions and answers for Activity 2***

*What components does a basic aquaponics system include?*

A tank, animals (usually fish) and the food they need; plants; and a pump to move water from the fish tank to the plant tank.

*What additional components has BiG added toward creating a zero-waste, grid-independent, economically viable system?*

Algal processing, biorefining, algae bioreactor, anerobic digester and biogas boiler, and fish processing.

*What is a systems approach?*

An approach that considers, plans for and studies all inputs and outputs. Other approaches to production and manufacturing often consider only the product and profits, ignoring possible environmental and human impacts.

*Why is a systems approach to food production important?*

It is essential to understanding and preventing unintentional burden shifting, whether between different parts of a system or different kinds of impacts. Improving one part of the food system is counterproductive if it has negative environmental, economic or social consequences in other parts of the system that may outweigh the advantages of the improvement. A systems approach goes beyond the traditional focus on a single commodity. It investigates improvements and reductions in the entire system, from raw material extraction and production to agricultural growing, food processing, packaging, distribution, preparation, consumption and disposal of all wastes.

*What should be included in your systems approach to planning for life after high school?*

Answers will vary. Students may suggest college, family, jobs, income, responsibilities of cooking, cleaning, or managing their money.

**Research System Inputs and Outputs**

| Component | Inputs | Outputs |
|---|---|---|
| **Fish, tanks, plants** | Fish, plants, tanks, equipment (pumps, tubing, etc.), fish feed, energy, water | Fish and plants (to sell)<br>Sludge, vegetable waste, wastewater |
| **Algae bioreactor** | Digestate, energy, wastewater | Algae cells, water |
| **Algal processing** | Algae slurry, fish waste (manure), food waste, sludge, vegetable waste | Biofertilizer, digestate, energy |
| **Anerobic digester, biogas boiler** | Algae slurry, manure, food waste, sludge, vegetable waste | Energy, digestate, biofertilizer |
| **Fish and plant processing** | Fish, plants | Fish products |
| **Biorefining** | Algae slurry, fish byproducts | Fish feed, bioactive peptides, phenolic compounds |

**Assessment**

- Teacher's analysis of the knowledge their students gained.
- The Q&A (above and in slide 16) can be used for discussion or as a quiz for students to hand in.

**Supplemental information**

Researchers have often studied how to create or improve a product without considering or testing all the impacts it causes. For example, the tractor and moldboard plow made farming easier and faster, and pesticides helped increase yields. But as farms and equipment got larger, and fertilizer and pesticide use increased, negative impacts became apparent: soil compaction, decreased soil health and water contamination.

The systems approach is increasingly used in many disciplines to ensure that all inputs, outputs, and social and environmental impacts are considered during product development. Understanding every aspect of a production system takes into account all benefits, costs and impacts. Failing to do so may overlook important human and environmental aspects of the product. Before beginning a new venture, producers must consider the entire food chain from seed to table, and the costs of inputs, outputs, profit margin, transportation, waste management and environmental costs.

Aquaponics combines aquaculture and hydroponics to use nutrients from animal waste as a natural plant fertilizer. Maintaining water quality is important in aquaponics to reduce the generation of sludge and wastewater. Sludge contains considerable amounts of nitrite, nitrate, ammonia and phosphate. System wastes are often used for soil enrichment or agricultural fertilizer. This waste has been fermented to produce biogas through anaerobic digestion. Researchers are studying microalgae, which can assimilate nutrients to produce biomass that can be converted into biofuels, to treat aquaponic waste. This has the potential to fully recycle the nutrients as resources for energy generation to power the system and achieve a zero-waste aquaponic operation.

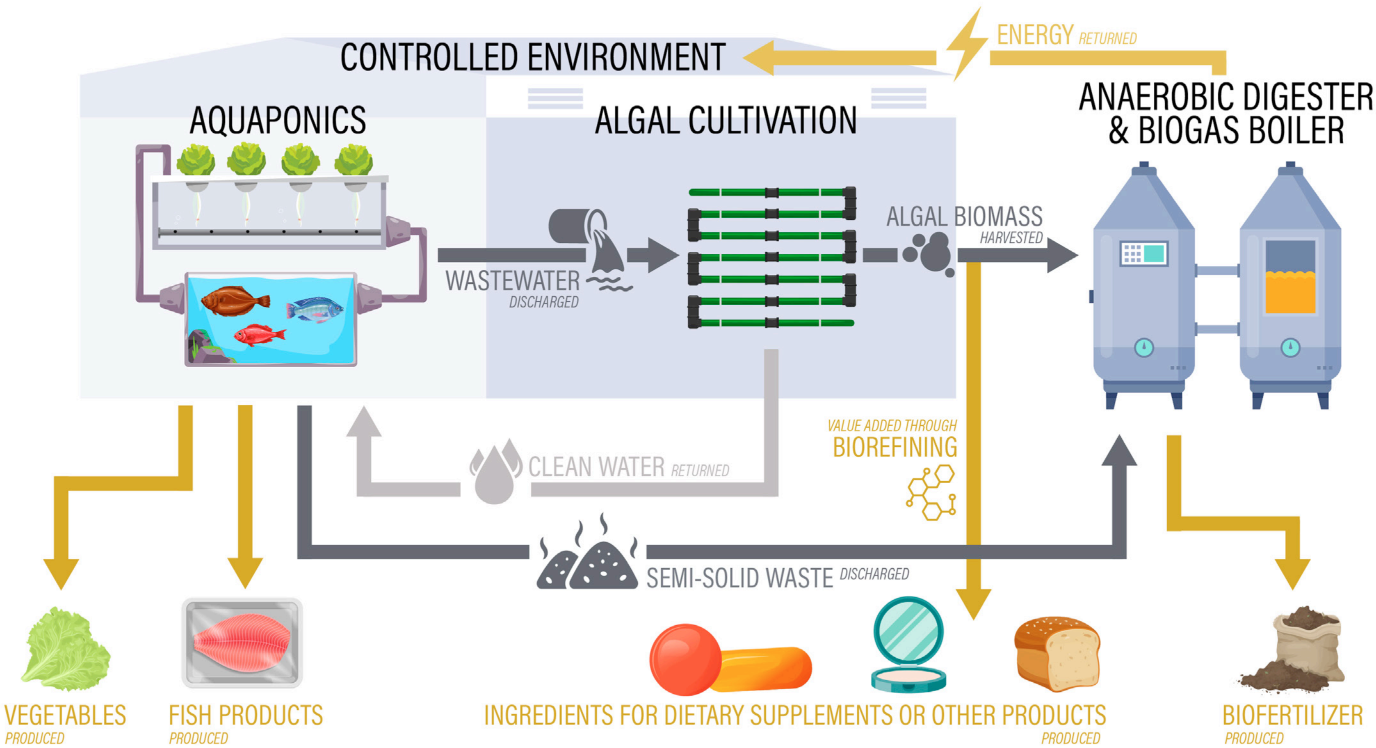
The schematic on page 47 can help students understand the BiG system.

**BiG Aquaculture System Components**

Despite using less land and water than conventional food production, aquaponics requires high energy input and creates considerable nutrient wastes, leading to high operational and maintenance costs. These costs challenge its economic sustainability, which may be a barrier to wider adoption.

Although growers are widely interested in the potential of aquaponics, gaps in research on animal-plant-microbe co-management, benefit-risk assessment, and financing holds them back. BiG researchers are working to solve these problems. Because a systems approach is critical, the project has many collaborators working on the following five objectives.

- Partner with diverse stakeholders to identify barriers and opportunities for blue foods and aquaponics.
- Design, construct and evaluate a resilient and sustainable food production system that integrates aquaponics with microalgae cultivation, anaerobic digestion, and biorefining processes.
- Assess economic and environmental performance of an integrated aquaponics food production system and develop evidence-based management practices and business models.
- Engage with stakeholders to support aquaponics and blue food market development.
- Create, pilot and publish education materials to foster a workforce prepared to support blue food supply chains.




The basic aquaponics system has fish, plants, tanks and a pump to move water. The wastewater and sludge from the fish tanks contain more nitrite, nitrate, ammonia and phosphate than plants can take up. As a result, current aquaponic systems discharge considerable amounts of water each day (up to 20%) and replace it with fresh water. BiG researchers are studying additional subsystems that may improve operational parameters, recycle nutrients, reduce costs, increase revenue streams and reduce waste output. These are described in the following paragraphs.

Researchers are studying microalgae to improve treatment of aquaponic wastewater. Algal bioreactors can help with nitrogen removal but do not remove all N, so the remainder is converted to nitrite and nitrate for plant crop use. Algae cells are further processed to create an algae slurry that is treated along with sludge from the fish tanks and vegetable wastes in an anerobic digester and biogas boiler.

BiG researchers hypothesize that adding an anaerobic digester to the aquaponics system will remove organic carbon from wastewater and produce more plant nutrients in solution to allow higher plant production. The algal slurry that remains after algae nutrient removal is then biorefined or treated in an anerobic digester and biogas boiler to create biofertilizer; nutraceutical ingredients such as bioactive peptides, and phenolic compounds; and fish feed ingredients. The anaerobic digester and biogas boiler are used to create digestate, energy and biofertilizer using the algal biomass.

This additional cycling of nutrients in the system and anaerobic digestion subsystems offers the promise of decreasing waste and generating fertilizer and biofuels. Researchers hope these system components will fully recycle the nutrients as resources for energy generation to power the system and achieve a zero-waste aquaponic operation. To complete the system, the fish and plants must also be processed.

**Glossary**

**Bioactive peptides:** Protein fragments with several amino acids — resulting from physical, chemical or enzymatic protein hydrolysis — that have a positive impact on physiological functions or conditions leading to improved health.

**Biofertilizer:** A product that is not chemically synthesized, is biodegradable and is usable as a fertilizer.

**Digestate:** The material remaining after the anaerobic digestion (decomposition under low oxygen conditions) of a biodegradable feedstock.

**Phenolic compounds:** Phenolic and polyphenolic products, either alone or in combination with vitamins, such as carotenoids, vitamin E, and vitamin C, that can serve as antioxidants to protect various tissues in the human body from oxidative stress.

**Sludge:** Fish excrement. A muddy or slushy mass, deposit, or sediment.

# Wastewater Recycling

**Contributing author:** Halis Simsek, assistant professor, Department of Agricultural and Biological Engineering

**Student objective:** Learn about efforts to reduce nutrients and contaminants from wastewater.

### Next Generation Science Standards

- NGSS Standards: HS-LS2-5, HS-LS2-7
- Disciplinary Core Ideas and Crosscutting Concepts: HS-LS2-4, HS-LS2-5

### AFNR Content Standards

- ESS.04.01. Develop systems of sustainability management for all categories of solid waste in environmental sustainability systems.
- ESS.04.02. Sustainably manage solid waste in environmental service systems.

### Materials/Supplies

- Waste Recycling.pptx
- Waste Disposal worksheet page 51 (one per student)
- Waste Disposal worksheet answers page 52

### Direct instruction: Students learn about waste disposal and environmental effects of waste.

Waste Disposal.pptx

- Introduction, slides 1-10.
  - Encourage students to take notes.
  - Or hand out the worksheet before you begin the PPT presentation.
- Assignment: Students complete the *Waste Disposal worksheet* on their own or in teams.
- Aquaponics has benefits but also challenges. Ask students if they can think of any solutions. Slides 11- 12.

### Assessment

- Teacher's analysis of the knowledge their students gained.
- The worksheet may be used as a quiz or for discussion.

### Glossary

**Benthic communities:** Groups of organisms that live in or near the bottom of lakes, rivers and oceans.

**Effluents:** Liquid waste or sewage discharged into a river, lake or stream.

**Eutrophication:** The process by which nutrient-rich water, often from agricultural runoff, causes excessive algae growth. It may kill aquatic animals due to a lack of oxygen in the water.

### Supplemental information

Reducing nutrients and contaminants from wastewater is vital for the health of surface and groundwater. Water pollution can harm plants and animals and reduce the availability of fresh water.

The primary agricultural pollutants of concern in the Midwest and the Mississippi River basin are atrazine, nitrogen and phosphorus. The Mississippi River basin drains approximately 41% of the land area of the contiguous U.S., ranging as far west as Idaho, north to Canada and east to Massachusetts. Rain in the Mississippi's watershed washes soil, organic debris, nitrogen and phosphorous fertilizers, and atmospheric deposition of oxidized nitrogen from the combustion of fossil fuels into the Gulf of Mexico.

Most land in the Mississippi's watershed is farmland. Each spring, as farmers fertilize their land in preparation for crop season, rain washes fertilizer off the land and into streams, rivers, and then the Gulf of Mexico. This leads to a dead zone in the gulf. Farming practices in the Midwest must be modified to reduce the amount of nitrogen and phosphorous leaving crop fields.

Recommendations to reduce water contamination include reducing fertilizer use; alternating crops grown each year; and timing fertilizer applications so rain won't wash them into water. The primary concern with row crops is a loss of nitrogen. Recommendations to reduce water contamination by nitrogen include incorporating manure into the soil; using filter strips between fields and surface water; and not applying manure to fields in winter.

Agricultural crop production also causes eutrophication concerns in the Great Lakes. For example, in 2014 the city of Toledo, Ohio, warned it residents not to drink or use the ater due to toxins from eutrophication in drinking water.

Aquaculture uses less water than conventional food production aquaculture practices but can discharge large quantities of nutrients into the environment because of non-treated, or poorly treated, wastewater.

Nutrients and organic matter released from aquaculture farm effluents affect the water ecosystem by depleting oxygen through overgrowth of cyanobacteria and microalgae. The primary waste products of aquaponics are the fish solids and uneaten food. Fish solids must be removed to maintain a healthy water quality. Nutrient-rich water is removed when cleaning out fish solids, and plant roots and other inedible plant parts culled during harvest are also waste products generated by aquaponics systems.

The wastewater from aquaponics systems can contain biological, chemical and physical contaminants. It's high organic matter, and dissolved nutrients can be a pollution source. These pollutants can cause eutrophication, oxygen depletion and degradation of benthic communities if not handled properly. Excessive feeding causes sediment to accumulate, which can increase the dissolved biological oxygen demand of bacteria in the water system.

Despite using less land and water than conventional food production, aquaponics continues to require high energy input and creates considerable nutrient wastes, leading to high operational and maintenance costs. These costs challenge economic sustainability, a main barrier to wider adoption. Although growers are widely interested in the potential of aquaponics, existing gaps in research on animal-plant-microbe co-management, benefit-risk assessment and financing inhibits initial engagement. Consequently, two of the goals of the BiG research are to:

- Design, construct and evaluate a resilient and sustainable food production system (FPS) that integrates aquaponics with microalgae cultivation, anaerobic digestion and biorefining processes.
- Assess economic and environmental performance of Integrated Aquaponics Food Production System (IAFPS) and develop evidence-based management practices and business models.

# WASTE DISPOSAL WORKSHEET

Name:

Date:

Class period:

**Complete the following sentences.**

1. Effluent from pipes is an example of ________________ pollution.

2. ________________ of pollution are particularly difficult to regulate because they come from many sources and may contain multiple pollutants.

3. ________________ systems serve communities.

4. ________________ systems serve individual homes in rural areas.

5. PPCPs are __________________________________________.

6. Neither municipal sewage treatment plants nor septic systems are equipped for ________________.

7. ____________ were the most frequently found PPCP in water samples and are believed to cause ecological harm.

8. ____________ exposure risks are higher than human risks because ____________ organisms have continual exposures, multigenerational exposures, exposure to higher concentrations, possible low-dose effects. (The same word fills both blanks.)

9. The primary waste products of____________ are the fish solids and uneaten food.

10. Pollutants can cause ______________ , oxygen depletion and degradation of benthic communities.

11. Eutrophication is __________________ that causes a profuse growth of algae and phytoplankton and increased availability of organic carbon.

12. BiG researchers are studying algal bioreactors because algae is _____________ for overall nitrogen removal than vegetables.

# WASTE DISPOSAL WORKSHEET

Name:

Date:

Class period:

ANSWER KEY

**Complete the following sentences.**

1. Effluent from pipes is an example of __point source__ pollution.

2. __Nonpoint sources__ of pollution are particularly difficult to regulate because they come from many sources and may contain multiple pollutants.

3. __Municipal__ systems serve communities.

4. __Onsite__ systems serve individual homes in rural areas.

5. PPCPs are __pharmaceuticals and personal care products__.

6. Neither municipal sewage treatment plants nor septic systems are equipped for __PPCP removal__.

7. __Steroids__ were the most frequently found PPCP in water samples and are believed to cause ecological harm.

8. __Aquatic__ exposure risks are higher than human risks because __aquatic__ organisms have continual exposures, multigenerational exposures, exposure to higher concentrations, possible low-dose effects. (The same word fills both blanks.)

9. The primary waste products of __aquaponics__ are the fish solids and uneaten food.

10. Pollutants can cause __eutrophication__, oxygen depletion and degradation of benthic communities.

11. Eutrophication is __nutrient-rich water__ that causes a profuse growth of algae and phytoplankton and increased availability of organic carbon.

12. BiG researchers are studying algal bioreactors because algae is __more efficient__ for overall nitrogen removal than vegetables.

# NOTES

# Water Quality and Aquaponics

**Contributing author:** Halis Simsek, assistant professor, Department of Agricultural and Biological Engineering

**Student objective: S**tudents learn to take and interpret water quality measurements.

**Next Generation Science Standards**

- NGSS Standard: HS-ETS1-1

**AFNR Content Standards**

- ESS.01.02. Properly utilize scientific instruments in environmental monitoring situations (e.g., laboratory equipment, environmental monitoring instruments, etc.).
- ESS.03.02. Apply soil science and hydrology principles to environmental sustainability systems.
- ESS.03.03. Apply chemistry principles to environmental sustainability systems.

**Materials/Supplies**

- Aquaponics WQ.pptx
- Aquarium water test kit ($10-$40 online)
- WQ and Aquaponics worksheet, page 56, Answers page 57

**Direct instruction: Students monitor the water quality of their system.**

Aquaponics WQ.pptx

- Introduction, slides 1-8.
- Activity 1. Water quality testing, slide 9.
  - » If you do not have an aquaponics system or aquarium, you can test water collected from a river, lake or stream.
  - » Test the water daily, Monday to Friday, and record the values.
  - » Keep records of the day and time you test and any changes to your system.
  - » Review any changes or trends in the water quality at the end of each week, and note any problems or correlations you see.
- BiG research water quality monitoring, slides 10-11.
- Activity 2. Learning water quality terms, slide 12.
  - » Students can cut, fold and tape the flashcards.
  - » Suggestions for use are on slide 12 but you can use them in many ways.
- BiG research focuses on the integration of microalgae cultivation, anaerobic digestion and biorefining processes in the aquaponics system.

**Assessment**

- Teacher's analysis of the knowledge their students gained.
- Students' ability to monitor and record water quality data over time.
- A competition to see who can identify the water quality terms the fastest.

**Supplemental information**

Goldfish are in the carp family, a hardier species than many other fish found in home aquariums. While these fish have a preferred temperature range that reduces stress and lowers their tendency to get sick, it is less critical than for many other common aquarium fish.

Aquaponics uses less land and water than conventional food production but requires high energy input and creates considerable nutrient wastes, leading to high operational and maintenance costs. Up to 20% of the nutrient-rich aquaponics wastewater — composed of ammonia, nitrites, nitrates, phosphates and organic carbon — must be discharged daily to maintain water quality, leading to potential environmental impacts. Before discharging to a waterway, large-scale farms must clean the wastewater to meet the expectations of the EPA's National Pollutant Discharge Elimination System permit. That generates additional maintenance costs. In contrast, small farms do not need discharge permits, so may be fouling the environment.

# WATER QUALITY AND AQUAPONICS WORKSHEET

Name:

Date:

Class period:

**Fill in the blank.**

A measure of water's ability to neutralize acids or resist changes that cause acidity, maintaining a stable pH of 8 or higher, is ____________________.

The amount of dissolved oxygen aerobic biological organisms need to break down organic material in a given water sample at a certain temperature over a specific time period is called the _____________________________.

The amount of oxygen needed to oxidize organic matter in water is called ___________________________.

The amount of oxygen present in water is called ____________________.

____________________ reflects the amount of dissolved calcium and magnesium in water.

The name for $NH_3$-N: ____________________.

The name for $NO_2$-N: ____________________.

The name for $NO_3$-N: ____________________.

The quantitative measure of the acidity or basicity of water is called ________________.

One of the major plant nutrients in soil essential for cell division and development of the growing tip of the plant is ____________________.

The level of heat present in water is ____________________.

A measure of the dissolved organic and inorganic substances present in water is called ________________________.

The amount of organic and inorganic particles suspended in water is called __________________________.

## Word Bank

**alkaline**
**ammonia nitrogen**
**biochemical oxygen demand (BOD)**
**chemical oxygen demand (COD)**
**dissolved oxygen (O)**
**hardness**
**nitrate nitrogen**
**nitrogen dioxide**
**pH**
**phosphorus**
**temperature**
**total dissolved solids (TDS)**
**total suspended solids (TSS)**

# WATER QUALITY AND AQUAPONICS WORKSHEET

Name:

Date:

Class period:

ANSWER KEY

**Fill in the blank.**

A measure of water's ability to neutralize acids or resist changes that cause acidity, maintaining a stable pH of 8 or higher, is **alkaline**.

The amount of dissolved oxygen aerobic biological organisms need to break down organic material in a given water sample at a certain temperature over a specific time period is called the **biochemical oxygen demand (BOD)**.

The amount of oxygen needed to oxidize organic matter in water is called **chemical oxygen demand (COD)**.

The amount of oxygen present in water is called **dissolved oxygen (O)**.

**Hardness** reflects the amount of dissolved calcium and magnesium in water.

The name for $NH_3$-N: **ammonia nitrogen**.

The name for $NO_2$-N: **nitrogen dioxide**.

The name for $NO_3$-N: **nitrate nitrogen**.

The quantitative measure of the acidity or basicity of water is called **pH**.

One of the major plant nutrients in soil essential for cell division and development of the growing tip of the plant is **phosphorus**.

The level of heat present in water is **temperature**.

A measure of the dissolved organic and inorganic substances present in water is called **total dissolved solids (TDS)**.

The amount of organic and inorganic particles suspended in water is called **total suspended solids (TSS)**.

## Word Bank

- alkaline
- ammonia nitrogen
- biochemical oxygen demand (BOD)
- chemical oxygen demand (COD)
- dissolved oxygen (O)
- hardness
- nitrate nitrogen
- nitrogen dioxide
- pH
- phosphorus
- temperature
- total dissolved solids (TDS)
- total suspended solids (TSS)

# Zero-Waste, Grid-Independent and Economically Viable Aquaponics System: Is it Possible?

**Contributing authors:** Abigail Engelberth, associate professor, Department of Agricultural and Biological Engineering and Jen-Yi Huang, associate professor, Department of Food Science

**Student Objective:** Students learn what a zero-waste, grid-independent and economically viable system entails.

**Next Generation Science Standards**
- NGSS Standards: HS-LS-6, HS-LS2-7, HS-ETS1-3
- Disciplinary Core Ideas and Crosscutting Concepts: HS-LS2-4, HS-LS2-5

**Materials/Supplies**
- ZeroWaste GridIndep.ppt
- Defining a Zero-Waste, Grid-Independent, and Economically Viable Aquaponics System worksheet, page 60 (one per 1-2 students). Answers, page 61
- Definition Questions, page 61 (one per 1-2 students ) Answers, page 62
- Pencil or pen

**Activity.**
**Direct instruction: Students complete a worksheet to understand definitions of zero-waste, grid independence and economic viability.**
- Introduce the activity using ZeroWasteGridIndep.pptx, slides 1-5.
- Assignment, slide 6.
  - Zero Waste worksheet (Zero Waste, Grid Ind worksheet.pdf)
    - Suggestion to teacher: A short competition where students face off on each topic. Whoever defines it correctly first wins a point for their team (or loses a point by shouting out an incorrect answer, which makes them stop and think before they answer).
  - Definitions worksheet (Definition Q&A.pdf)
    - See if students can complete this worksheet after they grade the first worksheet.
- Grading: Self, by classmate or hand in (as desired)
- Suggestion to teacher: A project in which students work in small groups to design their own zero-waste, grid independent and economically viable aquaponics system. You might be surprised by how innovative they can be.

**Discussion, suggested questions**
ZeroWasteGridIndep.pptx
- Answers to the Q&A activity, slides 6-8.

  ***Economic Viability***
  A product or project is economically viable if its economic benefits exceed its economic costs, when analyzed for society as a whole. A project's economic costs are not the same as its financial costs.
- Externalities and environmental impacts must be considered.
- Economic impacts on people who may not benefit from the product must also be considered.

  ***Energy independence***
  Eliminating reliance on energy a power company supplies.
- Reducing fossil fuel use, the source of 60% of U.S. electric power
- Autonomy from the national electric grid
- Produce more energy than you consume
- Goal: reduced energy costs

  ***Zero Waste***
  Maximize recycling, minimize waste, reduce consumption, and ensure that products are designed to be reused, repaired or recycled back into the environment or marketplace.
- Both community and industry are responsible.
- Summary, slide 9.

**Supplemental information**
Aquaponics integrates aquaculture and plant production systems (often as hydroponics) into a single closed/semi-closed loop system. This is called an integrated food production system (FPS). While FPS uses less land and water than conventional food production, aquaponics continues to require high energy input and creates considerable nutrient wastes, leading to high operational and maintenance costs. These costs challenge economic sustainability, a main barrier to wider adoption. Although growers are widely interested in the potential of aquaponics, existing gaps in research on animal-plant-microbe co-management, benefit-risk assessment and financing hold them back.

Technical and economic barriers currently make only a few U.S. aquaponics producers commercially successful. The overarching goal of the BiG project is to increase local and regional production of adequate, nutritious and affordable blue foods with a minimal environmental footprint to diversify U.S. agricultural systems and dietary patterns.

- Increased use of artificial intelligence (AI) is having a significant impact on power usage and energy use. In 2024, Microsoft confirmed (https://www.npr.org/2024/07/12/g-s1-9545/ai-brings-soaring-emissions-for-google-and-microsoft-a-major-contributor-to-climate-change) that its greenhouse gas emissions rose an estimated 29 percent since 2020 due to new data centers (https://www.popsci.com/technology/microsoft-nuclear-fusion-helion/) specifically "designed and optimized to support AI workloads." Google has also calculated (https://www.gstatic.com/gumdrop/sustainability/google-2024-environmental-report.pdf) that its own pollution generation has increased as much as 48 percent since 2019, largely because of data center energy needs.
- Appraising project economic viability. See https://ppp.worldbank.org/public-private-partnership/assessing-project-feasibility-and-economic-viability from the World Bank.
- Fossil fuels — petroleum, natural gas and coal — accounted for about 81% of total U.S. primary energy production in 2022. https://www.eia.gov/energyexplained/us-energy-facts/#:~:text=Fossil%20fuels%E2%80%94petroleum%2C%20natural%20gas,primary%20energy%20production%20in%202022

# DEFINING A ZERO-WASTE, POWER-INDEPENDENT, AND ECONOMICALLY VIABLE AQUAPONICS SYSTEM WORKSHEET

Name:

Date:

Class period:

**Indicate if the Goal of each Consideration listed refers to Energy independence (EI), Economic viability (EV), or Zero Waste (ZW) in the column on the left.**

**EI: Energy independence**
Eliminating reliance on energy supplied by a power company.

**EV: Economic viability**
A product or project is economically viable if its economic benefits exceed its economic costs, when analyzed for society as a whole. The project's economic costs are not the same as its financial costs; externalities and environmental impacts must be considered.

**ZW: Zero waste**
Maximize recycling, minimize waste, reduce consumption and ensure that products are designed to be reused, repaired, or recycled back into the environment or marketplace.

| Goal | Consideration |
|---|---|
| | Analyze society as a whole |
| | Autonomy from the national electric grid |
| | Both community and industry have responsibility |
| | Economic benefits exceed its economic costs |
| | Economic impacts that affect persons who may not benefit from a product |
| | Eliminating reliance on a power company |
| | Ensure that products are designed to be reused, repaired or recycled |
| | Externalities and environmental impacts must be considered |
| | Maximize recycling |
| | Minimize waste |
| | More than just financial costs |
| | Produce more energy than you consume |
| | Reduce energy consumption |
| | Reduced energy costs |
| | Reducing use of fossil fuels, the source of 60% of U.S. electric power |

# DEFINING A ZERO-WASTE, POWER-INDEPENDENT, AND ECONOMICALLY VIABLE AQUAPONICS SYSTEM WORKSHEET

Name:

Date:

Class period:

ANSWER KEY

**Indicate if the Goal of each Consideration listed refers to Energy independence (EI), Economic viability (EV), or Zero Waste (ZW) in the column on the left.**

**EI: Energy independence**
Eliminating reliance on energy supplied by a power company.

**EV: Economic viability**
A product or project is economically viable if its economic benefits exceed its economic costs, when analyzed for society as a whole. The project's economic costs are not the same as its financial costs; externalities and environmental impacts must be considered.

**ZW: Zero waste**
Maximize recycling, minimize waste, reduce consumption and ensure that products are designed to be reused, repaired, or recycled back into the environment or marketplace.

| Goal | Consideration |
|---|---|
| EV | Analyze society as a whole |
| EI | Autonomy from the national electric grid |
| ZW | Both community and industry have responsibility |
| EV | Economic benefits exceed its economic costs |
| EV | Economic impacts that affect persons who may not benefit from a product |
| EI | Eliminating reliance on a power company |
| ZW | Ensure that products are designed to be reused, repaired or recycled |
| EV | Externalities and environmental impacts must be considered |
| ZW | Maximize recycling |
| ZW | Minimize waste |
| EV | More than just financial costs |
| EI | Produce more energy than you consume |
| ZW | Reduce energy consumption |
| EI | Reduced energy costs |
| EI | Reducing use of fossil fuels, the source of 60% of U.S. electric power |

# DEFINING A ZERO-WASTE, POWER-INDEPENDENT, AND ECONOMICALLY VIABLE AQUAPONICS SYSTEM WORKSHEET

Name:

Date:

Class period:

**Complete the following statements.**

## Energy independence

- Definition: Eliminating reliance on ____________ supplied by a power company.
- Reducing use of fossil ____________, the source of 60% of U.S. electric power
- Autonomy from the national ____________energy grid.
- Produce ____________energy than you consume.
- Goal: Reduced energy _____________.

## Economic viability

- Definition: A product or project is economically ____________ if its economic benefits exceed its economic _________, when analyzed for society as a whole.
- The economic costs of the project are not the same as its ______________costs.
- Externalities and environmental ____________must be considered.
- The economic impacts on people who may not ____________ from the product must also be considered.

## Zero waste

- Definition: maximize ____________, minimize ____________, reduce ____________, and ensure that products are designed to be reused, repaired or recycled back into the _________________ or _________________.
- Who is responsible? Both ____________ and industry.

## Summary

A zero-waste, grid-independent, and economically viable aquaponics system would be possible when:

- All waste is used within the system or by complementary systems.
- All power requirements are generated by wastes from the system.
- The costs of production, including all inputs and outputs, are less than the income generated by the system.

# DEFINING A ZERO-WASTE, POWER-INDEPENDENT, AND ECONOMICALLY VIABLE AQUAPONICS SYSTEM WORKSHEET

Name:

Date:

Class period:

ANSWER KEY

**Complete the following statements.**

## Energy independence

- Definition: Eliminating reliance on __energy__ supplied by a power company.
- Reducing use of fossil __fuel__, the source of 60% of U.S. electric power
- Autonomy from the national __electricity__ energy grid.
- Produce __more__ energy than you consume.
- Goal: Reduced energy __consumption__.

## Economic viability

- Definition: A product or project is economically __viable__ if its economic benefits exceed its economic __costs__, when analyzed for society as a whole.
- The economic costs of the project are not the same as its __financial__ costs.
- Externalities and environmental __impacts__ must be considered.
- The economic impacts on people who may not __benefit__ from the product must also be considered.

## Zero waste

- Definition: maximize __recycling__, minimize __waste__, reduce __consumption__, and ensure that products are designed to be reused, repaired or recycled back into the __environment__ or __marketplace__.
- Who is responsible? Both __communities__ and industry.

## Summary

A zero-waste, grid-independent, and economically viable aquaponics system would be possible when:

- All waste is used within the system or by complementary systems.
- All power requirements are generated by wastes from the system.
- The costs of production, including all inputs and outputs, are less than the income generated by the system.

# ENVIRONMENTAL EDUCATION: GUIDELINES FOR EXCELLENCE

**Voluntary environmental education guidelines encourage environmental literacy, outlining what students should know and be able to do by 12th grade. They are published by the North American Association for Environmental Education (NAAEE), and available at https://eepro.naaee.org (Select Resources and Guidelines for Excellence). These BiG curriculum activities can help students develop a variety of environmental knowledge and skills, when your classroom discussion includes the following goals. Ask your students how they would address the items under (bullet list) the 'Strands' listed for the activities.**

## What are Blue Foods?

- **Students learn what blue foods are and why they are important.**
- **This activity requires students to estimate their (or a study subject's) food intake after estimating in class.**

**STRAND 3. Environmental Processes and Systems, Human systems**

Learners should be able to:

- Analyze the environmental impacts of personal actions with particular attention to variables such as technological advances and lifestyle changes. Deliberate the ongoing tension between meeting individual desires and gains, working for the common good of society, and environmental quality.
- Construct an evidence-based argument explaining examples of influences on individual behavior, particularly behavior that affects the environment.

**STRAND 4. Environmental Processes and Systems; Environment and Society**

Learners are able to:

- Predict differences in the future consumption of resources among nations using statistics, including population size of the country, birth rate, and energy use in kilograms of oil or equivalent as an indicator of consumption. Analyze projected use of resources over the lifetime of a child born in countries with various GDP levels.
- Examine actions the learner has taken or could take in the future to reduce their environmental impact.

## Let's Get Started!

- **Students set-up and monitor an aquaponics system.**

**STRAND 1. Questioning, Analysis and Interpretation Skills**

Learners are able to:

- Explain succession and equilibrium in ecosystems and resultant changes in constituent plant and animal communities.
- Apply the concepts of ecosystem and ecoregion to illustrate the multitude of relationships among organisms, including humans and environments.
- Trace the flow of matter and energy through living systems, and between living systems and the physical environment, identifying feedback loops.
- Illustrate how human activities affect the biosphere and how changes in the biosphere affect human activities.
- Propose a research question and/or define a problem, identifying and defining key variables.
- Select appropriate means of inquiry, including scientific investigations, historical inquiry, and social science observation and research for the environmental question under investigation.
- Evaluate the appropriateness of using quantitative and qualitative methods of researching the question. Working collaboratively, use census data, historic maps, and newspaper accounts from a selected region to investigate population shifts and settlement patterns over time.
- Design a detailed research strategy for investigating a selected environmental question or design problem.
- Identify a range of information and data gathering tools and technologies and, as appropriate, incorporate selected tools into their research strategy.
- Critique their strategy for investigating a selected environmental question, detailing their reasoning.
- Evaluate the effectiveness of available technology to access, collect, and store data and other information.
- Apply observation and data collection skills in field situations. Working collaboratively, conduct an energy audit of school buildings and grounds, interview community members about environmental concerns, or sample water in a local stream.
- Use basic sampling techniques such as spatial and random sampling. Evaluate when these techniques are appropriate.
- Evaluate the strengths and weaknesses of the methods of presentations and/or displays (e.g., written, graphic,
- visual, verbal) for different purposes and audiences.
- Use available technology designed to organize and display data, such as graphing and mapping software. For example, create and display maps showing animal migration patterns and potential conflicts with human settlements.
- Integrate and summarize information using a variety of methods such as written texts, graphic representations (e.g., graphs, charts, sketches, and photographs), maps, and digital media.
- Perform statistical analyses to describe data using quantitative measures such as ratios, rates, mean, median and mode.
- Use mathematical models to represent processes. Discuss the relationship of habitat changes and species interactions to the growth rates of plant and animal populations. Consider variations in habitat size, fragmentation, introduced species, and resource availability in relation to fluctuations in pH, dissolved oxygen, temperature, available light, or precipitation.

## Comparing the Financial and Environmental Costs of Food Production

- **Students are introduced to the food production supply chain and learn about inputs and outputs.**
- **Brainstorming plant sale, all inputs & outputs; consider aquaponics in the MW financial & environmental costs**

**STRAND 3. Environmental Processes and Systems, Human systems**

Learners are able to:

- Compare the goals of economic development and environmental sustainability.
- Apply research and analytical skills to describe how economic activity can result in costs that are external to the producer.

## Flow rates, Why They Matter

- **Students learn how flow rate can affect the concentrations of various substances in an aquaponics system.**
- **Setting up and monitoring a test system.**

**STRAND 1. Questioning, Analysis and Interpretation Skills.**
Learners are able to:

- Trace the flow of matter and energy through living systems, and between living systems and the physical environment, identifying feedback loops.
- Illustrate how human activities affect the biosphere and how changes in the biosphere affect human activities. Pose and evaluate researchable questions and design problems.
- Propose a research question and/or define a problem, identifying and defining key variables.
- Select appropriate means of inquiry, including scientific investigations, historical inquiry, and social science observation and research for the environmental question under investigation.
- Design a detailed research strategy for investigating a selected environmental question or design problem.
- Identify a range of information and data gathering tools and technologies and, as appropriate, incorporate selected tools into their research strategy.
- Critique their strategy for investigating a selected environmental question, detailing their reasoning.
- Evaluate the effectiveness of available technology to access, collect, and store data and other information.
- Apply observation and data collection skills in field situations.
- Use basic sampling techniques such as spatial and random sampling. Evaluate when these techniques are appropriate.
- Use available technology designed to organize and display data, such as graphing and mapping software. For example, create and display maps showing animal migration patterns and potential conflicts with human settlements.
- Integrate and summarize information using a variety of methods such as written texts, graphic representations (e.g., graphs, charts, sketches, and photographs), maps, and digital media.
- Perform statistical analyses to describe data using quantitative measures such as ratios, rates, mean, median and mode.

## Waste Water Recycling

- **Teach students about efforts being made to reduce nutrients and contaminants from wastewater.**
- **Reading and completing worksheet on wastewater.**

**STRAND 1. Questioning, Analysis and Interpretation Skills.**
Learners are able to:

- Illustrate how human activities affect the biosphere and how changes in the biosphere affect human activities. Pose and evaluate researchable questions and design problems.
- Identify a range of information and data gathering tools and technologies and, as appropriate, incorporate selected tools into their research strategy.

**STRAND 4. Environmental Processes and Systems; Environment and Society**

- Evaluate the cumulative effects, positive and negative, of human actions on a specific species or environmental system, such as a stream or a watershed.

## Water Quality and Aquaponics

- **Students learn to take and interpret water quality measurements.**
- **Reading and completing worksheet on wastewater.**

**STRAND 1. Questioning, Analysis and Interpretation Skills.**

Learners are able to:

- Evaluate the effectiveness of available technology to access, collect, and store data and other information.
- Apply observation and data collection skills in field situations. Working collaboratively, conduct an energy audit of school buildings and grounds, interview community members about environmental concerns, or sample water in a local stream.
- Use basic sampling techniques such as spatial and random sampling. Evaluate when these techniques are appropriate.
- Evaluate the strengths and weaknesses of the methods of presentations and/or displays (e.g., written, graphic, visual, verbal) for different purposes and audiences.
- Use available technology designed to organize and display data, such as graphing and mapping software. For example, create and display maps showing animal migration patterns and potential conflicts with human settlements.
- Integrate and summarize information using a variety of methods such as written texts, graphic representations (e.g., graphs, charts, sketches, and photographs), maps, and digital media.
- Perform statistical analyses to describe data using quantitative measures such as ratios, rates, mean, median and mode.
- Use mathematical models to represent processes. Discuss the relationship of habitat changes and species interactions to the growth rates of plant and animal populations. Consider variations in habitat size, fragmentation, introduced species, and resource availability in relation to fluctuations in pH, dissolved oxygen, temperature, available light, or precipitation.

## Zero-Waste, Grid-Independent, and Economically Viable Aquaponics System

- **Students learn what a zero waste, grid independent and economically viable system entails.**
- **Worksheet: Energy independence, Economic viability, zero waste**
- **And brainstorming**

**STRAND 3. Environmental Processes and Systems, Human systems**

Learners are able to:

- Compare the goals of economic development and environmental sustainability.

**STRAND 4. Environmental Processes and Systems; Environment and Society**

Learners are able to:

- Using examples of particular technologies or technological systems, discuss the social and environmental costs, benefits, risks, and possibilities associated with the technologies humans use to shape and control the environment. Consider whether some groups are advantaged or disadvantaged more than others by using these technologies.
- Compare management systems that promote sustainable use of resources using environmental, social, and economic indicators.

https://purdue.ag/big-project

Find out more at
**THE EDUCATION STORE**
**edustore.purdue.edu**

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