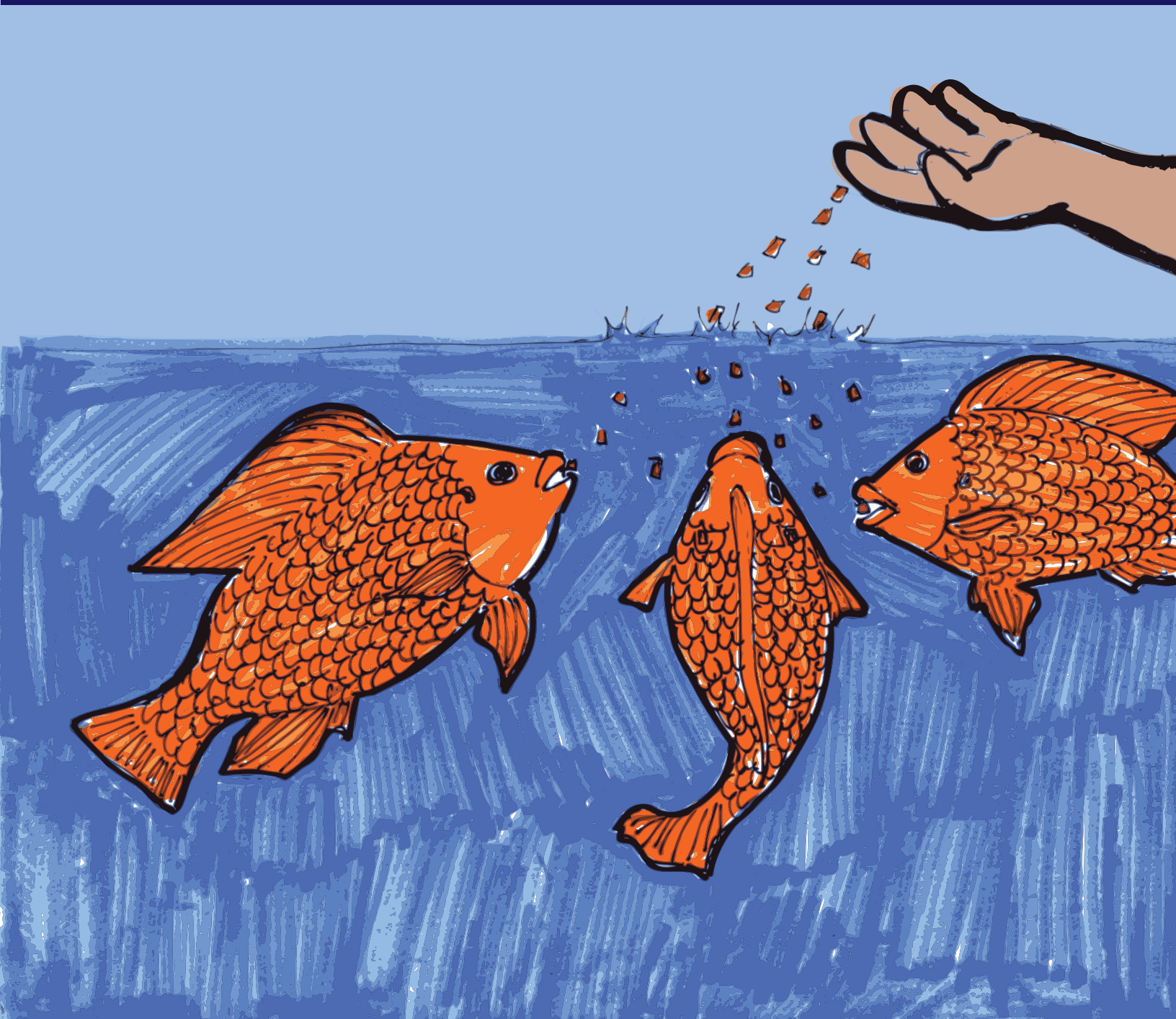


# A.Q.U.A.

A Quest to Understand Aquaculture



An easy-to-follow  
informal aquaculture curriculum  
for teachers of all grade levels

## Acknowledgements

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## The AQUA Project

This curriculum was created as part of the AQUA project, a public outreach and K-12 education project that aims to educate residents in Hawaii and U.S. Affiliated Pacific Islands about aquaculture. It is a collaborative effort between multiple organizations involved in aquaculture in the region, and is managed by the Center for Tropical and Subtropical Aquaculture (CTSA). Initial funding for the project was provided by NOAA, and ongoing support and management are provided by CTSA. Learn about the project at [www.pacificAQUA.org](http://www.pacificAQUA.org)

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## Preface

### Introduction

The AQUA (A Quest to Understand Aquaculture) curriculum for all grade levels offers educators and students the opportunity to experience how fun and productive it can be to learn science and other subjects through aquaculture. From the history of aquaculture (worldwide and in the Pacific), to step-by-step instructions on building, maintaining, and experimenting with a system at your school, this curriculum provides hands-on learning that encompasses a variety of subjects, including science, math, history, art, and more!

### Curriculum Application

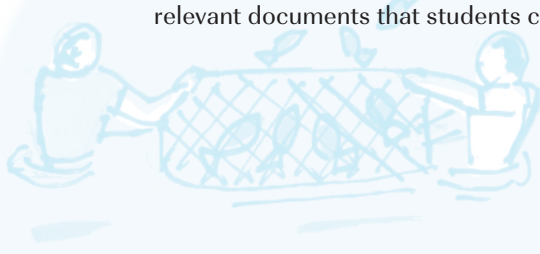
Teachers of all different subjects and grade levels can use the AQUA curriculum to introduce aquaculture and aquaponics to their students. This simple, informal curriculum provides essential information on practicing aquaculture, as well as background information on many different aspects of the industry. It is meant to be a guide for teachers and home educators, complete with central concepts, activity ideas, and several worksheets. Activity ideas are broken down into the following groups: I (elementary), II (intermediate), and III (high school). Most of the activities are applicable or can be adapted to multiple grade levels, so it is a good idea to read through the entire document and choose which concepts, activities, and worksheets can be applied in your classroom. Most lessons feature "Dive Deeper" and "Did You Know" spotlight boxes. "Dive Deeper" contains links and suggestions for additional discussion topics, and "Did You Know?" features facts relevant to the Central Concept.

### AQUAFarm

If you decide to establish an aquaculture or aquaponics system(s) at your school or home, one possibility is to run it like a model business. In a classroom setting, students can take on different roles of the business and have different responsibilities in the management of the system(s). They can start by developing a business plan, just like a potential aquaculture farmer must do before they start a business, and end with the harvest of their crops. Throughout the curriculum, you will see green "AQUAFarm" boxes that contain suggestions for relevant activities.

### AQUA Activity Folder

This curriculum features worksheets and activity ideas that are fun for students of all ages. We recommend creating an AQUA Activity Folder to keep track of the art work, worksheets, and other relevant documents that students create while participating in the AQUA program.



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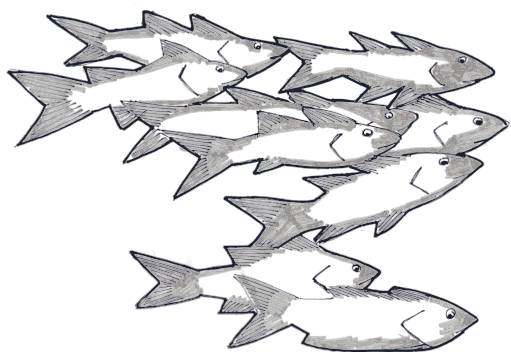


## Section I: Introduction to Aquaculture





## Central Concept I: What is Aquaculture?

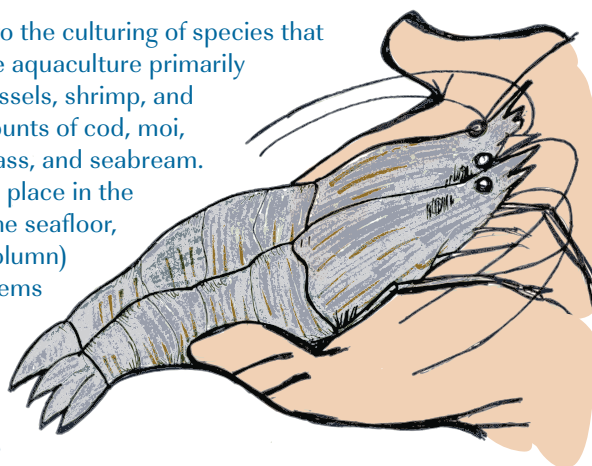


The National Oceanic and Atmospheric Administration (NOAA) Fisheries Service defines aquaculture — also known as fish or shellfish farming — as the breeding, rearing, and harvesting of plants and animals in all types of water environments including ponds, rivers, lakes, and the ocean. Researchers and aquaculture producers are "farming" all kinds of freshwater and marine species of fish, shellfish, and plants.

Aquaculture produces food fish, sport fish, bait fish, ornamental fish, crustaceans, mollusks, algae, sea vegetables, and fish eggs.

Aquaculture includes the production of seafood from hatchery fish and shellfish which are grown to market size in ponds, tanks, cages, or raceways. Stock restoration or "enhancement" is a form of aquaculture in which hatchery fish and shellfish are released into the wild to rebuild wild populations or coastal habitats such as oyster reefs (read more about that in the next lesson). Aquaculture also includes the production of ornamental fish for the aquarium trade, and growing plant species used in a range of food, pharmaceutical, nutritional, and biotechnology products.

**Marine aquaculture** refers to the culturing of species that live in the ocean. U.S. marine aquaculture primarily produces oysters, clams, mussels, shrimp, and salmon as well as lesser amounts of cod, moi, yellowtail, barramundi, seabass, and seabream. Marine aquaculture can take place in the ocean (that is, in cages, on the seafloor, or suspended in the water column) or in on-land, manmade systems such as ponds or tanks. Recirculating aquaculture systems that reduce, reuse, and recycle water and waste can support some marine species.



**Freshwater aquaculture** produces species that are native to rivers, lakes, and streams. U.S. freshwater aquaculture is dominated by catfish but also produces trout, tilapia, and bass. Freshwater aquaculture takes place primarily in ponds and in on-land, manmade systems such as recirculating aquaculture systems. (NOAA Fisheries Service)

Throughout Hawaii and the U.S. Affiliated Pacific Islands, there are aquaculture farmers growing a wide variety of aquatic species, including shrimp, tilapia, Pacific threadfin (moi), amberjack (kahala), mangrove crabs, oysters, sea cucumbers, Chinese catfish, Hawaiian mullet, freshwater prawns, rabbitfish, abalone, seaweed, microalgae, and more. Technologies on each island range from simple pond systems to intricate intensive tank culture, as well as open ocean mariculture. Learn more about different aquaculture systems in Section 3, CC1.

### ACTIVITY IDEAS

**All:** Lead students in a discussion about seafood. Ask them if they know where fish come from, if they like to eat seafood, and what type. If/when a student names a fish that is being grown in the U.S. Affiliated Pacific Islands using aquaculture, use that to begin a discussion about aquaculture. You can also ask students about aquarium fish, and explain that many come from aquaculture.

**I:** Have students illustrate a fish or other species that is being raised through aquaculture in the Pacific Islands. Ask them to say or write a sentence about aquaculture, and include it on the bottom of their drawing.

**II & III:** Ask students to do further research to create a compare and contrast chart on marine and freshwater aquaculture.

### DIVE DEEPER

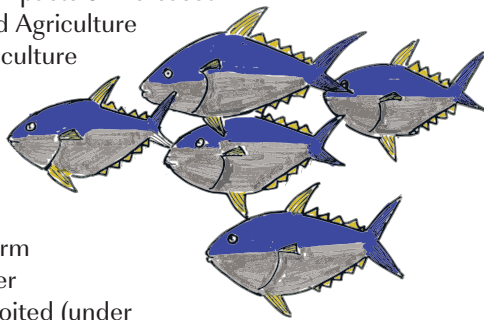
Aquaculture is different from fisheries. Fisheries deals with the catching, processing, and selling of fish and other seafood taken from natural environments. Research similarities and differences between aquaculture and fisheries, and incorporate the information into a discussion with students. You can also make comparisons and contrasts between aquaculture and agriculture.

### DID YOU KNOW?

Aquaculture is considered a form of agriculture in the United States. Aquaculture is managed under the same federal laws and restrictions as agriculture.

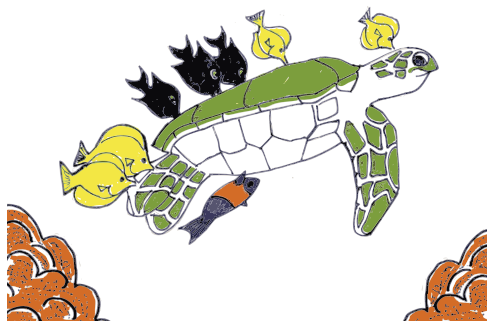
## Central Concept 2: Aquaculture & Our Changing Planet

Worldwide, ocean ecosystems are feeling the impacts of increased harvesting pressure. According to the Food and Agriculture Organization (FAO) report "Fisheries and Aquaculture 2012," 57% of the monitored marine fish stocks are fully exploited (fishery is operating at or close to an optimal yield with limited potential for expansion), 29.9% are overexploited (fishery is exploited at above a level believed to be sustainable in the long term with no potential room for expansion and higher risk of depletion), and 12.7% are non-fully exploited (under low fishing pressure with potential for production increase). Most of the top ten species consumed worldwide are fully exploited, which has a direct impact on food security.



The term "food security" refers to the availability of food and one's access to it. For centuries, Pacific Islanders and other coastal residents have depended on fish and other food from the ocean for their food security. Globally, fish provides more than 3 billion people with almost 20 percent of their average per capita intake of animal protein, and 4.3 billion people with 15 percent of such protein\*. However, the security of fish as a dietary staple is in jeopardy. Considering the effects of overfishing on our ocean, the fact that total production from capture fisheries worldwide has reached maximum yield (90 million tons in 2009), and the rapid rate at which Earth's population is growing, it is easy to see how seafood may become scarce if we don't find a solution.

Many people believe that sustainable aquaculture is a part of the solution to the global food crisis. Across the world, the expansion of aquaculture production has helped meet growing demand for edible seafood as capture fisheries output has leveled off. Currently, nearly half of the seafood consumed worldwide is from aquaculture. Most of the food we eat in the Pacific Islands is shipped in on boats and airplanes, including the seafood! A lot of it comes from aquaculture farms in other countries. Local aquaculture can help islanders restore a sustainable food supply, and cut down on transportation of food to the islands. It can also add revenue streams and significantly improve rural economies.



In addition to food fish, many important ornamental fish, such as yellow tangs, and filter feeders like sea cucumbers and oysters, have experienced a decrease in population, mainly due to overfishing. These animals are important because they eat or filter organisms that are harmful to their ecosystem. Aquaculture can help to

restore these populations through restocking programs that release young fish and other native species back into the ocean. For example, a Center for Tropical and Subtropical Aquaculture (CTSA) project in the Federated States of Micronesia has resulted in the restocking of thousands of sea cucumbers in lagoons. Without these critical filter feeders, waste would build up on reefs and in lagoons, resulting in an unbalanced ecosystem. There are many similar projects across the Pacific region and worldwide.

### ACTIVITY IDEAS

**I, II, & III:** Have students make a collage. It can be of pictures that represent the ocean and how it is changing, aquaculture, or a number of other related issues.

**II & III:** Ask students to conduct additional research and write an essay on the status of fish stocks in the ocean. Ask students to present potential solutions to problems they identify.

**II & III:** How do U.S. fish stocks compare with the rest of the world? Ask students to look up the most recent NOAA "Status of Stocks" report and compare it with the FAO report "State of World Fisheries and Aquaculture". Determine percentages for the U.S. versus other countries. Are there differences? To dive even deeper, you can ask students to look at the different fisheries management strategies of different regions.

**III:** Have students look at human population growth predictions and make their own predictions of when fisheries will be depleted.

### WORKSHEETS

1a. Food Security

### DIVE DEEPER

Visit [http://www.education.noaa.gov/Marine\\_Life/](http://www.education.noaa.gov/Marine_Life/) for more information and fun activities!

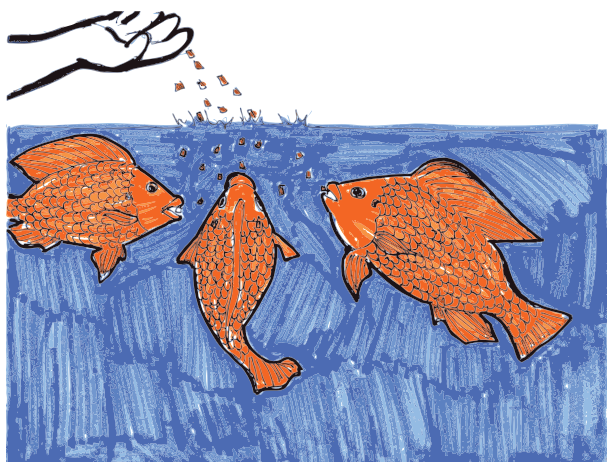
### DID YOU KNOW?

According to FAO projections, global aquaculture production will need to reach 80 million tons by 2050 just to maintain the current level of per capita utilization!

\*State of World Fisheries and Aquaculture 2012, FAO

## Central Concept 3: Aquaculture—Overcoming Challenges

Like any human activity, aquaculture can impact the environment, which is why U.S. aquaculture operators adhere to strong environmental and food safety regulations. When practiced responsibly, aquaculture's impact on wild fish and shellfish populations, marine habitats, and water quality is minimal. In fact, aquaculture can benefit the ecosystem – for example, oyster aquaculture creates habitat and enhances water quality. (NOAA FishWatch)



In aquaculture, one of the most critical aspects to ensuring an environmentally sound operation is selecting the appropriate site to develop facilities. Competition with natural habitats for space, conflict with natural predators, and the potential for escape are all environmental aspects that need to be considered when

selecting the site for an aquaculture farm. Learn more about site selection in Section 3, CC1. Effective management of effluents, or wastewater coming out of an aquaculture tank or pond, is another critical aspect of maintaining an environmentally-friendly operation. There are ways to manage effluents so there is no impact on the environment. For example, aquaponics uses 100% of the effluent water from a fresh-water fish tank to grow vegetables in a closed system, leaving no environmental footprint. Learn more about aquaponics in Section 3, CC4.

One of the major challenges facing aquaculture, particularly in the Pacific region, is creating sustainable feeds for non-herbivorous fish. Just like when they are in their natural habitat, carnivorous or omnivorous fish being raised in an aquaculture system need to consume nutrients from other fish and seafood. These nutrients have historically come from small wild-caught fish (e.g. anchovies) that are processed into fishmeal or fish oil and used as ingredients in aquaculture feeds. In the past, the aquaculture feeds industry has been criticized for using several pounds of wild-caught fish to make just one pound of farmed fish. However, with advances in technology and an increased focus on sustainability, researchers have been able to create diets that use only 1/2 - 1 pound of wild fish to make one pound of carnivorous farmed fish. Furthermore, the one pound of wild fish does not need to be fished from the ocean solely for the purpose of aquaculture. Many feeds researchers and manufacturers are working with seafood processors, such as tuna canneries, and other industries to obtain fishmeal made from byproducts.

*Feed Conversion Ratio (FCR) indicates the number of pounds of feed that it takes for an animal to gain one pound of protein. Animals with a low FCR, such as most fish, are considered efficient users of feed. To compare, cattle have an FCR of 8:1. Do some more research on FCR and incorporate into your discussion.*

### ACTIVITY IDEAS

**I, II & III:** Review and discuss the information on sustainable and unsustainable aquaculture practices in Worksheet 1b with students. Have students follow the instructions to complete the activity.

**II & III:** Ask students to research 3-5 specific environmental concerns about aquaculture (include citation of source), and respond to those concerns using knowledge from AQUA and additional research. The SeaWeb report "At A Crossroads: Will Aquaculture Fulfill the Promise of the Blue Revolution?" is a good resource for this activity: [http://www.seaweb.org/resources/documents/reports\\_crossroads.pdf](http://www.seaweb.org/resources/documents/reports_crossroads.pdf)

### WORKSHEET

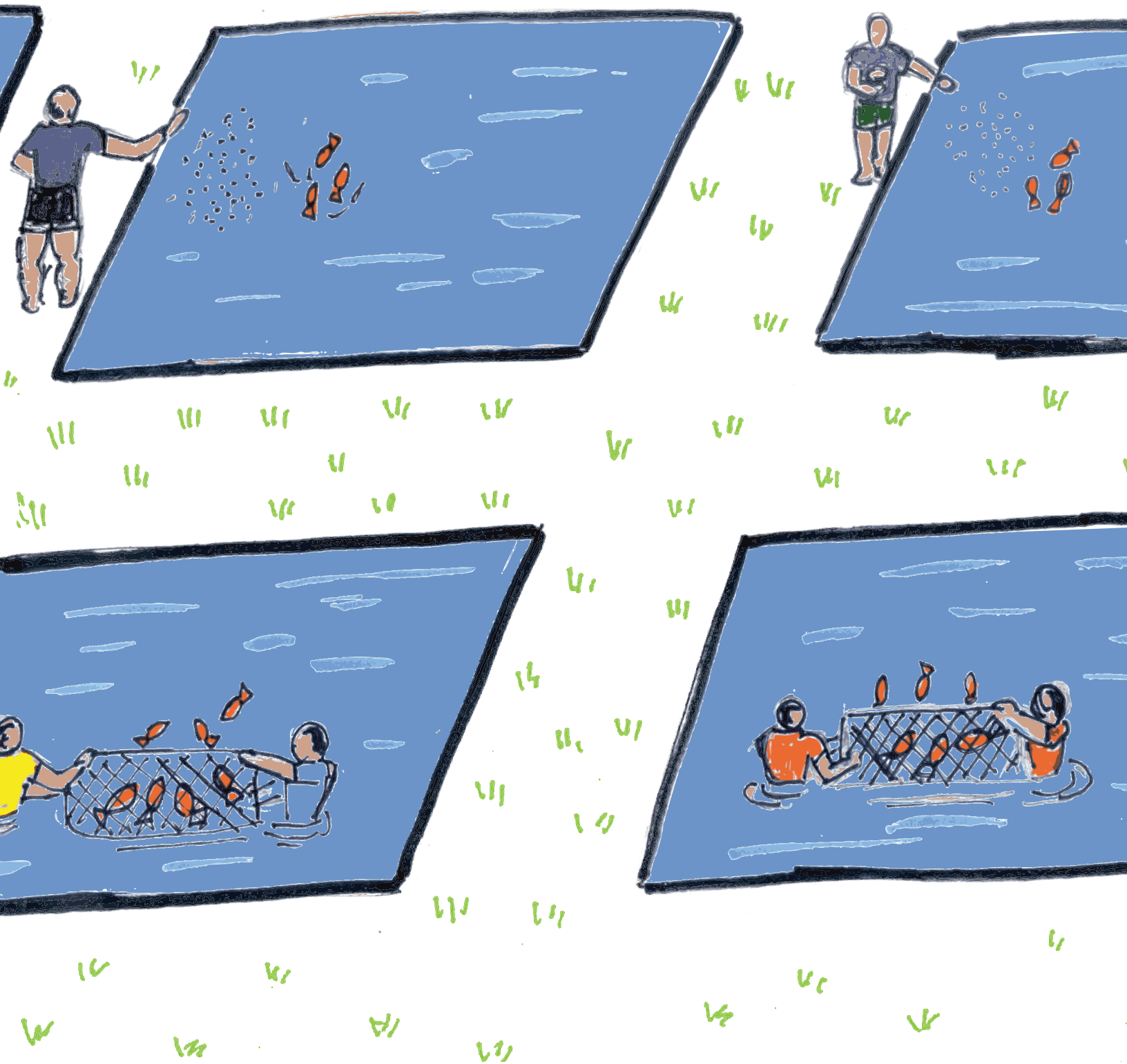
#### 1b. Sustainable Aquaculture Practices

### DIVE DEEPER

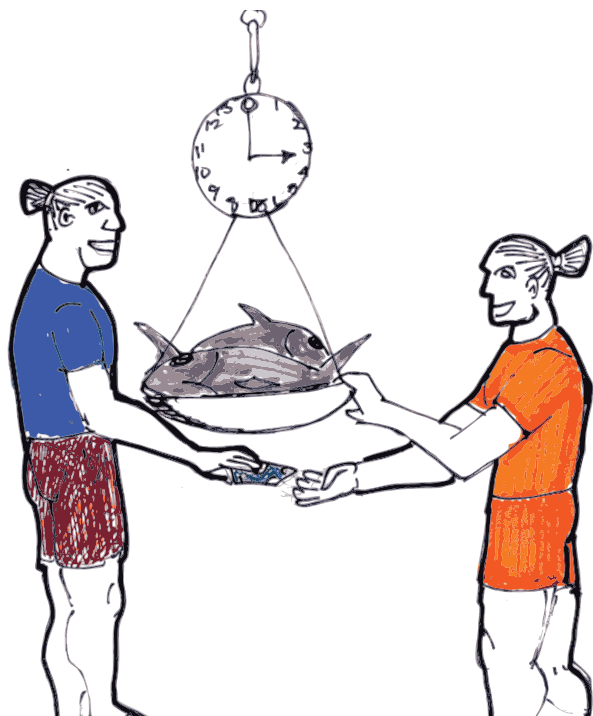
There has been much discussion surrounding one of the newer aquaculture technologies, open ocean mariculture. Through this technology, juvenile fish are placed in an offshore cage, where they float in the ocean currents until they grow to harvest size. Many aquaculture stakeholders believe that this technology has the capability to sustainably alleviate pressure on decimated wild fish stocks, however some groups have expressed concern with this method of aquaculture. Do further research and incorporate information on this technology into your discussion with students. To start, watch the video on the Velella Project, a research project that is testing an unanchored drifter pen in Federal waters (3-150 miles offshore) off the Big Island of Hawaii (type "Velella Project" into the YouTube search engine).



## Section 2: The Business of Aquaculture



## Central Concept I: The Value of Global Aquaculture



Aquaculture is a major player in the global economy. In 2010, worldwide aquaculture production reached 79 million tons, with a farmgate value of \$125 billion (including aquatic plants and non-food products).<sup>\*</sup> However, U.S. aquaculture is quite small in comparison, with a value of around \$1 billion (both freshwater and marine). Although the aquaculture industry has grown steadily over the past decade, production from U.S. aquaculture peaked at 607,570 tons in 2004. Nationwide production in 2010 was 495,499 tons, a nearly 19 percent decrease

from 2004. However, the value of the country's total aquaculture production reached \$1.016 billion in 2010, a 10.2 percent increase over sales in 2004.<sup>\*\*</sup>

Compared with U.S. production of nearly half-a-million tons, the top aquaculture producer in the world, China, generated 36.7 million tons (61.4 percent) of aquaculture products (excluding plants and non-food products) in 2010.<sup>\*</sup> India had the second largest total aquaculture production in 2010, followed by Vietnam, Indonesia, Bangladesh, Thailand, Norway, Egypt, Myanmar, and the Philippines. The United States is not currently ranked in the top ten producers.<sup>\*\*</sup>

To make up for what we lack in production, imports continue to supplement the seafood supply to U.S. consumers. We import about 86% of the seafood we eat, and approximately half of that comes from aquaculture in other countries. Only 5% of the seafood we eat comes from domestic U.S. aquaculture (freshwater and marine).<sup>\*\*\*</sup> The U.S. and Japan are the top importers of fish and fishery products, respectively depending on imports for 60% and 54% of fishery consumption.

Edible fisheries imports—valued at \$17.5 billion in 2010—make up the largest contributor among agricultural products to the U.S. trade deficit and form the second largest contributor after petroleum among natural resources products.<sup>\*\*</sup> The value of imported fisheries products has almost doubled in the past 10 years. In 2010, the seafood trade deficit surpassed the \$10 billion mark for the first time and reached \$10.9 billion in 2011.

<sup>\*</sup>State of World Fisheries and Aquaculture 2010, FAO, <sup>\*\*</sup>FAO 2012 Online Statistics Data, <sup>\*\*\*</sup>NOAA Fisheries Service

### ACTIVITY IDEAS

**All:** To start this discussion, talk about money with students. Talk about how different industries make different sized contributions to the economy, and make comparisons between aquaculture and other industries. Ask students what they would do with \$10.9 billion to help the U.S. seafood industry. Use that to start a discussion about the value of aquaculture.

**II & III:** Ask students to review the FAO document "State of World Fisheries and Aquaculture 2012" in sections or in its entirety (available on the FAO website). Have them compare U.S. aquaculture production figures with those of other countries. Create calculations for students to determine, including percentages of production difference between countries. Students can also track where seafood we eat in the U.S. is being imported from. Note: this activity is building on the activity on page 3.

### DIVE DEEPER

The FAO document "State of World Fisheries and Aquaculture 2012" is full of the most recent global aquaculture statistics. Download the document on the FAO website, and incorporate information into your discussion with students.

### IMPACT ON PACIFIC ECONOMIES

In 2010, farm sales from aquaculture producers in Hawaii reached \$30 million. There is much potential to expand the industry in the Pacific region and positively impact local economies.

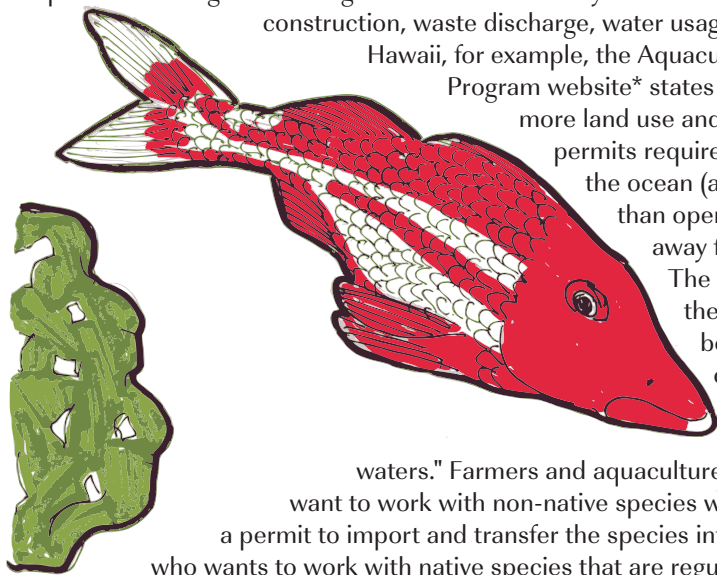
## Central Concept 2: Aquaculture Regulations & Laws

Anyone interested in conducting aquaculture research or starting an aquaculture farm in the United States will have to adhere to certain rules, regulations, and laws. Aquaculture in the United States is not governed by one single agency or set of rules. In most instances, state and local governments and their respective departments of agriculture regulate the local industry and issue permits for zoning, construction, waste discharge, water usage, etcetera. In

Hawaii, for example, the Aquaculture Development Program website\* states "there are generally more land use and environmental permits required for projects near the ocean (along the coast), than operations located away from coastal areas. The State also offers the opportunity to be permitted to conduct offshore aquaculture in State marine

waters." Farmers and aquaculture researchers who want to work with non-native species will need to obtain a permit to import and transfer the species inter-island. Anyone who wants to work with native species that are regulated by fisheries laws will need to obtain a special permit.

On the federal level, there is legislation that includes provisions and stipulations for aquaculture. One of the most important among them is the Farm Bill, which is the primary agriculture and food policy of the U.S. government. Every five or so years, a new Farm Bill is voted on and enacted. The Farm Bill includes provisions for commodity programs, trade, research programs, food and nutrition, conservation, and more. Another important Act that affects the aquaculture industry is the Lacey Act of 1900, which is legislation that combats the trafficking of "illegal" fish (among other species). The Dive Deeper section lists additional legislation that affects U.S. aquaculture.



\*<http://www.hawaii.gov/hdoa/adp>

### AQUAFarm:

Ask students to research local laws pertaining to aquaculture. Have them find information on the permits they would need to obtain to go forward with their business plan.

### ACTIVITY IDEAS

**All:** To start this discussion, ask students about rules they have to follow (at home, in school, and elsewhere). Discuss the importance and purpose of rules, and lead the discussion to aquaculture.

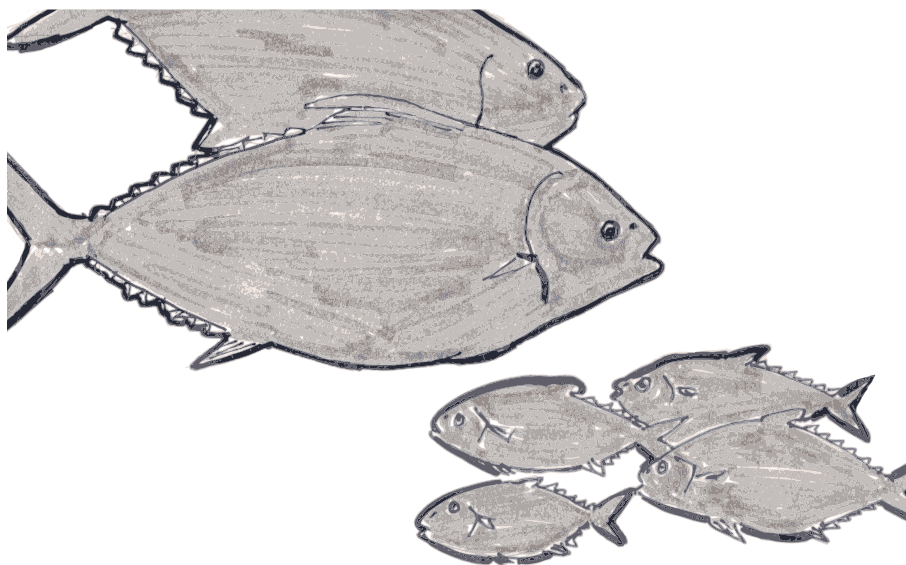
**II & III:** Ask students to research the Farm Bill (the current is titled "Food, Conservation, and Energy Act of 2008") or the new NOAA aquaculture policy. Have them create a presentation for the class about how it affects aquaculture in the U.S.

**III:** Write a letter to your local legislators about changes you would like to see related to aquaculture regulations.

### DIVE DEEPER

- The Environmental Protection Agency (EPA) has compiled detailed information on their website about aquaculture laws, regulations, policies, and guidance pertaining to environmental concerns. Visit the following link and include the information in a discussion with students: <http://www.epa.gov/agriculture/anaquilaw.html>
- There is much discussion surrounding the Lacey Act within the aquaculture industry. Do some research and discuss how this legislation affects the industry with students. A good place to start is with the SRAC publication "Aquaculture and the Lacey Act", available at the following link: <https://srac.tamu.edu/index.cfm/event/getfactsheet/whichfactsheet/247/>





### DID YOU KNOW?

Researchers in Hawaii are working with the Department of Health and the U.S. Food and Drug Administration (FDA) to obtain the necessary approvals and permits to begin culturing bivalves (such as oysters and clams) in the coastal waters of Hawaii. Learn more about this project on page 13.

On June 9, 2011, NOAA and the Department of Commerce released national aquaculture policies. These policies establish a framework to allow sustainable domestic aquaculture to contribute to the U.S. seafood supply, support coastal communities and important commercial and recreational fisheries, and help to restore species and habitat. NOAA sees aquaculture as a critical component to meeting increasing global demand for seafood and maintaining healthy ecosystems.

Each policy identifies nine actions that will promote science-based management of aquaculture consistent with natural resources protection and collaboration among resource users and management agencies.

Priorities in the NOAA policy include the following:

- making timely management decisions based on the best available science;
- continuing to advance aquaculture science;
- ensuring aquaculture decisions protect wild species and healthy coastal and ocean ecosystems;
- developing aquaculture in locations compatible with other uses;
- working with partners domestically and internationally;
- and promoting a level playing field for U.S. aquaculture businesses engaged in international trade.

(Department Of Commerce and NOAA Aquaculture Policies)\*

In addition to their new policy document, NOAA aquaculture activities also adhere to national aquaculture, fisheries, and ocean legislation including the below. Share information and discuss each of these with students.

- National Aquaculture Act of 1980 (most recently reauthorized under the 2008 Farm Bill)
- Magnuson-Stevens Fishery Conservation and Management Act
- Coastal Zone Management Act
- Endangered Species Act
- Marine Mammal Protection Act

### DID YOU KNOW?

Under the provisions of the Federal Water Pollution Control Act Amendments of 1972 (Clean Water Act), effluent discharge into waters of the United States is regulated by the United States Environmental Protection Agency (EPA) to maintain and improve potability, aesthetics, and recreational quality of the receiving waters. The 1972 amendments created the National Pollution Discharge Elimination System (NPDES) program, which requires that any facility discharging pollutants from a point source to a water of the United States apply for a discharge permit.

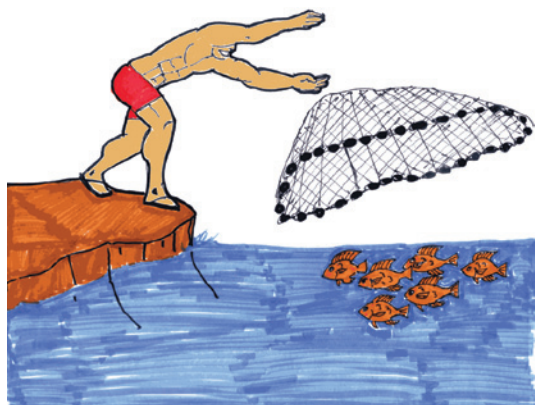
The NPDES permit can be issued by the EPA or by an authorized state agency. The authorized agency in Hawaii is the State of Hawaii Department of Health (DOH), as designated in the Hawaii Administrative Rules, Title 11, Chapter 55.

—excerpt from "Best Management Practices for Hawaiian Aquaculture," CTSA Publication #148.

\* [http://www.nmfs.noaa.gov/aquaculture/policy/2011\\_policies\\_homepage.html](http://www.nmfs.noaa.gov/aquaculture/policy/2011_policies_homepage.html)

## Central Concept 3: Occupations and Education in Aquaculture

There are a wide variety of career opportunities in the field of aquaculture, from farming to researching and beyond. The FAO estimates that worldwide, around 16.6 million people are currently engaged in the industry.\* Compared with other locations across the globe, the aquaculture industry in the U.S. Affiliated



Pacific Islands is relatively small. However, there are still opportunities for employment. Furthermore, the industry is expanding and with each new aquaculture opportunity comes new aquaculture jobs.

Like agriculture and other multi-faceted industries, there are a variety of occupations in the exciting field of aquaculture. Let's start on the farm! The amount of employees on an

aquaculture farm depends on the size of the operation. On a smaller farm, there may be fewer people taking on several roles. Some of the jobs available on farms include:

- 🐞 Farm Manager: oversees all farm operations; directs, plans, organizes, and controls the activities of the farm, and is in charge of human resources.
- 🐞 Production Manager: plans, directs, and coordinates production.
- 🐞 Laboratory Technician: conducts laboratory tasks.
- 🐞 Harvest Superintendent: oversees harvest of products.
- 🐞 Unskilled and Skilled Laborers: completes work as-needed on farm, either in general or specific to their skills.
- 🐞 Water Technician: manages water on-site.
- 🐞 Hatchery Technician: conducts hatchery tasks.
- 🐞 Hatchery Manager: oversees operations of hatchery.
- 🐞 Marketing Manager: connects the farm and promotes the product to clients and consumer.

Some farms, especially those conducting research of their own, also hire biologists to work for them directly.

Jobs available in other areas of the industry include researcher (Ph.D level), research technician (conducts research based on specific training and/or education), extension agent (transfers new technology and information from the research field to the farmers; conducts on-site training and education), veterinarian, government officer (manages research grants, programs, fisheries, etc.), grants officer, and research program manager. Consultants are an important part of the industry, and there are different consultants for many aspects of aquaculture, including business development, marketing, site design, animal selection, and more. There are also many traditional jobs in the aquaculture industry, such as financial officers to coordinate both the initial funding of your venture and the day-to-day activities, and administrative support. There are workers that people rely on to start an aquaculture operation, including those in

### AQUAFarm:

Assign each student an AQUAFarm role. Have them research the details about their assigned roles, write a detailed description, and include it in the AQUAFarm Folder. They can use the library and internet to compile their information. They can also try to contact farm(s) and/or researcher(s) and identify themselves as students conducting research to obtain information. They should include a description of the expected duties, education and/or training required to obtain the position.

### ACTIVITY IDEAS

**All:** To start this discussion, ask students what types of jobs they think there may be in the field of aquaculture. Write their responses on the board, and begin reviewing the occupations.

**I:** Select a few aquaculture occupations that you think your students might enjoy learning about and discuss them. Have each student select an occupation and write or tell a pretend story about an imaginary day at work.

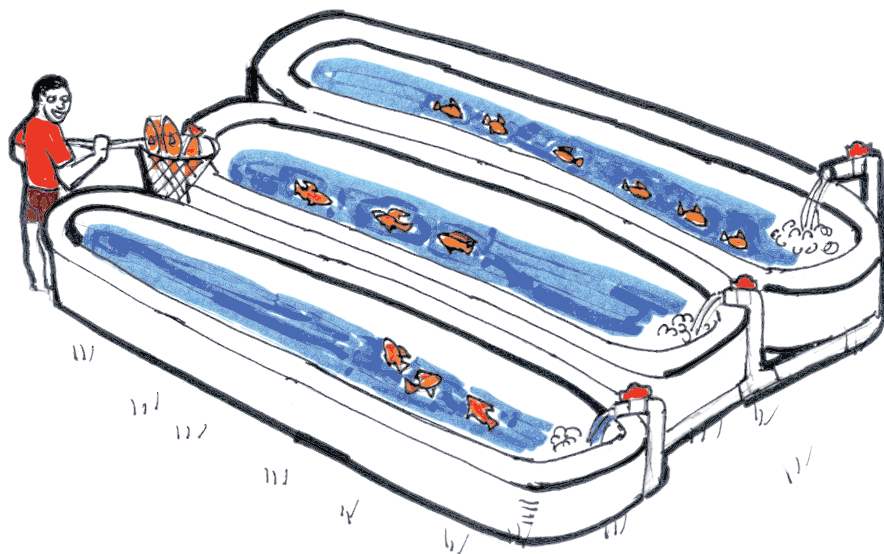
**II & III:** Assign each student an aquaculture job as a research topic. Have them compose a presentation about the job duties, education and/or training requirements, and any other relevant information they find.

**III:** Search and apply for a grant for seed money for an aquaculture project. Resources are available on the AQUA website.

### DIVE DEEPER

- Invite someone from the local aquaculture workforce to come and speak with your class about careers in aquaculture. For information on finding someone in your area, please email [info@pacificaquaa.org](mailto:info@pacificaquaa.org)
- Take a field trip to a local farm and meet with and/or interview the various employees.

\*State of World Fisheries and Aquaculture 2012, FAO



the construction and equipment sectors, as well as workers that are necessary to manage the product once it leaves the farm. Unless processing is unnecessary or is done on-site, the product will head to a processing plant, and then on to markets. Critical jobs in the post-production sector of the industry include transportation, distribution, marketing, and promotion. In addition, there are several jobs that go into the feed sector of the industry, such as feed mill manager, nutritionist, and feed specialist.

## Education and Training

The education and training requirements to obtain a position in aquaculture vary depending on the position. According to the Hawaii Aquaculture Development Program\*, “many employers like to see “hands-on” farming experience, together with formal course work at a college or university in such areas as agriculture, aquaculture, marine biology, zoology, fisheries biology, and oceanography. A background in business can also be particularly helpful. Other employers prefer an employee who has a strong interest and work ethic, who is willing to learn. Many workers in the Hawaii industry have come from public or private research institutions.”

Throughout the Pacific, there are institutions that offer programs in aquaculture or aquaculture-related fields of study. In the state of Hawaii, the University of Hawaii Manoa and Hilo campuses both have aquaculture courses and related degree programs for undergraduate and graduate students. However, only UH Hilo offers an undergraduate degree in aquaculture at this time. Community Colleges in the UH system also feature aquaculture-related coursework, such as Windward Community College on Oahu. The University of Hawaii system also offers the Marine Option Program, an educational program for students in any field of study who have an interest in the ocean. On the island of Oahu, Hawaii Pacific University offers undergraduate and graduate courses and degrees related to aquaculture, including a Masters Degree in Marine Science through their affiliation with the Oceanic Institute. The University of Guam offers an undergraduate degree in Agriculture, among other aquaculture-related coursework. In the Commonwealth of the Northern Mariana Islands, the Northern Marianas College offers courses and degrees related to the field of aquaculture. In addition, the CREES program (located on campus) is a great place to get involved with local aquaculture. The College of Micronesia (campuses throughout the Federated States of Micronesia), Palau Community College, and American Samoa Community College also offer coursework relevant to aquaculture.

\*<http://www.hawaii.gov/hdoa/adp>

## DID YOU KNOW?

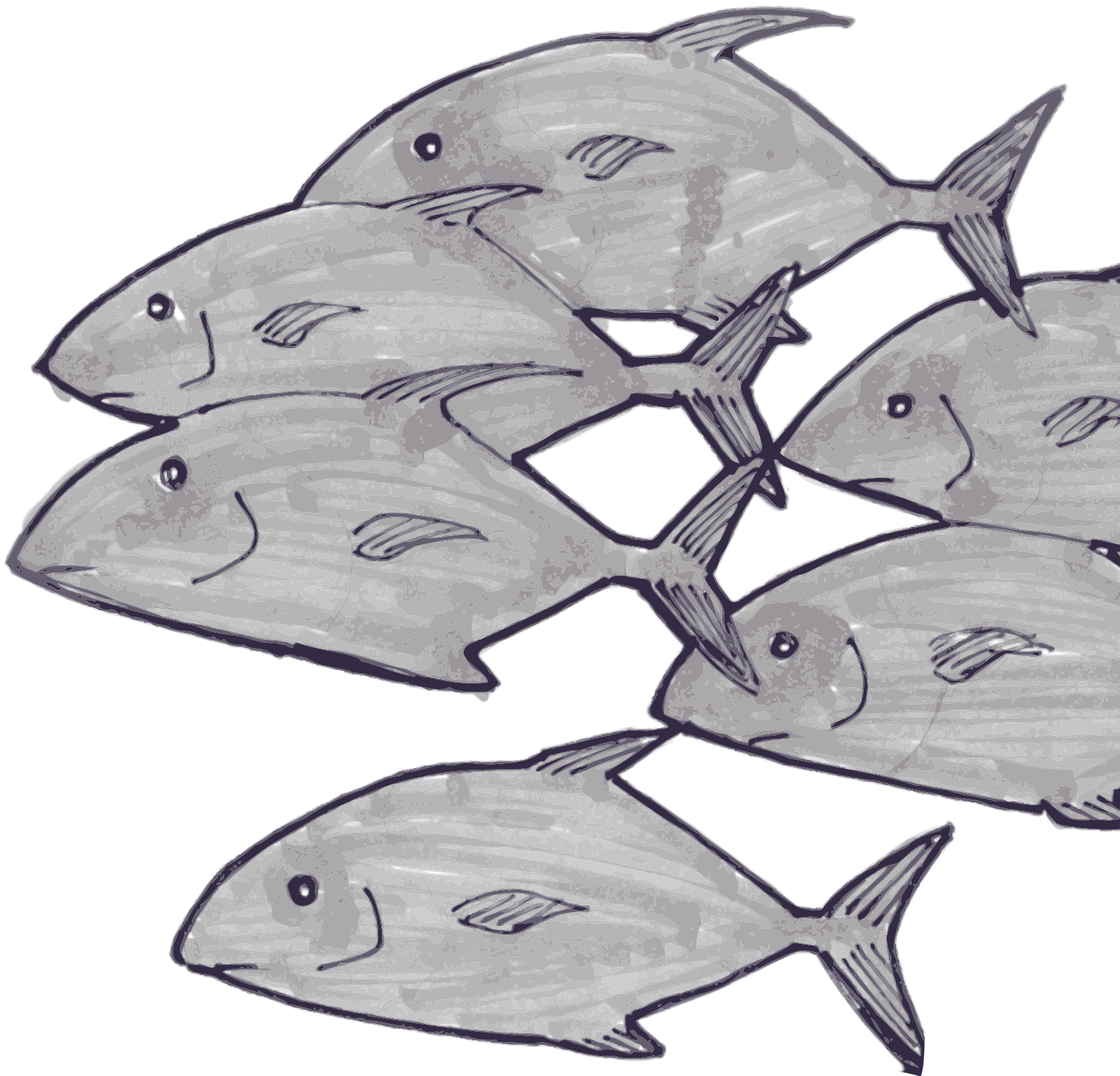
- Lead researchers working on projects are called Principle Investigators.
- Principle Investigators typically apply for grant money to fund their activities (and often times, their salaries). There are several government and non-government entities that set aside monies to support aquaculture research, training, and education each year. and The U.S. Department of Agriculture (USDA) and NOAA are two of the larger government organizations that provide funding to applicants nationwide through competitive and non-competitive grants. CTSA is a regional organization that is allocated funds from the USDA's National Institute of Food and Agriculture (NIFA) to distribute as needed for regional aquaculture research and extension support.

Students interested in learning more about higher education in an aquaculture-related subject should visit the following websites:

[www.hawaii.edu/mop](http://www.hawaii.edu/mop)  
[www.hawaii.edu](http://www.hawaii.edu)  
[www.hpu.edu](http://www.hpu.edu)  
[www.uog.edu](http://www.uog.edu)  
[www.nmcnet.edu](http://www.nmcnet.edu)  
[www.comfsm.fm](http://www.comfsm.fm)  
[www.palau.edu](http://www.palau.edu)  
[www.amsamoa.edu](http://www.amsamoa.edu)



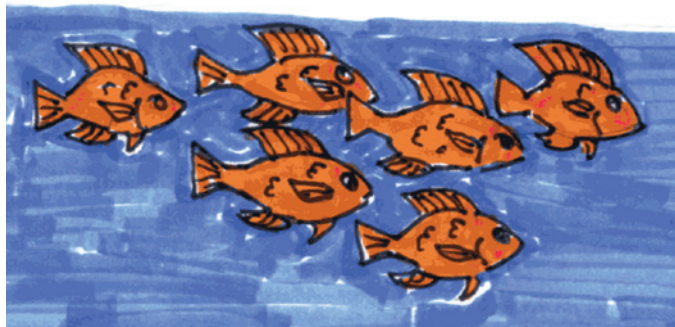
### Section 3: Aquaculture in Practice



## Central Concept I: Starting a Farm

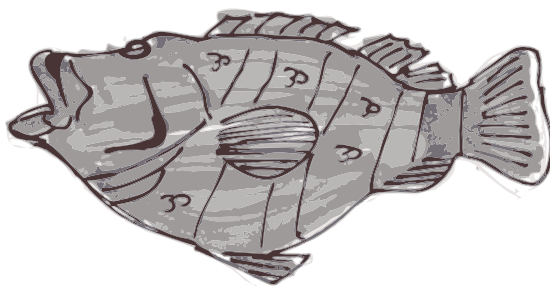
Before an aquaculture farm can start producing and making money, there are a variety of factors that must be taken into consideration. Among them are selecting the right species, selecting the right aquaculture system, and selecting an appropriate site with an adequate water source.

A good place to start is to determine whether you want to practice "monoculture" or "polyculture" farming. Monoculture farming is the farming of a single species in a system. Polyculture farming is the farming of more than one species in the same system.



Monoculture systems are often easier to understand because you only have to learn the requirements (nutrient needs, water temperature, etc.) of one species. Since each species has different requirements, you will need to understand and plan for the needs of multiple species

in a polyculture system. However, polyculture systems have some advantages over monoculture systems. For starters, they mimic what happens in nature. They are multi-dimensional environments where different species grow together in symbiosis. Some can help to keep the pond clean, like fish that feed solely on the solid waste of other fish or plants that thrive on nutrients from waste water (learn more about this process in CC4 of this section). There are also some fish that eat the plants, which keeps both the fish and plants growing strong. The species inhabit different areas of the environment, and are often separated through the use of structures including cages, pens, drop lines (oysters), and more.



### Species Selection

When selecting a species to grow in an aquaculture system, there are a variety of factors to consider to ensure you are choosing a species that will do well in a controlled environment and is also marketable. Some of the more important characteristics to consider include nutritional needs, reproductive habits, disease resistance, stocking density, ability to succeed in polyculture, and marketability.

- Nutritional needs of fish are one of the most crucial factors to consider when selecting a species because feed is often one of the primary costs of running an aquaculture business. You can choose a species that is lower on the food chain and has cheaper feed requirements, such as carp or milk fish. Alternatively, you can select a species that is higher on the food chain with more expensive protein requirements, such as shrimp or amberjack. Even though it is more expensive to culture these animals, they often times have a much higher value on the market. Feed requirements of fish are discussed further in CC3 of this section.

### AQUAFarm:

Record important information about your farm, such as your water source, the species you have chosen to culture, and the type of system you have chosen to culture them in.

### ACTIVITY IDEAS

**All:** To begin this discussion, ask students what they think someone needs to do to start an aquaculture farm. Write the answers on the board, and share the factors described here with students.

**I & II:** Have students draw (or build a model of) a polyculture pond, illustrating different species living together.

**III:** Have students research other advantages and disadvantages of the culture systems described in this Central Concept. Also have them look up the advantages and disadvantages of other types of culture systems, and prepare a persuasive argument/solution for school site and/or fictional scenarios.

### WORKSHEETS

3a. Aquaculture Systems in the Pacific

3b. Choosing the Right Species

### MAKE THE CONNECTION

What type of farming closely resembles the Hawaiian ahupuu'a? (Section 4, CC 2)

- It is equally as critical to understand the reproductive habits of the species you select. It is important to know the time of year that natural spawning occurs, especially if you plan to conduct hatchery work with the species. It is also important to ensure that there is a viable and adequate (preferably local) supply of fry/fingerlings (baby fish) or seedstock (oysters, bivalves, crabs) to keep the farm continuously producing.
- It is a good idea to choose a species that is durable and disease-resistant. Different species will react differently to culture conditions, and some may be more adaptable to changes than others. For example, tilapia are a durable fish that can be grown in crowded conditions with low oxygen levels; many other fish would not be able to handle such conditions.
- Stocking density and the ability of a species to survive crowding are particularly important considerations for anyone wishing to conduct intensive aquaculture. The more fish that can be raised in a system, the more production yield the farm will have. On the other hand, a dense aquaculture tank requires more management of effluents, oxygen, and other water quality parameters. Learn more about water quality management in CC2 of this section.
- Selecting species that can adapt to polyculture systems can be profitable for a farmer. Due to the efficient use of water, space and nutrients in the system, polyculture farmers can often produce more fish and use less feed than with other methods. When selecting species for polyculture, it is important to consider the needs of each species to plan pond feeding and maintenance.
- The marketability of a species depends on multiple factors. Before starting a venture, it is wise to determine 1) if there are consumers who want to buy your product; 2) if your product can be sold at a price that consumers can afford while still keeping your business in tact; 3) if there are any product-flavor concerns that must be addressed either before the product leaves the farm or through processing; and 4) if/how your product can be transferred and adequately stored (so as to maintain freshness).



## DIVERSIFYING AQUACULTURE OPPORTUNITIES

CTSA is a sponsor of an ongoing research project to assess the potential for bivalve culture in the state of Hawaii. Most bivalves are filter feeders that help to maintain a balanced ecosystem, and culturing them can result in both economic and environmental benefits. The current absence of bivalve culture represents a substantial lost opportunity for the State.

In collaboration with industry cooperators on both Oahu and Moloka'i, including Paepae 'O He'eia (He'eia fishpond), The Hawaiian Learning Center (Keawanui fishpond), Keawanui Shrimp Farm, Kualoa Ranch (Moli'i fishpond), growth trials for clams and oysters were conducted in Hawaiian fishponds. The trials were conducted to determine which species show the best promise for aquaculture. Researchers found that as many as two dozen Hawaiian bivalve species show good potential for aquaculture. Among them are the Hawaiian oyster, *Dendroostrea sandwichensis*, which was found to have an excellent taste and could be a good local replacement for popular oysters from the mainland United States.

There are still some important legal steps to making bivalve culture in Hawaii a reality. However, if successful, the emergence of bivalve culture will offer new business opportunities to produce local food and at the same time restore populations of ecologically important animals that have been over-harvested from Hawaii's coastline.

## System Selection

Once you select the species you want to culture, you need to choose which type of system you want to grow them in. This determination will depend on the requirements of the species and any limitations you must adhere to (such as financing, space, etc.). The following are examples of some typical culture systems found in the Pacific region:

**Earthen ponds** are one of the most commonly found fresh or brackish water culture systems in the Pacific. They are in-ground ponds that are relatively easy and inexpensive to build, and they require lower maintenance than many other aquaculture systems. Culturists frequently use earthen ponds for polyculture farming. A potential downside to this system can be an increased chance for predation by birds and other animals.

**Recirculating Aquaculture Systems (RAS)** are fresh or salt water systems usually in the form of above-ground tanks. They are closed systems in which the entire production process can be controlled by the culturist. Depending on the scale of the



operation, they require a small amount of space and can be kept either indoors or outdoors. A potential downside to this system can be increased efforts in water quality management.

**Open Ocean aquaculture** cages are large cages that are anchored, tethered, or floating in the open ocean. They are stocked with fish (usually fingerlings), which are fed regularly and monitored for changes in health until they grow to harvest size. Water quality is typically less of a concern with these systems, as they have a constant flow of water passing through them from ocean currents. A potential downside to this system can be the high cost of capital investment.

There are many additional types of onshore and offshore aquaculture systems. Some culturists in Hawaii use the ancient Hawaiian fishponds for modern day aquaculture (learn more in Section 4, CC 2). Aquaponics systems are another type of aquaculture system that are gaining popularity in the Pacific and around the globe (learn more in CC 4 of this section).

### Site Selection

There are a variety of factors affecting the selection of an appropriate aquaculture site. Among them are environmental, socio-economic, and legal factors. Environmental factors to consider include quality of soil (if using earthen ponds), climate, existing vegetation/habitat, native species, and topography. You want to ensure that you are choosing a site that will meet your needs, but not at the expense of environmental destruction. Water supply is another environmental factor, and one of the most important factors in selecting an aquaculture site. After all, water is half of aquaculture. A good site will have access to high quality water in ample quantity. Some typical sources of fresh water for aquaculture include municipal water (from the tap), rain water, lake water, stream water, and reservoir water. Sources of salt water for aquaculture include the ocean, some lakes, and artificial sea water. There are a few different ways to determine what water is available at a particular site, including conducting a visual survey, or checking with government agencies and public records for information. You can also hire private consultants and well-drillers to assist you in the process and help you determine the associated costs and other important factors affecting water availability at the site.

Socio-economic factors to consider include availability and quality of local labor, local customs and/or culture, capability to build facilities (cost and availability of materials and manpower), and access to the market where you will sell your products, among others. There are also legal factors to consider. For more information on aquaculture laws and regulations, see Section 2, CC 2.

### CONSIDERING SOIL IN SITE SELECTION

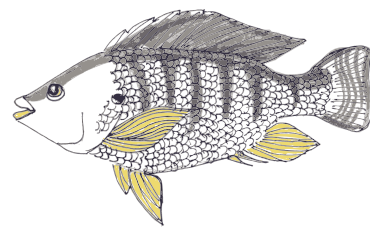
Soil characteristics are an important consideration when choosing a potential aquaculture site. Characteristics of soils suitable for earthen pond construction include: adequate clay content, low organic content, proper soil texture, and proper pH.

Clay soils have chemical characteristics that help reduce or eliminate water loss due to seepage. This is called the shrink-swell capacity of the soil. Soils with adequate clay content can considerably slow down or eliminate seepage, reducing the need for adding more water to ponds. Reducing water exchange cuts down on costs. The clay content must be adequate on the pond banks and of sufficient depth on the pond bottom. Core samples should be taken to ensure that the clay layer is deep enough to build ponds. If there is not enough clay, additional fill can be added from topsoils taken from other places. The University of Hawaii Agricultural Diagnostic Service Center (808-956-6706) can assist with soil sampling.

— excerpt from "Best Management Practices for Hawaiian Aquaculture," CTSA Publication #148.

### AQUAModel:

To address concerns about the water column and benthic impact of offshore fish farming, NOAA has developed a site evaluation tool to help in the selection of an environmentally-appropriate aquaculture site. *AquaModel provides a scientifically based tool for site selection which allows evaluators to input site-specific data and simulate various options in order to minimize the impact on the environment and to maximize the health of the fish. The system is flexible in accepting a broad range of input data from very general seasonal parameters to any specificity level the user desires such as hourly observations of current velocity, direction, dissolved oxygen, nutrient content, etcetera.* ([noaa.aquamodel.net](http://noaa.aquamodel.net))

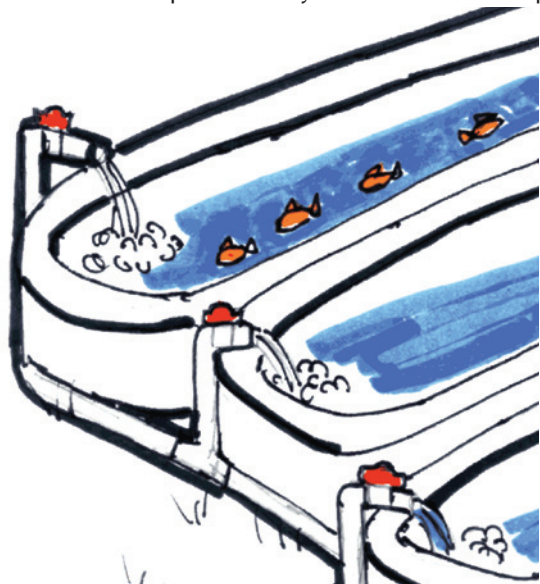


## Central Concept 2: Water Management

Water is one of the two main components in aquaculture. Maintaining good water quality is therefore one of the most important tasks when working with an aquaculture system.

### Moving Water

The movement of water is an important factor in water quality and subsequently aquatic species health. In some aquaculture systems, water is moved around by gravity. Gravity naturally pulls water from a higher source to a lower source, and can be used to move water into or out of an aquaculture system. In other systems, pumps are used to push water from one part of the system to others. Pumps vary in size depending on the



amount of water they can move through them (usually measured in gallons per minute), and can either be electric, gas-powered, or air lift. Pumps are selected based on the volume of a tank and the rate at which water needs to flow for optimum quality conditions (flow rate). Using pumps to move water can be beneficial because flow-rate can be adjusted as needed to enhance the quality of the water or system. Using gravity to move water can be beneficial because it is cost-effective and reliable (no break-downs to worry about). In an earthen pond system, water may not always be moving.

### Characteristics of Water

A successful culturist will regularly test the water, and manage its quality from start of production to finish using a variety of proven techniques. Aquatic species require specific water characteristics to maintain good health and grow at an optimal rate, and those characteristics are not always the same for every species. That's why it is critical to research the needs of any and all species before culture begins.

Some of the common water properties that are measured to determine quality in aquaculture of aquatic animals include temperature, dissolved oxygen (DO), nitrogen, pH, and water hardness. Other water quality tests are also done to measure chloride, carbon dioxide, basicity, alkalinity, and salinity.

- Temperature can greatly affect the chemical and biological processes taking place in an aquaculture system. In fact, "as chemical and biological reaction rates double for every 10 degrees C increase in temperature, the metabolic activity of aquatic organisms also increases and animals use twice as much oxygen. Oxygen used in the breakdown of organic material also increases dramatically. Even more critical is that warmer water generally is not able to hold as much dissolved oxygen as cooler water."<sup>\*</sup>

<sup>\*</sup>"Best Management Practices for Hawaiian Aquaculture," by Robert Howerton. CTSA Publication #148. This publication is the source of the majority of information included in this Central Concept.

### AQUAFarm:

Regularly track the quality of water in your system using the Water Quality log included in the worksheets section. Determine the volume of your system using the formulas on page 17.

### DIVE DEEPER

- Water quality management has a lot to do with chemistry. Think about ways you can connect this CC to difficult chemistry concepts. Start by researching the chemical reactions related to pH more in-depth.
- Seaweed and other aquatic plants also have specific water characteristic requirements to succeed in aquaculture. Do some research to learn more, and share what you find with your students. Ask them to compare and contrast the needs of plant species and animal species.

### WORKSHEETS & HANDOUTS

#### 3c. Comparisons of Water Quality



- Dissolved Oxygen and aeration are very important in aquaculture because animals require oxygen to live. It is crucial to maintain a good DO level in any system. A level lower than 2 ppm (parts per million) can be fatal to most species. The amount of DO can rise when water temperature is cooler, and can lower when there is not enough aeration, when stocking density is too high, or when there is too much salt in the water. When the oxygen level is low, aquatic animals can become lethargic and may stop eating. If the oxygen level is dangerously low, it can cause acute stress and even mortality. On the other hand, if the oxygen level is too high, it can affect the respiratory system and metabolism of the animals. Oxygen can enter an aquaculture system from the atmosphere, from water circulation, and also from photosynthesis of plankton living in the system. Mechanical aerators, such as pumps and paddlewheels, are used to circulate water and increase oxygen in many aquaculture systems, including tanks and raceways. In Earthen ponds, the primary source of oxygen is usually photosynthesis.
- The level of nitrogen in an aquaculture system is measured as ammonia, nitrites ( $\text{NO}^2$ ), or nitrates ( $\text{NO}^3$ ). Ammonia can enter a system a couple of different ways, but most of it comes from the animals. In order for fish to absorb necessary amino acids from protein they consume, they must first release the ammonia from their system. They do so by excreting most of it through their gills, and the rest through their waste. Ammonia is the most toxic form of nitrogen, but if too much nitrogen in any form is in the tank, animals can experience difficulty respirating and die. Even in small amounts, nitrogen can suppress immune systems and leave a fish more susceptible to disease. Therefore, it needs to be broken down to nitrate, a less harmful form of nitrogen, through a process called nitrification. During nitrification, nitrosomonas bacteria convert ammonia to nitrite, and then nitrobacter convert nitrite to nitrate. In earthen ponds, nitrification occurs in the surface layers of the mud. In most recirculating aquaculture systems, it occurs in a biological filter. The nitrification process also generates protons (hydrogen ions), which inherently lowers the pH level of the water. When starting a new system, it is common to have ammonia and nitrite levels of 5ppm, but once established the levels should be at zero ppm. In a freshwater system, a desirable nitrate level is 40 ppm or less. An excess of food and buildup of other organic materials, such as plants, can also increase nitrogen levels in a system. Learn more about the nitrogen cycle in CC 4 of this section.
- pH is a determination of the concentration of Hydrogen in the water, measured on a scale of 0 to 14. It is important to monitor because it is a controlling factor in many chemical reactions occurring within a system. A pH of 7 ppm is neutral; anything below 7 ppm is acidic (more ammonia) and anything above 7 ppm is basic (more alkalinity). However, it is typical for pH to fluctuate throughout the day, and a normal range for freshwater aquaculture is considered between 6-9 ppm. Both higher and lower pH levels can result in slower growth. If pH is too high, the surface of fish gills become inhibited from releasing ammonia, resulting in a toxic situation. A pH level below 4ppm or above 11ppm can result in mortality.
- A measurement of water hardness involves measuring the amount of calcium, magnesium, and other dissolved minerals in the water in the form of calcium carbonate ( $\text{CaCO}_3$ ). This is also considered a measurement of the total alkalinity of the water. Calcium is important for fish, and the right amount can affect how long it takes a fish to grow (too little calcium will result in slower growth). It is therefore important to measure and monitor. Fish can absorb calcium through water or food. Acceptable levels of  $\text{CaCO}_3$  for fish will vary depending on the species, but in general are in the 40-100 ppm range.

## ACTIVITY IDEAS

**All:** To begin this discussion, talk with students about the difference between dirty and clean water. Ask them if they would want to take a shower in dirty water, and explain that fish don't want to live in dirty water, just like they don't want to bathe in dirty water.

**I, II & III:** Have students make a solution (mixture). Younger students can make pudding or jello together, and older students can mix more complex solutions. Explain why and how aquaculturists sometimes mix solutions to improve water quality.

**II & III:** Have students use the formulas on page 17 to calculate the volume of different tank sizes. For example:

1) What is the volume of a square tank that is twenty feet long, twenty feet wide, and eight feet deep?

2) What is the volume of a round tank that has a radius of fourteen feet and is four feet deep?

3) What is the volume of a rectangle pond that is 30 feet long, eleven feet wide, and ten feet deep?

Create more calculations for your students to solve in a math quiz.

**II & III:** Do an experiment to test how temperature difference affects fish growth. You can purchase a small water heater to adjust water temperature as needed for your experiment trials from most aquarium and pet stores. Note: please check your state regulations regarding vertebrate animal research before conducting experiments with fish.



## Maintaining Water Quality

There are many practices that can be put into place to maintain water quality. A good place to start is ensuring that animals are not being overfed. Monitoring the various water characteristics, especially DO, on a regular basis is also important. Culturists who monitor water on their own typically use portable test kits, meters, and probes. Test kits are most often the least expensive and most accessible method of monitoring; they can be purchased individually (i.e. a kit to test only DO, or only pH) at aquarium and pet stores. There are also more expensive, comprehensive test kits that include all of the necessary materials to test multiple water characteristics. Meters and probes are other options for on-site testing. Although they can be expensive, they last a long time and provide accurate measurements immediately. Culturists who wish to have their water quality monitored by a professional can hire a consultant to conduct testing on-site, or send samples of water to a laboratory for analysis. A downside to sending water to a lab to be tested is that ammonia and oxygen can escape during transport, and the resulting analysis may be inaccurate.

Once the characteristics of water are determined, the next step is adjusting levels as needed to meet the culture requirements of the species. If DO is too low, a direct injection of oxygen or an increase in aeration in the system, either by speeding up the pump or using other aerators to splash more water along the surface, should solve the problem. However,



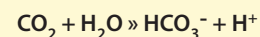
low DO (especially when coupled with high ammonia) can indicate that there are too many animals in the system, and some should be removed to decrease density. Aside from removing animals, another way to address a high level of ammonia in a system is to do a water exchange. Typically, changing out  $\frac{1}{3}$  of the water in a tank will help to improve the quality. High ammonia can indicate a build-up of organic nutrients in the system, and if the problem continues it may be a good idea to look into different filtration options.

Sometimes, chemicals are added to improve water quality, but this should only be done using great precaution. Before any chemicals can be added to a system, it is necessary to know the volume of the system to determine the appropriate amount of chemicals to add. Determining volume will differ depending on the shape and type of system. The formula to calculate the volume of a round tank is **Volume =  $3.14 \times \text{radius squared} \times \text{depth}$**  (radius squared is radius x radius). The formula to calculate the volume of a square or rectangular tank, pond, or raceway is **Volume = length x width x depth**. Once the volume and ratio are known, the appropriate chemical solution can be mixed. Some examples of common chemicals added to aquaculture include chloride (to decrease the level of nitrites) and agriculture limestone (to increase pH).

The Southeastern Regional Aquaculture Center (CTSA's sister-center) created a useful publication with instructions on calculating the volume of ponds and tanks. In addition to tanks in the shape of squares, rectangles, and circles, the publication features details on calculating volume of oddly shaped systems. Download SRAC publication 103 titled "Calculating Area and Volume of Ponds and Tanks" on the SRAC website <http://srac.msstate.edu/>

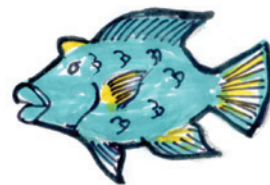
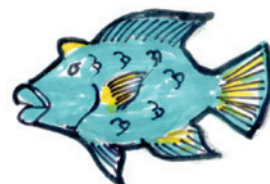
### DID YOU KNOW?

Changes in pH during the day are a direct result of photosynthesis and the use of CO<sub>2</sub> during that process. Carbon dioxide is considered acidic, as displayed in this equation:

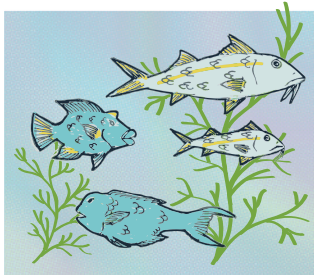


Conversely, at night when all organisms are respiring, carbon dioxide levels increase and pH falls. Considerable fluctuations in pH can occur when phytoplankton levels are high. Ponds with moderate or high total alkalinity have smaller daily fluctuations of pH than ponds with lower total alkalinity. This is a result of the buffering capacity that is provided by the total alkalinity.

— excerpt from "Best Management Practices for Hawaiian Aquaculture," CTSA Publication #148.



## Managing Effluent Water



Effective management of effluent water (waste water from an aquaculture system) is essential when conducting aquaculture. The type of culture system can greatly affect the amount of effluent water that needs to be managed. For example, Recirculating Aquaculture Systems circulate and clean water, and are intended to reduce the amount of effluents, while aquaponics systems and other methods of integrated farming use all of the effluent water to produce plants through a process called bioremediation. In bioremediation, living organisms (such as bacteria) help to eliminate or reduce toxic pollutants in effluent water.

The following are excerpts from "Best Management Practices for Hawaiian Aquaculture" (CTSA Publication #148) on the management of effluents. The publication goes on to list specific tips on best practices for removing effluents in different types of systems. Read the full document for more useful information:

*The water quality variables of most concern in effluents include dissolved nutrient load and suspended solids. Highly dissolved nutrient loads can cause adverse environmental impacts in areas which receive effluent discharge. Suspended solids may be either particulate material or soil particles from erosion. Ultimately, the quantity and quality of effluent will be dictated by management strategies and the most significant decision is culture intensity. Stocking rate and hence feeding intensity are the most important factors influencing the levels of dissolved nutrients and toxic metabolites found in effluent.*

### Sedimentation Ponds

*Sedimentation ponds can be used to treat aquaculture effluents. The most important criteria for the effective use of sedimentation is the residence time of the wastewater. There are also other considerations for the design of sedimentation ponds. The pond depth, flow rate of incoming waters, and the pond surface area all have an effect on the settling time of suspended particles. Smaller particles stay in suspension longer than larger heavier particle. Consequently, a longer residence time is needed to allow small particles to settle.*

### Constructed Wetlands

*Constructed wetlands have been successfully used to treat aquaculture effluents. Wetland plants are very efficient at removing dissolved nutrients from effluent. A sufficient retention time is needed for wetlands to be effective. If wetlands are to be used to treat effluent waters, accurate calculations must be made concerning the size of the wetlands and the amount of discharge water released during harvest. Constructed wetlands should be large enough to provide a two- to four-day retention time. This allows sufficient time for the removal of dissolved nutrients and the settling of suspended solids. Ideally, wetlands should be downslope of production ponds, allowing gravity to drain ponds.*

### Integrated Agriculture-Aquaculture

*The concept of integrating aquaculture with agriculture production is not new. Ancient Chinese culture practices combined recycled resources from livestock and crop production with that of fish culture. Discharge waters from aquaculture production contain dissolved nutrients and organic materials. Rather than viewing this as a problem, aquaculture effluent can be used for irrigation of an alternative crop of value.*

*In shrimp culture, edible seaweed such as *Gracilaria* sp. can be used as a nutrient scrubber to remove dissolved nutrients from effluent. When shrimp ponds are harvested, or water exchange is needed, pond water can be discharged into a settling pond or ditch holding seaweed. Fish species such as tilapia, milkfish, and mullet may also be stocked in discharge ponds or ditches, providing an additional cash crop.*

*In freshwater culture, effluent can be used to irrigate terrestrial crops. In smaller culture systems water can be discharged to irrigate fruit trees including bananas, papayas, and avocados. Although effluent waters commonly do not contain enough nutrients to significantly reduce fertilizer requirements for agriculture crops, they can supplement fertilization. By using effluents for irrigation there will be a reduction of effluents discharged into receiving waters.*

### Biological Filtration and Water Recirculation

*Recirculating aquaculture systems are intended to allow for greater control of the culture environment, reduce water exchange, and conserve resources. Recirculating production systems, or closed systems, are well suited for the ornamental fish industry in Hawaii and can be used in hatcheries, aquaria systems, and backyard aquaculture. They can be set up in small parcels of land where pond culture would not be feasible. In many areas where water resources are limited or too expensive for larger production units, recirculating systems can be economically viable. Through bio-filtration and water reuse, recirculating systems significantly reduce water requirements.*

## Central Concept 3: Animal Health

Addressing and monitoring animal health concerns are essential to conducting responsible aquaculture. Animal health and growth can be affected by a variety of factors, including poor water quality, diseases, poor nutrition, and mismanagement.



Health management programs differ depending on what type of culture system is being used. For example, there may be more fluctuations in water quality in a recirculating aquaculture system, requiring closer monitoring than an earthen pond. Since many health problems stem from issues with water quality, maintaining an optimal water quality is essential. Aside from maintaining good water quality, it is also important to ensure that aquatic animals receive all of the nutrients they need from a good quality feed. In general, it is also a good idea to have a full understanding of physical composition of the species being grown.

### Fish Disease

Disease can be caused by a number of factors, alone or in combination, which act to weaken the immune system of the animal. Factors may include pathogenic micro-organisms, parasites, environmental influences, aquaculture conditions, and poor nourishment. Fish and shellfish farmers—as well as state and federal regulatory agencies—take many precautions to prevent infection and transmission of pathogens and parasites (which are the agents that cause disease). At commercial hatcheries, juveniles are reared under carefully controlled conditions to prevent the introduction of disease-causing agents from outside sources. Before fish or shellfish are transferred to farm sites or released into the wild, veterinarians and other aquatic health professionals evaluate them to ensure that they are free of pathogens or parasites. Most states also have regulations requiring fish and shellfish to be screened before they are transferred to another site or released into the wild. Farmed fish are vaccinated against most of the diseases that have caused problems in the past. Antibiotics are rarely used and, if required, their use is strictly regulated and always under the supervision of a veterinarian.

Because of the success of vaccines to prevent disease in farmed fish, the use of antibiotics and other drugs has been reduced dramatically. While good management practices and vaccines alone are usually enough to prevent or control disease, a farmer may, in consultation with a licensed veterinarian, use a limited number of aquatic animal drugs including antibiotics, in the case where they have been approved by the U.S. Food and Drug Administration (FDA) to treat specific conditions. In fact, only two antibiotics have been approved for use in aquaculture. Drug use in fish, as in land-based farm animals, is subject to strict application requirements. Before a drug is approved for use, FDA requires that it be demonstrated effective, safe for the environment, and safe for humans who consume the treated product. (NOAA Fisheries Service)

### ACTIVITY IDEAS

**All:** Start the discussion with students by asking them what they do to maintain their health (good food, exercise, etc.). Lead the discussion to what aquatic species require to maintain good health.

**I, II, & III:** Have students make individual gyutaku fish paintings, and discuss the structure of a fish. Gyutaku instructions are available for download in the curriculum section of the AQUA website.

**I:** Look up some pictures of different types of fish and share with your class. Compare and contrast the structure of different mouths. Have students make a fish mouth using classroom and/or household items (empty paper rolls, coffee filters, pipe cleaner, etc.).

**I:** To illustrate how some animals find food using scent, put different items that have strong smells in brown paper bags (i.e. garlic, onion, cinnamon, etc.). Each item should have its own bag (and its own distinct smell). Do not let students see what is in the bag. Have students sit in a circle, and pass the paper bag around and take turns guessing what is in the bag.

**II & III:** Do some more research on fish anatomy and the function of each body part included on page 21. Review with students and have them fill in the blanks in Worksheet 3d.

**II & III:** Make a detailed 3-D model of a fish. Use the diagram on page 21 as a reference.

**II & III:** Have students do some more research on typical fish diseases affecting the fish they profiled in Worksheet 3b (or any fish).

**II & III:** Dissect a fish. Detailed instructions are available online.



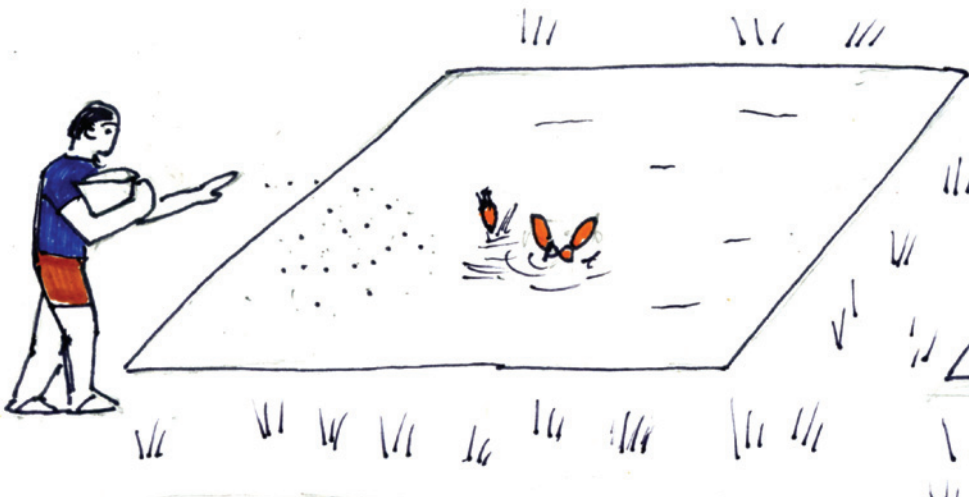
## Feeds

Farmed fish and shrimp eat feed that is specially formulated to contain all the essential nutrients they need to keep them healthy and growing and maintain the human health benefits of seafood consumption. The ingredients are formed into pellets, similar in many ways to dry dog food. There are about 40 essential nutrients needed by all animals. Categories of essential nutrient include vitamins, dietary minerals, essential fatty acids and essential amino acids. These are provided by a number of feed ingredients including fish, plant, and processing waste meals and oils.

Fish nutritional needs vary by species. Herbivorous fish eat a feed mixture that may contain plant proteins (e.g., soy, corn), vegetable oils, minerals, and vitamins. In the wild, carnivorous fish such as amberjack eat other fish. Therefore, feeds for farmed carnivorous fish (as well as many herbivorous fish) include fish oils and proteins as well as plant proteins, minerals, and vitamins that achieve the nutrition requirements of the fish and offer health benefits to humans. Traditionally, diets for carnivorous fish contained 30-50% fish meal and oil; however, continued research is leading to greatly reduced reliance on these ingredients. (NOAA Fisheries Service)

The type of food an aquatic animal eats depends on the nutritional needs of the animal, as well as the feeding behavior and structure of the mouth. An animals' feeding behaviors can change depending on environmental factors, including the time of year (some fish do not eat during their spawning season) and the time of day (some fish feed more at dusk and dawn). There are also variations in mechanisms used to find food in water. For example, some animals use smell, while others use sight or taste to find food. The structure of an animals mouth plays an important role in food selection as well. Some fish are bottom feeders, and have mouths that are facing downward, while others are surface feeders and have mouths facing upward. Each animal has adapted to find food that they can consume based on the structure of their mouth.

Pelleted feeds are a good option for many aquatic species, but there are different types of pelleted feeds. Some have a tendency to sink to the bottom of a tank quicker than flake feeds (typically used in aquarium tanks) and are therefore best for bottom-feeding fish such as catfish. Other pelleted feeds float at the surface and are good for fish that feed at the surface, such as tilapia, and goldfish. Live feeds, such as algae and copepods, are other options that many culturists use.



## DIVE DEEPER

- The USDA's National Animal Health Monitoring System (NAHMS) program conducts studies on health and health management of aquatic species and other livestock. Learn more at [www.aphis.usda.gov/animal\\_health/nahms/aquaculture/](http://www.aphis.usda.gov/animal_health/nahms/aquaculture/)
- The NOAA Fisheries FAQ page has a lot of information on aquaculture feeds. Visit the following link: [http://www.nmfs.noaa.gov/aquaculture/faqs/faq\\_feeds.html](http://www.nmfs.noaa.gov/aquaculture/faqs/faq_feeds.html)
- The purpose of the NOAA-USA Alternative Feeds Initiative is to identify alternative dietary ingredients that will reduce the amount of fishmeal and fish oil contained in aquaculture feeds while maintaining the human health benefits of farmed seafood: [http://www.nmfs.noaa.gov/aquaculture/supplemental\\_pages/feeds\\_homepage.html](http://www.nmfs.noaa.gov/aquaculture/supplemental_pages/feeds_homepage.html)
- The FAO also has detailed information on fish health management in aquaculture: <http://www.fao.org/fishery/topic/13545/en>
- Ask an aquatic animal health expert to visit your classroom and conduct a presentation for your students. Topics can include determining the sex of fish, fish pathology, and much more.

## WORKSHEETS

3d. Anatomy of a Fish

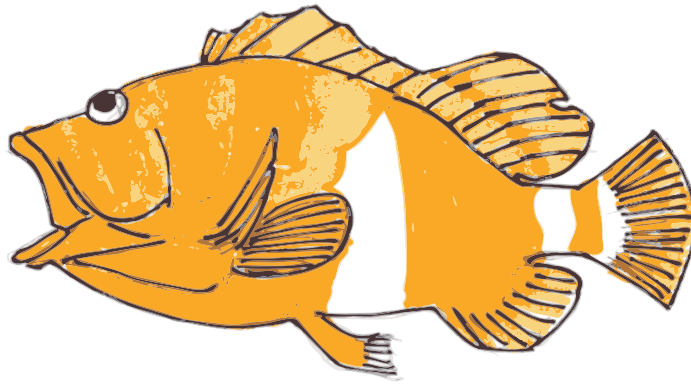
3e. Feeding Behavior and Growth Experiments

## Additional Health Management Considerations

In addition to understanding the nutrient and feeding requirements of aquatic species in aquaculture, it is also a good idea to learn about their physiology (body functions and activities), anatomy, and genetics. Understanding these factors is an important step in creating an effective, individualized health management plan. Learning about the structure and function of necessary bodily systems of any animal being grown in a controlled environment can result in better management of the needs of that species.

Vital systems of aquatic species include skeletal, muscular, excretory, respiratory, circulatory, sensory, reproductive, and digestive systems. Learning the anatomy of the species being cultured can also aid in distinguishing between sexes and recognizing diseases and other abnormalities.

It is also important to understand how the species you are controlling change as they grow. For example, crustaceans such as shrimp, lobsters, and crabs lose their shells as they grow larger through a process called molting. Anatomy and physiology are different for each species, as are genetics. It is a good idea to understand the genetics of a species, particularly if the culturist plans to breed it.



### BIOSECURITY

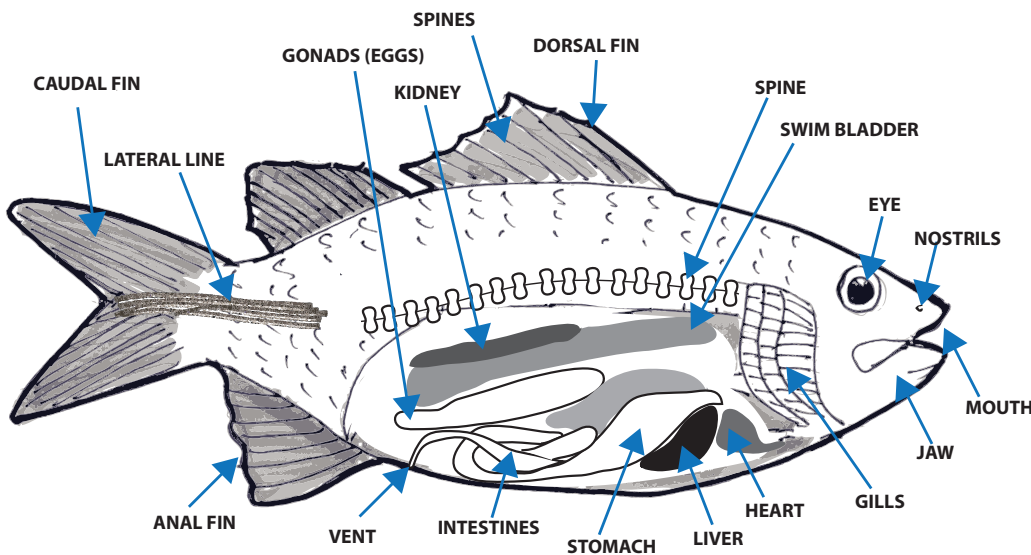
Most aquaculture operations practice some form of biosecurity. Biosecurity is a set of preventative measures put in place to reduce the risk of transmitting diseases, invasive species, and other organisms that can be harmful to otherwise healthy aquatic animals.

### AQUAFarm:

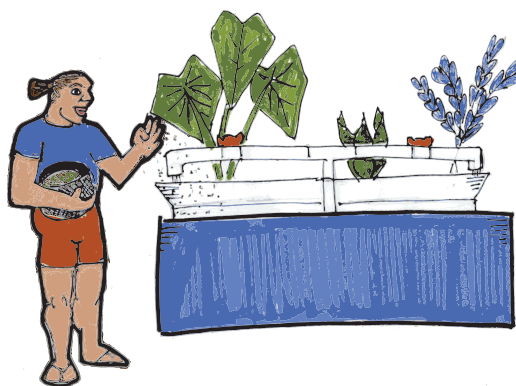
Create a biosecurity plan for your farm.

### DID YOU KNOW?

- CTSA has sponsored over ten years of aquatic animal disease management and research in the Pacific region, including a recent project to analyze the biosecurity of shrimp farms in Guam and the CNMI.
- There are Specific Pathogen Free (SPF) animals. These animals are bred to be resistant to specific pathogens that could otherwise be detrimental to healthy populations of their species. Learn more about SPF animals in the CTSA Publications #112 and #116: [www.ctsa.org/index.php/publications](http://www.ctsa.org/index.php/publications)
- Researchers in the Pacific region are working to develop more sustainable fish feeds that meet nutrient requirements while using less fish meal. Some of the feeds they are now testing contain less than 20% fish meal.



## Central Concept 4: Introduction to Aquaponics



Aquaponics is the symbiotic cultivation of plants and aquatic animals in a recirculating environment. It is a combination of aquaculture and hydroponics. In an aquaponics system, nitrogen-rich effluent water is transferred from a fresh or low-salinity water fish tank to at least one grow bed, or garden, of plants. The plants soak up the nitrogen (which is good for them but harmful for fish as you learned in CC2 of this section), and clean water is returned

to the fish tank. The water in an aquaponics system is commonly transferred by pumps or gravity through PVC or snorkel pipes connecting the tank and grow beds. However, there are systems that rely on the manual transfer of water (which can be beneficial if you are trying to limit energy use or live in an area with frequent energy blackouts).

Aquaponics is rapidly gaining popularity in the Pacific Islands and across the world among commercial farmers and non-farmers who have "backyard" systems at home, school, or work. There are many attractive factors of this type of farming. For starters, it produces at least two products (fish and vegetables) that can either be sold or used to feed a family and/or community. It is also very environmentally friendly because it uses only a fraction of the amount of water that traditional agriculture uses (some estimate as low as 4%). Since all effluent water is naturally cycled in the closed system, the only time water needs to be added is when the system is being established, when water evaporates and needs to be replaced, or when a water exchange is required. Furthermore, many people are experimenting with alternative feeds for the most commonly grown species of fish in aquaponics, tilapia. Some potential alternative feeds in aquaponics include duck weed, azalea, and black soldier fly larvae. When coupled with vermiculture as a source of micronutrients and solar or other alternative energy source for the required pump, a system can be entirely self-sustaining. Also, many natural pesticides are available to grow vegetables organically.

### Aquaponics and the Nitrogen Cycle

The Nitrogen Cycle is an important part of all aquaculture activities, but is especially critical in aquaponics. As discussed earlier in the section, the nitrogen cycle begins in aquaculture when fish are stocked in the pond or tank and begin eating. Just like humans, fish need to release the waste left over after their bodies process the food. This waste is released in the form of ammonia through both fish gills and fish waste (urine and solid waste). Ammonia is harmful to fish, and therefore needs to be removed from the system. In earthen ponds, the process that breaks down ammonia occurs in the surface layers of the mud. In aquaculture tank systems, including those used in aquaponics, this build up of ammonia is broken down through biological filtration systems.

In aquaponics, ammonia-rich water passes through a biological filter where it goes through nitrification. As you may remember, nitrification is the process where aerobic bacteria called nitrosomonas convert ammonia to less toxic nitrite, and then nitrobacter convert nitrite to nitrate, the least toxic form of nitrogen. Plants absorb nitrates, and clean water is returned to the fish tank. In order for this process to occur, the bacteria need a place to grow. This is called the biological filter.

### ACTIVITY IDEAS

**All:** There are a variety of ways you can begin a discussion about aquaponics with students. You can start by talking about types of food students like to eat, and mentioning the types of food you can grow using aquaponics. You can also begin by talking about sustainable farming, water conservation, or symbiosis.

**I, II, & III:** Ask students to explain how aquaponics is different from traditional aquaculture. They can compare and contrast the advantages and disadvantages of each.

**I:** Complete the activity in Worksheet 3g.

**I:** Use a celery stick to illustrate how plants soak up nutrients. Cut the bottom off of a celery stick. Put some water in a cup and add food coloring. The colored water represents nutrient rich water in an aquaponics system. Place the celery inside the cup with the cut-off portion touching the water. Wait twenty minutes, and then look at the bottom of the celery stick. What do you see? Capillaries inside the plant soak up the "nutrient water."

**II:** Have students research and build a filter using different materials. Ask them to explain why filtration is important in aquaponics.

**II & III:** A common concern with traditional aquaculture is effluent water management, as previously discussed. Conversely, one concern with traditional hydroponics is the need to constantly add soluble nutrients to the water so the plants can grow. Ask students to explain or illustrate in detail how aquaponics resolves both concerns.

**II & III:** Have students design (and perhaps even construct) a model of their own aquaponics system using the principles learned both here and from the "Building an Aquaponics System" handout.



A biological filter is typically constructed using a container or drum filled with material, such as lava rock, clay balls, non-calcified pebbles, PVC blocks, bio balls, or other commonly used filtration materials. This material is what the beneficial bacteria attach to and grow on. The design and placement of biological filters can differ depending on the design of the aquaponics system. For example, in a raft system, a biological filter can either be submerged or built outside of the fish tank. In an ebb-and flow system, the biological filter is in the grow bed itself. Growing medium, such as lava cinders or clay balls, serves as aggregate on which both plants and nitrogen-converting bacteria grow.

## System Construction

Aquaponics is easily adaptable to almost any location and the specific needs of the culturist. Systems vary in sizes, from a small system like the one pictured to much larger commercial-grade systems. The modular design allows for an increase or reduction in the size depending on the space available. Systems can be either horizontal (traditional) or vertical (stands alone or attaches to a wall to save space). All necessary supplies can be purchased in the Pacific Islands and depending on the size and type you want to install, you can either buy a pre-fabricated system from a one-stop-shop or you can make one yourself. Small systems can be installed in as little as a few hours. Some take longer, but most can be fully installed within 72 hours, start to fin-fish! There are many different aquaponic system designs. The AQUA program primarily works with systems being designed by researchers at the University of Hawaii's College of Tropical Agriculture and Human Resources (CTAHR). Learn more about different system designs in the "Building an Aquaponics System" section on the following pages.

Depending on the type of system you construct, it can also be more affordable than other aquaculture and hydroponic systems, costing less than \$250 to construct. You can use items ranging from traditional fish tanks made from concrete, PVC, or fiberglass to empty barrels or food-grade drums to contain fish. You can also use fabricated grow beds or build your own using wood, food-grade drums (cut in half length wise), or other materials. Most wood grow beds are lined with durable plastic to avoid wood rot and maintain water quality.

## What to Grow

Fish raised in aquaponics need to be durable and able to withstand fluctuations in water quality, particularly during the time period where a system is being established when there are greater spikes in ammonia and pH levels. Fish in aquaponics also often need to be adaptable to crowding. Most aquaponics in the Pacific Islands is done with tilapia, although carp, chinese catfish, koi, and freshwater prawns are also some of the species that can adapt to the system conditions. Scientists in the region are conducting trials to find other species that can also adapt. Considering the wealth of beneficial nutrients naturally available in the system, many plants are able to adapt to aquaponics conditions. Some plants that do very well in aquaponics include Manoa lettuce, taro (kalo), green onions, chard, tomatoes, chili peppers, cucumbers, basil, okra, bok choy, and watercress.

The success of an aquaponics system largely rests on the nutrient cycle. All living things need nutrients to grow, from the tiniest fish to the largest tree. As you learned earlier in this section, fish absorb nutrients from the food they eat and the water they live in. Plants absorb nutrients, including nitrogen, from fertilizers, nutrient-rich soil, or nutrient-rich water. In fact, nitrogen is the second highest chemical on a plant's food list, next to carbon dioxide.

### DIVE DEEPER

- Ask students why it might not be a good idea to use calcified materials, such as limestone pebbles, in an aquaponics (or any aquaculture) system. Research and discuss the affects it can have on water quality.
- There is a lot of information available on different types of aquaponics systems. Do some additional research and share it with students. Have them design or draw models of different systems for various sites.
- Vermicast is the end result of the breakdown of organic materials by worms. Vermicast is very rich in vital nutrients and using it can help your plants grow strong. Make a worm bin with students and use the vermicast when planting seeds (before transferring them to an aquaponics grow bed or traditional garden). Instructions to make a worm bin are available in the following CTAHR publication: <http://www.ctahr.hawaii.edu/oc/freepubs/pdf/HG-45.pdf>

### WORKSHEETS

3f. How Much Sunlight? Experiment

3g. Aquaponics Nitrogen Cycle

Water Quality Log (page 30)

### DID YOU KNOW?

In hydroponics, farmers need to constantly add soluble nutrients to their water. In aquaponics, most of the necessary nutrients are naturally present in the system.

## Establishing Aquaponics at Your School



Image a

There are many aquaponics system designs in use across the world. The AQUA project works with two different systems designed here in the Pacific region. The first is a system called the "Waimanalo Prototype," designed by Dr. Bradley "Kai" and Dr. Clyde Tamaru of the University of Hawaii (UH) College of Tropical and Agriculture and Human Resources (CTAHR). The second system was designed with the remote Pacific Islands in mind by Dr. Harry Ako and Adam Baker, also of UH CTAHR.

The system designed by Dr. Ako and his team uses simplified raft technology. The "Waimanalo Prototype" system uses both ebb-and-flow and raft technology. Both systems can be scaled to virtually any size. For full details on constructing the Pacific Island system, download the publication "Small Scale Lettuce Production with Hydroponics or Aquaponics" on the AQUA website, or on the CTAHR publications website.

We recommend that you download this publication even if you choose to use a different system design. It is full of valuable information for anyone who wants to conduct aquaponics. Details on constructing the Waimanalo Prototype are provided here. The following instructions are based on a model system that uses a 180 gallon fish tank paired with two 4'x4' grow beds. One grow bed is ebb-and-flow, and the other is a raft grow bed.

### System Construction Materials (does not include bell siphon or optional materials)

- Fish tank (high density polyurethane (HDPE) fish tanks are durable and have a 1,000 year half-life. Tanks can also be made out of concrete or other available materials)
- 700 gal/hour magnetic drive pump (the size of your pump will depend on the size of the system you are building)
- Grow beds (HDPE grow beds work well. Alternatively, you can build your grow beds - also called trays - out of wood, or use food-grade barrels cut in half lengthwise). Instructions on how to build wood grow beds are included in the "Ako and Baker" publication).
- Polystyrene foam or wood boards (the "raft" in the raft grow bed. Size to fit perfectly inside the grow bed).
- Net pots (several 2" pots and one 6" pot for the raft)
- Growing medium (such as volcanic cinders, hydroton clay balls, etcetera. You will need enough to fill the ebb-and-flow grow bed).
- Zip ties
- Plastic mesh/shade cloth (to make a shade cloth and a fish tank cover)
- PVC glue (researchers recommend gluing all sections that are pressurized)
- Steele horses or concrete blocks (to make a table stand)
- 4' x 8' plywood (or other materials to make a table)
- Oil based sealant (to seal any wood used in the system, such as the table, grow beds, or raft board)
- Electric drill and other tools as needed
- Hole saw (an attachment that attaches to a standard drill. You can purchase hole saw fittings in a variety of sizes)
- Bell siphon materials (download the CTAHR publication "Construction of Automatic Bell Siphons for Backyard Aquaponic Systems" –a list of materials and comprehensive instructions: <http://www.ctahr.hawaii.edu/oc/freepubs/pdf/BIO-10.pdf>)

### PVC Materials (all of these should be "slip")

- 3/4" PVC slip pipe (depending on the size of your system, you will need around 60 feet of PVC pipe for the main piping. CTAHR recommends using 3/4" pipe to avoid clogging that can occur with smaller pipes)
- 3/4" short nipples (small pieces of PVC pipe; connectors)
- 3/4" female adapter (to connect to the pump)
- 3/4" ball valves (to control the flow of water. Model system uses five)
- 3/4" union fittings (to allow for easy access to the inside of pipes at critical junctures where you may have to check for clogs. Model system uses five)
- 1" PVC slip pipe (enough for each stand pipe)
- 1" unseal (one for each grow bed drain)
- 45 degree PVC elbows
- 90 degree PVC elbows
- PVC T's
- PVC pipe cutters





Image b

### Setting up a System

- Before purchasing your materials, ensure that you have adequate space set aside to establish your system. Find a flat area that has enough space for your desired-size fish tank and grow beds, and for you to comfortably access all points of the system.
- Determine where you want to place your fish tank and grow beds. You can set it up spaced out with your fish tank in the center of two grow beds (per image b) or with all components closer together (per image a). As long as you can connect your tank to your grow beds, you can set it up any way you choose.
- A day before you set up your system, paint a piece of 3/4", 4' x 8' plywood with an oil based sealant. Cut it in half so you have two 4' x 4' boards.

### Create a table/platform for the grow beds.

- First, establish a base. Steel horses are a good option and can be purchased at hardware stores. Concrete blocks are a good, cheaper alternative. Set a base that is at least a few inches taller than the fish tank.
- Once the base is established, place one of the 4' x 4' pieces of treated plywood on top.
- Repeat the same steps to build a table for each additional grow bed(s).

Alternatively, you can line multiple smaller grow beds up on one long table. You can also use PVC tables.

### Grow bed drainage

- Place a grow bed centered on top of the plywood table, and mark where the center of the grow bed is.
- With another person holding the grow bed securely in place, drill a small hole through the center of the grow bed and down to the plywood table. Make sure the drill hits the plywood.
- Remove the grow bed, and use a 2 1/2" hole saw fitting to drill a hole in the plywood where the drill mark is.
- Use a 1 3/4" hole saw fitting to drill a hole in the center of the grow bed.
- Fit a 1" uniseal inside the hole in the grow bed.
- Determine the size of the stand pipe. The top of the pipe should be about 3 inches below the top of the grow bed, and the bottom of the pipe should stick out from underneath the table at least an inch.
- Place the stand pipe inside the uniseal. Tap it with a larger piece of PVC pipe to wedge it in place.
- Connect a 90 degree PVC elbow to the bottom of the standpipe. Connect a piece of PVC pipe to the elbow (long enough to run from the drain to inside the edge of the fish tank). Connect another 90 degree elbow to the other end of the pipe, facing downward so water returns to the fish tank.



## Setting up your pipes

Think of setting up the pipes like legos; you are connecting many parts that are made to fit perfectly together to build a structure. Use the illustration as a guide. Individual steps are as follows:

- 1) Connect a female adapter to the pump and set the pump down.
- 2) Connect a PVC pipe to the adapter. The length of this pipe should match the depth of water in your tank. Our model system has a water depth of 21 inches, so this pipe is 21 inches.
- 3) Connect a union fitting to the top of the pipe.
- 4) Connect a short nipple to the other side of the union.
- 5) Connect a PVC "T" to the top of the short nipple.

## Building the spray bar

(a bypass that allows some water to flow into the tank and aerate the water while the remainder flows out to the grow beds, taking the place of a traditional air pump. Remember, aeration is critical in aquaculture!)

- 6) Connect another short nipple to the PVC "T" as shown to make the spray bar.
- 7) Connect a ball valve to the short nipple.
- 8) Connect another short nipple to the other side of the ball valve.
- 9) Connect a 45 degree PVC elbow to the short nipple.

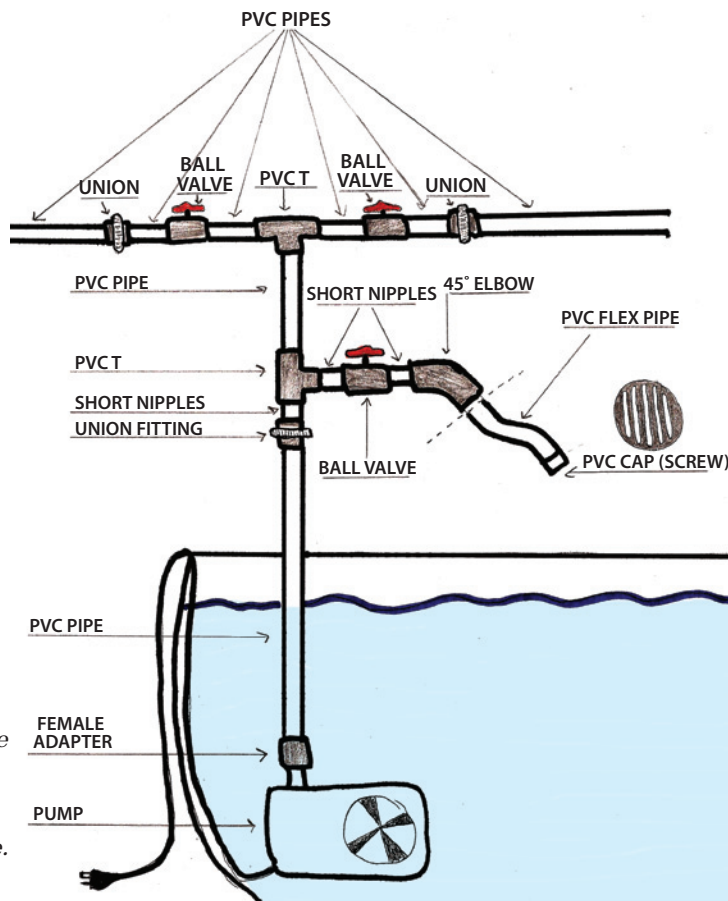
**Optional:** attach flex PVC pipe to the short nipple. Screw on a PVC cap containing slits (to allow water pressure to build).

- 10) Once the spray bar is complete, connect an 8" PVC pipe to the top of the "T" on the base.
- 11) If you plan to use two or more grow beds, connect another PVC "T" to the top of the pipe. If you plan to use only one grow bed, connect a 90 degree PVC elbow to the top of the pipe instead.
- 12) Connect a 3" PVC pipe to the "T" or elbow.
- 13) Connect a ball valve to the pipe.
- 14) Connect another 3" PVC pipe to the other side of the ball valve.
- 15) Connect a union fitting to the PVC pipe.

**Now, you have setup the core of your piping. From here, the details will vary depending on the scale and placement of your system. The following are the steps for connecting the piping core to the grow bed.**

- 1) Connect a PVC pipe to the union fitting. The length of this pipe will depend on the setup of your system and size of your grow bed. The pipe will run along side the grow bed.
- 2) Drill a few small holes along the top lip of the grow bed. Use zip ties to secure the pipe to the grow bed along the lip.
- 3) Connect a 90 degree PVC elbow to "round the edge" of your grow bed.
- 4) Connect another PVC pipe to the elbow. The pipe should run from the corner of the grow bed to about half-way to the opposite corner.
- 5) Connect a 90 degree PVC elbow to the pipe, facing upwards.
- 6) Connect a four-inch PVC pipe to the 90 degree elbow so it is standing above the top of the grow bed.
- 7) Connect another 90 degree elbow to the pipe, facing towards the grow bed.
- 8) Connect a four-inch PVC pipe to the elbow.
- 9) Connect a 45 degree elbow to the pipe. The elbow should be facing down so water will be pumped into the grow bed.

**Repeat these steps for each grow bed.**

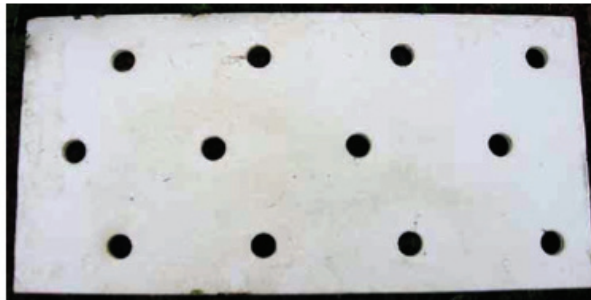


### Setting up the ebb-and-flow grow bed

- Build a bell siphon according to the CTAHR handout instructions.\*
- Make a gravel guard to fit around the outside of the bell siphon. Some retailers sell gravel guards already made, or you can make your own using a four-inch PVC pipe. The gravel guard should be as high as the walls of the grow bed.
- Place the bell siphon over the stand pipe, and then place the gravel guard on the outside of the bell siphon.
- Rinse the growing medium thoroughly before adding it to the grow bed.
- Fill the grow bed with growing medium. When filling your grow bed, start with the area around the gravel guard. Ensure that you do not allow gravel to get inside the guard and bell siphon. Depth is important in an ebb-and-flow grow bed, and you want to maximize the space you have. A good idea is to aim for 12-14 inches of gravel. Ensure that gravel stops one inch below the top of the bell siphon.

### Setting up the raft grow bed

- Cut the raft (foam or wood) so that it fits inside the lip of the grow bed.
- Cut a 6" hole in the raft directly underneath where the water flows into the grow bed. This will be for a 6" net pot to capture any solid waste.
- Drill holes in the raft. Space them so they are in staggered rows and about 8 inches apart (per image)



*Polystyrene Panel with hole spacing*

### Final Steps

- Create a cover for your fish tank by stretching shade cloth over a PVC frame (connected together using PVC elbows and your creativity). Use zip ties to secure the cloth to the PVC.
- Create a shade cover for your grow beds as desired.

### Starting Your System

- Fill your tank with water and let the pump run for at least 24 hours before stocking fish.
- Stock fish in the system. A good stocking density for this tank size is 60-80 fish, but the DO will dictate the appropriate stocking density as your fish grow larger. Fish should grow to a harvestable size within 9-12 months.
- Begin planting. Start by placing a 6" net pot filled with growing medium underneath the flow of water into the raft grow bed. Plant green onions in the net pot. This is a great way to capture any organic materials that pass through the pipes, but be sure not to eat the onions from that particular pot.
- Plant other seeds and transfer them to the grow beds when ready (per instructions on page 25).
- Follow the instructions on the following pages to maintain your system.

### GOOD IDEAS








- When using a raft system, it is a good idea to place guppies or other mosquito eating fish directly in with the plants.
- Purchase a little air pump to have just in case something happens to your main pump. Even though you can continue doing aquaponics without pumping water to grow-beds, fish tank water still needs aeration to maintain an optimal DO level.



\*<http://www.ctahr.hawaii.edu/oc/freepubs/pdf/BIO-10.pdf>

# Aquaponics Maintenance Manual

## Regular Maintenance

-  Feed your fish once or twice a day to satiation. You can use any standard tilapia/trout/carp feed, or make your own (such as black soldier fly larvae).
-  Take a small handful of feed in the palm of your hand and throw it into the tank. If the fish eat it, throw more. If they do not eat for 30 seconds, do not throw any more feed.
-  Check the water level on a daily basis to ensure that you are not losing water to evaporation.
-  Monitor pH levels every week. Learn why in the Water Quality section below.
-  Monitor Dissolved Oxygen (DO) levels on a weekly basis. Learn why in the Water Quality section below.
-  Observe and respond to your fish. If something seems wrong and they are not eating, DO NOT add any more food to the system. Remove any feed left floating in the tank that has not been eaten after five minutes of waiting. Measure DO levels and respond as needed per instructions below. If your fish do not respond to the suggested strategies and continue not eating after three days, you might have a disease problem and you should call your extension agent for advice.
-  Your plants will not need much regular maintenance. Refer to the Tending Your Garden Section on the next page for more information.

## AQUAFARM

Plant something new every week to see the progression in the nutrient balance in your system. Record your findings in your class aquaponics log.

## DID YOU KNOW?

- Black soldier fly larvae are an alternative feed for fish in an aquaponics system. You can grow and harvest them on the same site as your system. Learn more by searching online.
- If you are using an ebb-and-flow grow bed, it is a good idea to put a few worms into the growing medium. They will help to breakdown any organic materials, such as solid waste, that pass from the fish tank into the grow bed.

## Water Quality Essentials

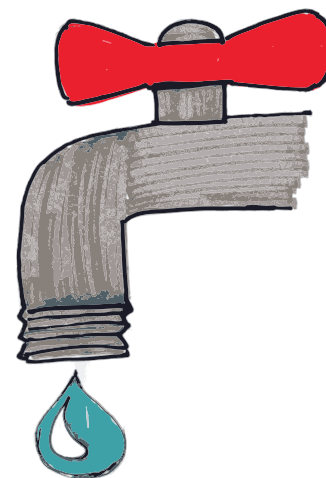
### Maintaining pH

pH level should be maintained at 6 ½ or lower. If pH remains low, ammonia in the tank remains non-toxic. However, once the pH level increases, the water becomes toxic to the fish.

### Maintaining Dissolved Oxygen (DO)

The DO level in an aquaponics system should be maintained at about 3mg/L. If your system has a low DO level, there are a few basic things you need to check:

1. Check the mechanism you are using to add oxygen to your tank (usually a spray bar or aerator). Make sure that it is aerating the fish tank correctly, and that there are no fish scales or other debris stopping the flow.
2. There may be too many fish in the system, or fish that are too big. Harvest a few fish (up to 1/3).
3. If you are still suffering from low DO, exchange some of the tank water (up to 1/3) for fresh water.





## Starting & Tending Your Garden

Plants are very opportunistic. When they are small, they will store any available nutrients. They can successfully compartmentalize specific nutrients, including iron, which is a critical nutrient to healthy plant development. Furthermore, research



shows that the nutrients a plant receives while it is a seedling have the most significant impact on its development. Therefore, it is important to ensure that your plants begin their lives with adequate nutrients.

Most seeds should be planted in a dirt cup until

they begin to sprout true leaves. Place your seed in a small cup with a well-balanced, fertilized soil. You can also start seeds in oasis cubes (which can be purchased at most gardening stores or online).

Once a leafy green has at least four true leaves, you can transfer it to its respective grow bed. This should take about two weeks.

You can begin planting in your system immediately after you build it, but you should expect anything you plant to struggle while the nitrogen levels are balancing and the remediating bacteria is growing.

If a plant starts to turn yellow, it is likely suffering from Chlorosis, an iron deficiency. Add a ½ teaspoon of iron chelate every 5-7 days until the plants are healthy again.

## Food Safety & Harvesting

Food safety considerations are crucial in aquaponics because food plants are grown in the same system as fish effluents. It is important to ensure that the food you are producing and harvesting is safe to consume and will not transmit foodborne illnesses. There are several food safety practices that can be put into place before, during, and after harvesting to minimize risk. The CTAHR handout "On-Farm Food Safety: Aquaponics" discusses these practices in detail, and is a great resource that anyone conducting aquaponics should read. Download from the CTAHR website: [www.ctahr.hawaii.edu/freepubs/](http://www.ctahr.hawaii.edu/freepubs/)

The following are some helpful food safety and harvesting tips:

- Always wash hands thoroughly before harvesting.
- Wear protective gloves when handling fish or vegetables, or when digging around in a grow bed.
- Touch ONLY the produce when harvesting. Never touch the system water when handling plants; it can contaminate the plants.
- If using a raft system, do not lift or touch the raft, grow cup, or roots of a plant when harvesting.
- It is a good idea to harvest earlier in the day. This is especially true for lettuce, which may wilt if harvested mid-day.
- A good way to keep lettuce from wilting is to mist it lightly with water before or immediately after harvesting.
- Clean harvesting containers regularly.

## PESKY PETS

Aquaponics plants do not typically suffer from pest problems. However, should a pest problem arise, have your students conduct research on the pest and ways to effectively mitigate it. Be as conservative as possible with pesticides. Organic options, such as Neem Oil, can be considered. The NMC CREES program has a helpful video on how to make your own Neem oil: <http://vimeo.com/17320321>

Common pests include aphids and white mold. Any leaves experiencing white mold should be removed from the plant. If you have any severe pest problems, remove the affected plants completely from the system.

A good way to avoid pests all together is to use nets around your produce. Nets can help to keep your plants free from pests and their feces, which can be vectors for foodborne illnesses. Many commercial farms use nets to shield produce.

Visit the AQUA website for more helpful pest control tips.

## HANDLING FISH

Many fish, such as tilapia, have sharp spines that can easily puncture human skin. Although it is uncommon for a disease to transfer from a fish to a human, being poked by a spine or exposing an open wound to fish blood can increase the possibility.

There are preventative measures you can take to minimize your risk. When handling fish, it is a good idea to 1) cover any open wounds with a waterproof band-aid; 2) wear pierce-proof protective equipment (gloves, boots, etc.); and 3) wash hands with antibacterial soap immediately after touching fish or system water.

## Aquaponics Water Quality Data Log

Date	Tester'sName	pH	Ammonia	Nitrite	Nitrate	DO	Notes

## Section 4: History of Aquaculture





## Central Concept I: Ancient Aquaculture



The history of aquaculture is not fully understood due to a lack of detailed recorded information. However, it is generally believed that the first practice of aquaculture took place in China. The exact date of when it began is unknown, but it is speculated that it

emerged before or around 2000 B.C.. Common carp, a durable freshwater fish, was the first species cultured. There are no detailed descriptions of the techniques that were used, but it is known that juvenile carp were taken from rivers and placed into special ponds to grow to harvest size.

During the Tang Dynasty (618 to 906 A.D.), the cultivation of common carp was prohibited. This led to the discovery that grass carp, silver carp, big-head carp, and mud carp could also be grown successfully in aquaculture. Furthermore, Chinese farmers cultured these four species together in the same aquaculture pond and realized they complimented each other, resulting in the development of polyculture techniques still used today.

It has also been speculated that Egyptians began experimenting with aquaculture thousands of years ago. Hieroglyphs depicting intensive fish culture have led historians to believe that Egyptians grew tilapia, but little additional information exists. Another early civilization that experimented with aquaculture was Rome. Around 100 B.C., the Romans developed oyster beds to cultivate oysters. While early forms of aquaculture are very different from those we see today, this technology remains largely unchanged and still in practice today. Aquaculture was also practiced in ancient Hawaii, which is covered in detail in the next Central Concept.

Aquaculture did not emerge in the continental United States until the 19th century, when it was introduced for stock enhancement of rivers (mainly trout). The book "A Manual of Fish Culture" was published by the U.S. Commission on Fisheries in 1897, and describes culture techniques for several aquatic species, including trout, oysters, and lobsters. The manual was regarded as a standard resource for culturists during the infancy of American aquaculture.

### DIVE DEEPER

We have only scratched the surface of the history of aquaculture; there is a lot more for your students to uncover. Visit the following link and share the information with your students: <http://www.fao.org/docrep/field/009/ag158e/AG158E02.htm>.

### ACTIVITY IDEAS

**I:** Have students break up into four different groups, one representing each type of carp grown in the first polyculture pond in China. Look up some pictures of the four different types of carp and share them with students. Talk about the differences between each species. Instruct each student to draw (or construct) an individual carp (the same one their group represents). Add all of the carps to a classroom "polyculture pond."

**I & II:** Using Worksheet 4a, have students create their own aquaculture hieroglyphs.

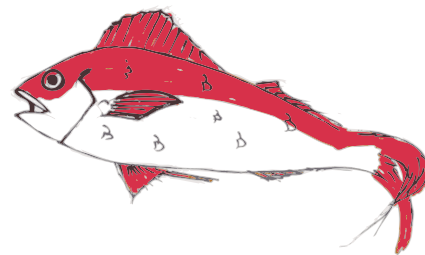
**II & III:** Ask students to do more research and create a detailed and artistic timeline on the history of aquaculture, from its infancy to modern times.

### WORKSHEETS

4a. Egyptian Hieroglyphs

### DID YOU KNOW?

The earliest description of aquaculture practices can be found in the book "The Classic of Fish Culture" by author Fan Li (approximately 500 B.C.).



## Central Concept 2: Aquaculture in the Pacific

In some Pacific Island communities, aquaculture has played a significant role in the cultivation of food for generations. Ancient systems of raising fish in ponds have been uncovered across the Pacific, but none are more impressive or advanced than the loko i'a (fish ponds) of Hawaii.

The following are excerpts from the book "Keeper of Moli'i Pond," written by Vernon T. Sato and Cheng-Sheng Lee, and published by CTSA.

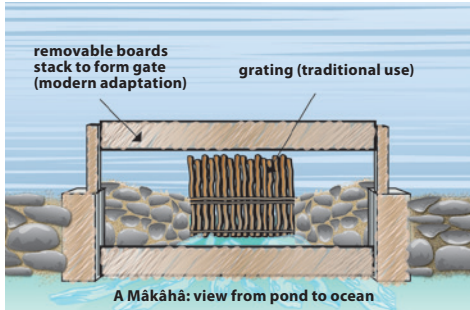
Historians and archaeologists have dated the origins of Hawaiian fishponds to 1000-1200 A.D. Fishponds were considered to be a part of the *ahupua'a* that extended from the mountains to the ocean. These land divisions were under the control of the *konohiki* (*ahupua'a* headmen who controlled fishing rights and supervised the building of the fishponds). In contrast to fishing, harvesting from fishponds did not come under the restrictions of *kapu* and could be done at any time of year. Fishponds belonged to the *ali'i* and could only be harvested by their order. As civil projects, ponds were there to benefit the community, and the *ali'i* who were respectful of their people considered the ponds as living food pantries to be used to provide for the *maka'ainana* or commoners during periods of poor fishing or other food shortages.

Applying their knowledge of the natural habits of the fish, the Hawaiians constructed *loko kuapā* (walled ponds) along the shorelines to capture the rich runoffs that attracted the young fry into the pond. The *mākāhā* is a channel opening through the *kuapā* that contains stationary grating. Traditionally, the grating systems were made of straight sticks positioned upright and spaced within the openings in the rock walls. Ancient Hawaiians referred to their stationary sluice gates as *mākāhā*; the sluice channels themselves were called *'auwai o ka mākāhā*. The moveable weir is a modern-day modification, probably added by Asians. The movable gates

were adjusted with the ebb and flow of the tides to manage water quality, to stock the fishpond with fry and to harvest mature adults. Today, pondkeepers tend to refer to the entire system as *mākāhā*.

The pond provided all food needed by these important fish, a group that consisted primarily of herbivores such as *'ama'ama* and *awa* (milkfish or *Chanos chanos*). A few predators helped to keep the population in check and contributed to

a healthy and balanced ecosystem. Although the *kia 'i loko* (daily caretaker who maintained the fishpond and protected it from poachers) occasionally fed the fish and enriched the pond, the system was nearly self-sustaining. Each species that entered the pond was harvested in its own time, which was determined by nature.



### ACTIVITY IDEAS

**I, II, & III:** Re-enact the construction of a fishpond as a class. Use props, and consider turning it into a play that students perform for your school!

**I, II, & III:** Make a topographic map of a loko i'a (or an entire *ahupua'a*).

**I:** Have students color in the picture on the next page.

**II & III:** Do some research on the history of aquaculture in your specific location. Write a poem about its significance to the native people.

### AQUATip:

Take a field trip to a nearby fishpond.

### DIVE DEEPER

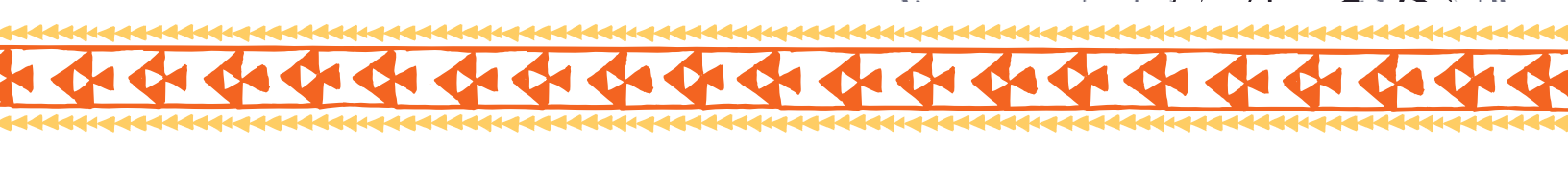
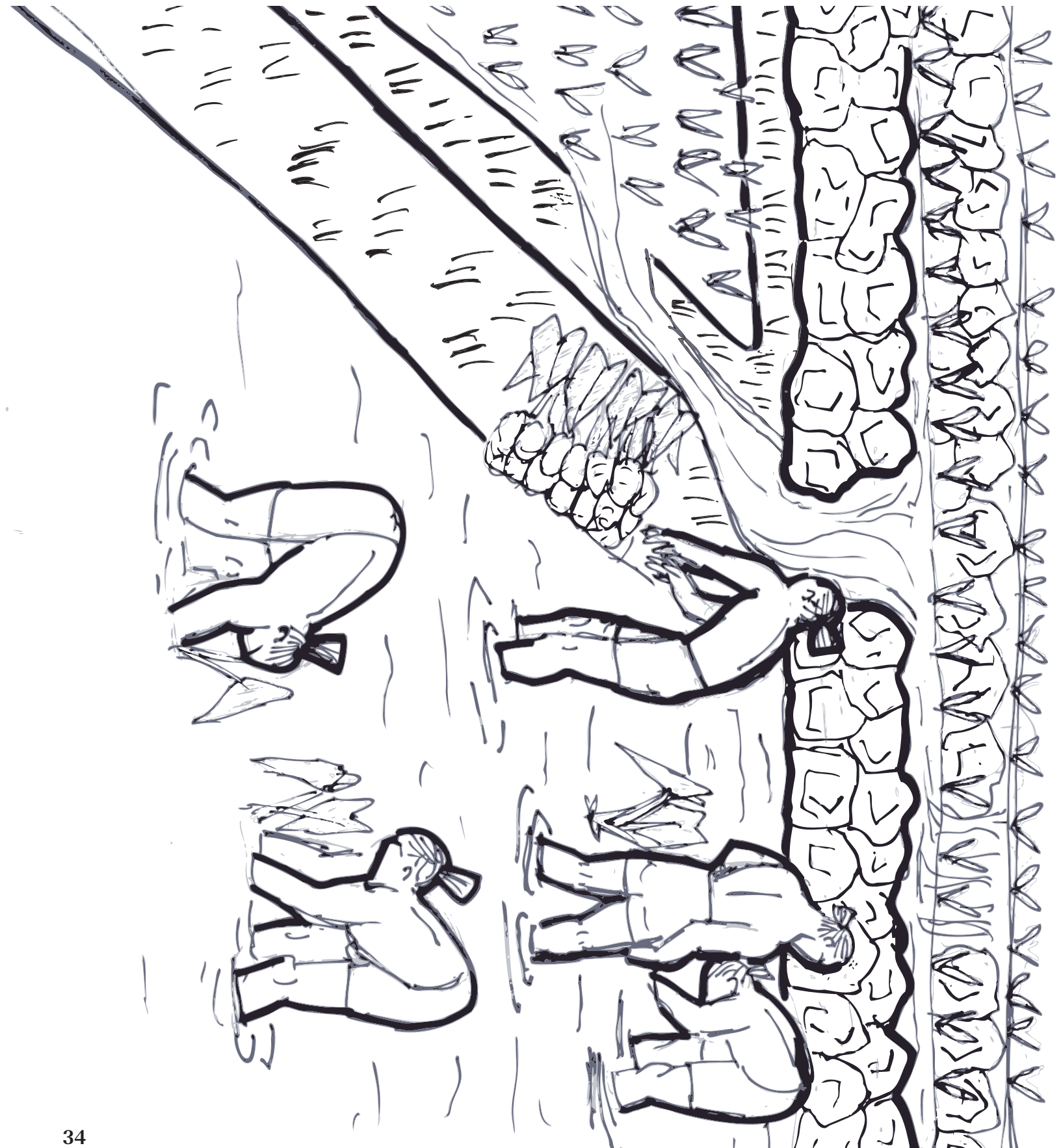
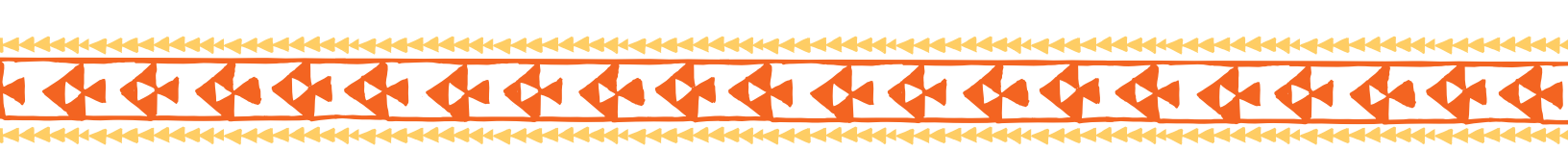
There is a lot of information available on Hawaiian fishponds. For a complete bibliography on Hawaiian fishpond publications, please visit the website <http://praise.manoa.hawaii.edu/fishbib.php>

### DID YOU KNOW?

Loko i'a are the oldest form of aquaculture in the United States!

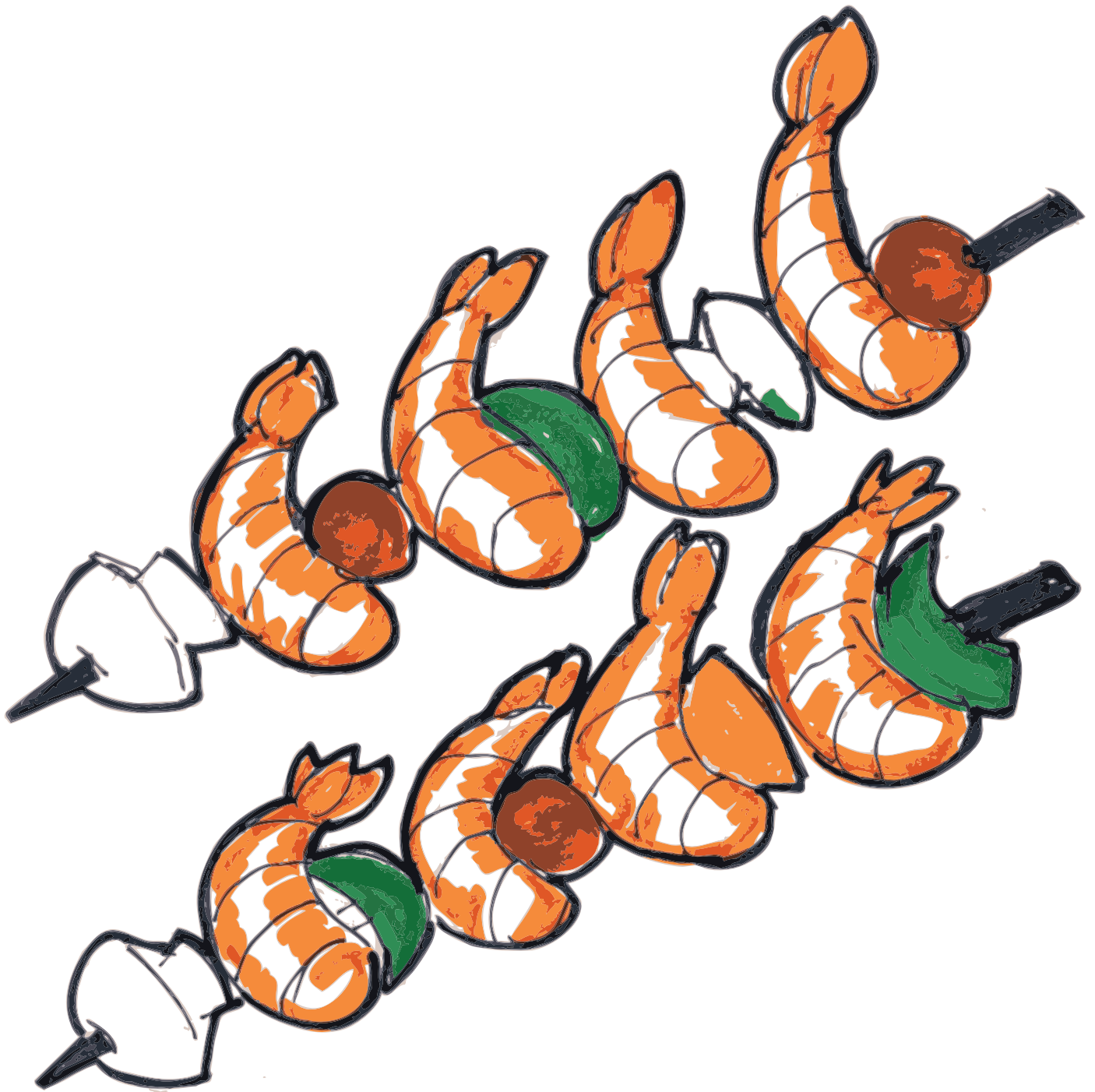
The loko kuapā is the largest type of Hawaiian fishpond. Loko kuapā were constructed by building kuapā (walls) of basalt rocks or coral out onto a reef, and enclosing a portion of the reef to protect it from the full force and influence of the ocean.

The *'ama'ama* (striped mullet, *Mugil cephalus*) was an important food fish for the ancient Hawaiians, so much that they gave distinct names to its different life stages and banned its harvesting during the winter months. When the fish came to shore in great schools, they were called pua *'ama'ama* as they entered the nursery grounds and *'o'ola* when they grew to the length of a human hand. Years later, they returned to the ocean as *'anae* (full-size mullet, 12 inches or longer) to spawn and reproduce.



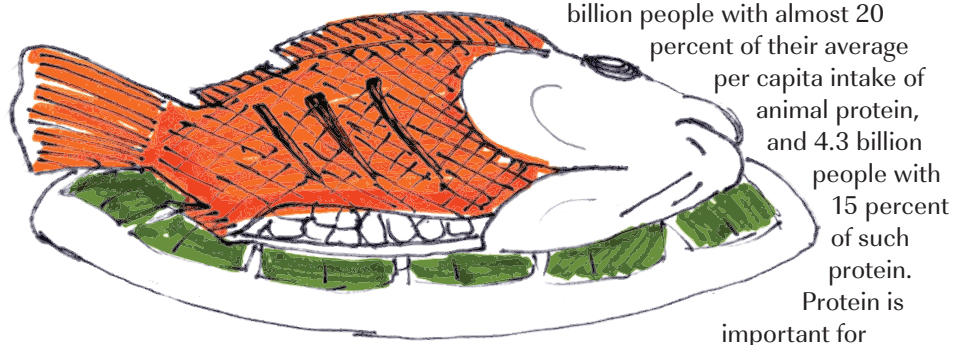


## Section 5: Aquaculture & Human Nutrition



## Central Concept I: Why Eat Seafood

The health benefits of consuming seafood rich in protein and other nutrients, such as Omega 3 fatty acids, are widely known. Currently, the USDA recommends eating at least two servings of seafood per week. For many people across the world, seafood is a dietary staple. In fact, as discussed in Section 1, CC2, fish provides more than 3 billion people with almost 20



humans to eat because it helps to build and maintain muscles, bones, and skin. It is also important in the development and maintenance of vital organs and blood. A lack of protein can result in a loss of muscle mass, decreased immunity, and low energy. Seafood can be a low calorie alternative to other animal proteins.

Seafood is a low-fat source of high-quality protein, and depending on the species, can be loaded with beneficial Omega-3 fatty acids. Omega-3's are credited for lowering the risk of heart disease and blood clots and improving cholesterol levels. In addition, clinical trials have also shown that eating fish may help reduce the risk of cancer and the development of Alzheimer's disease. Some aquatic species, such as seaweed, even contain anti-biotic and anti-viral compounds and are considered "super foods."

Seafood can also be a good source of several vitamins and minerals that humans need, including vitamins A, B and D, and minerals phosphorus, potassium, and selenium. Vitamin A is important to maintaining good vision and eye-health, and is also beneficial for the immune system and cell production. Vitamin B12 is important to keep nerves functioning properly, and helps our bodies turn food into energy. Vitamin D strengthens bones. Sea vegetables, such as seaweed, are also a great source of vitamin C.

### ACTIVITY IDEAS

**All:** To start this discussion, ask students if they like to eat fish. Ask them what type of fish they like to eat, and what they like about eating it.

**I, II, & III:** Complete Worksheet 5a.

**I, II, & III:** Carrageenan, an extract from seaweed, is an ingredient in a lot of commonly used products, including many processed foods, toothpaste and cosmetics. Instruct students to go home and look for products containing the ingredient carrageenan. Have them make a list of the products they find and combine with classmates.

### WORKSHEETS

5a. Seafood Habits

### DID YOU KNOW?

Both freshwater and marine seafood contain unique omega-3 fatty acids. However, marine seafood has a higher content of heart-healthy EPA and DHA.

### DIVE DEEPER

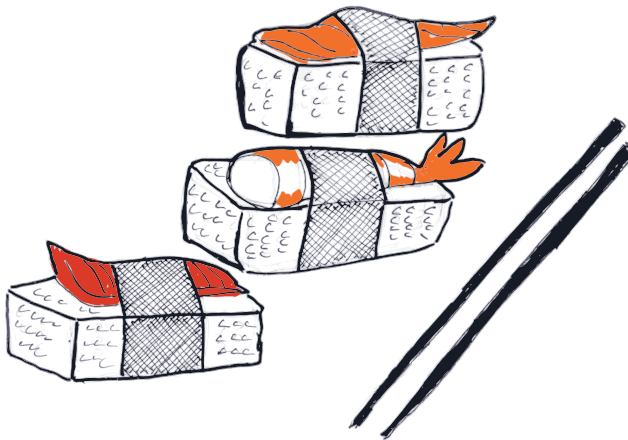
- There are several websites and books dedicated to the nutritional facts about seafood. A great place to start is [www.seafoodhealthfacts.org](http://www.seafoodhealthfacts.org), where the Seafood and Nutrition section contains information on the following topics: Dietary Advice, Calories, Protein, Fat content, Omega-3's, Cholesterol, Sodium, and Vitamins and Minerals. Share the information with your students in a discussion.
- Another great resource is the Monterey Bay Aquarium Seafood Watch Program. The program produces recommendations annually that categorize seafood available on the U.S. market as "Best Choices," "Good Alternatives," or seafood to "Avoid." Visit [www.montereybayaquarium.com/seafoodwatch](http://www.montereybayaquarium.com/seafoodwatch)
- The U.S. Food and Drug Administration's (FDA) Center for Food Safety and Applied Nutrition (CFSAN) works to assure that the food supply is safe, sanitary, wholesome, and honestly labeled. For information on food safety monitoring, food ingredients & packaging, labeling & nutrition, and more, visit the website [www.fda.gov/food](http://www.fda.gov/food).

### BATTLING OBESITY

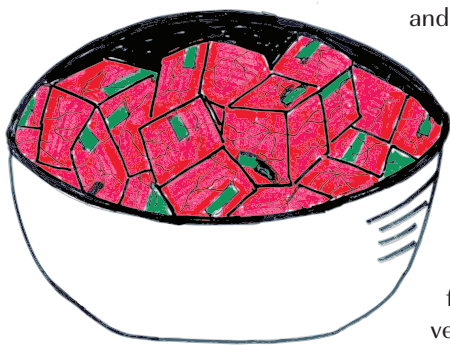
Childhood Obesity is one of the most preeminent growing problems facing children and adolescents in the United States today. The epidemic is causing risks in both the short and long term to the physical and economic health of our nation and its children. Eating fresh fish and vegetables is a positive step in the fight towards a healthier America.

## Central Concept 2: How to Eat Seafood

There are many different ways to eat seafood. Some is eaten raw, like sushi and sashimi, and other is cooked all day long, like some stews and soups. As discussed in CC1 of this section, seafood can be very beneficial to eat and should be a part of any healthy diet. A common misconception, however, is that all seafood dishes are healthy. While the animal might contain healthy protein, many common dishes and recipes are loaded with unhealthy ingredients. For example, salmon is a fish that has a high content of beneficial nutrients, but if it is prepared using a large amount of butter and salt, it can be very unhealthy to eat.



A popular way to prepare fish in the Pacific Islands is to steam it. This can be done using a pit in the ground, such as a Hawaiian imu, or a steamer basket on the stove. Fish can also be steamed on a grill or inside an oven, as long as it is sealed inside a fire-proof container. When using this cooking method, fish is typically rubbed or marinated with various spices and then either placed in a steaming basket on the stove or wrapped (in tin foil or organic materials such as ti plant leaves) and put into the pit, oven, or on the grill. A great way to make healthy, delicious steamed fish is to limit the amount of salt, oil or butter used in preparation, and wrap vegetables to steam along with the fish!



Another common way to cook fish is to grill it by itself. Fish only need to be grilled for a few minutes on each side before they are ready, so it is a good idea to keep a close eye on them. Broiling is a popular alternative to grilling, but fish can easily become dried out if they are grilled or broiled for too long. Poaching fish with chicken or vegetable stock is a great way to retain the moisture of the fish and keep the taste mild at the same time. Fried fish is also popular, but the amount of

oil used to cook it often makes it a less healthy choice. Baking fish can be a great-tasting healthy alternative to frying it, but it is important to read the recipe and ensure you are not cooking with too much butter, mayonnaise, cheese, or other fat-filled ingredients.

Shrimp and vegetable kabobs cooked on a grill, like the ones in the section cover picture, are delicious and healthy. Seaweed is high in nutrients and low in calories, and used in a variety of seafood dishes and many cultural foods, including sushi.

There are many more aquatic species that are delicious and beneficial food for humans. Discover the different ways to prepare and enjoy healthy seafood dishes!

### IMPORTANT NOTE

It is imperative to adhere to all health and education regulations when preparing food with and for your students. Consuming raw seafood can induce illness.

### ACTIVITY IDEAS

**I, II, & III:** Prepare fish with your students. There are several delicious, healthy recipes available on the AQUA website.

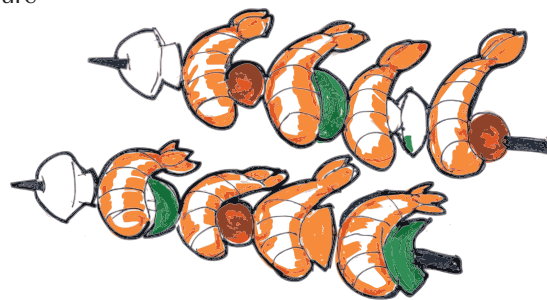
**II & III:** Have students develop their own recipes, and conduct a class-wide cook off.

### DID YOU KNOW?

When steaming fish on a grill, wrap tin foil loosely around the fish, and pinch the edges together to make a sealed container. Make sure there is enough room inside for the fish to be adequately steamed.

### DIVE DEEPER

The Monterey Bay Aquarium Seafood Watch program has several sustainable recipes listed on their website. Visit the following link and find a sustainable recipe to prepare with your students: [http://www.montereybayaquarium.org/cr/cr\\_seafoodwatch/recipes/default.aspx?c=ln](http://www.montereybayaquarium.org/cr/cr_seafoodwatch/recipes/default.aspx?c=ln)







## Experiment Data Log

**Question:** \_\_\_\_\_

\_\_\_\_\_

**Hypothesis:** \_\_\_\_\_

\_\_\_\_\_

**Experiment design (including description of variables and control, methods used, amount of trials conducted, etc.):**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**Results:** \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**Analysis/Conclusion:** \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

# Food Security

Unscramble the words and use them to fill in the blanks in the below statements.

otxlepdei	secsac
alsbneiuast	epidphs
rutlqaeacu	yetwtn
loibl ni	ent
blviyaitalia	aofoesd

- 1) Food security refers to the \_\_\_\_\_ of food and one's \_\_\_\_\_ to it.
- 2) Fish provides 3 \_\_\_\_\_ people with \_\_\_\_\_ percent of their average per capita intake of animal protein.
- 3) Fifty-seven percent of fish stocks are fully \_\_\_\_\_. 29.9 percent of fish stocks are overexploited.
- 4) Most of the top \_\_\_\_\_ species consumed worldwide are fully exploited.
- 5) Most of the food we eat in the Pacific is \_\_\_\_\_ here.
- 6) \_\_\_\_\_ can help to meet a growing demand for edible \_\_\_\_\_ worldwide.
- 7) Local aquaculture can help Pacific Islanders restore a \_\_\_\_\_ food supply.
- 8) Explain the importance of food security. What does it mean to you? What do you think it means to other people across the Pacific, and across the world?

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- 9) In your opinion, what can be done to improve food security where you live?

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## Sustainable Aquaculture Practices

### Explanation of Sustainable Practices

#### Adopting Aquaculture Best Management Practices (BMP's)

BMP's are a series of practices and protocols designed to help aquaculture producers run an effective, environmentally friendly operation. BMP's are often presented in manuals and vary depending on the species, facility type, and other variables. Best management practices in the areas of site selection, water quality, farm operations and effluent management are often included.

#### Determining environmental impact before building facilities

To ensure that an aquaculture operation will not have a harmful impact on the environment of the desired site, it is a good idea to conduct an environmental impact assessment before breaking ground, especially if you are considering a site in close proximity to an ecologically sensitive area.

#### Integrated Farming

When multiple, complementary species are grown together in the same pond, they can benefit each other and their environment. Fish raised in ponds can be fed by-products of the farm, cutting down on the need to use manufactured feeds. In addition, effluent water from fish ponds can be used to water terrestrial crops. This nutrient-rich water makes plants grow like no other fertilizer!

#### Using alternative energy to power aquaculture pumps

Energy costs are high, especially in the U.S. Affiliated Pacific Islands. To lower costs and help the environment, many aquaculture farms use solar, wind, or other alternative energy sources to power the pumps for their systems.

### Explanation of Un-sustainable Practices

#### Clearing a mangrove forest to build your facility

Destroying native habitat that the local ecosystem depends on is un-sustainable. When shrimp farming first expanded, the clearing of mangroves to make shrimp ponds was common practice in some countries (especially in southeast Asia). Most governments now recognize that clearing mangroves can be hazardous to the environment, and have stopped allowing this practice.

#### Releasing effluent water without a permit

Effluent discharged into waters of the United States is regulated by the United States Environmental Protection Agency (EPA). Any aquaculture operation that wishes to release effluent water into any body of U.S. water must obtain a permit and adhere to strict regulations. Instead of discharging water, farms can sustainably use effluents as fertilizer for terrestrial plants.

#### Releasing non-native species into local bodies of water

Restocking programs release native marine animals that have been overfished, and can help restore our ocean. However, they must be done in a controlled manner according to the law.

#### Unfair wages and work conditions for farm workers

Not all countries regulate work conditions like the United States. In some developing nations, wages and work conditions for aquaculture workers are poor.



### INSTRUCTIONS

Photocopy and cut-out each individual statement. Have students draw a line down the center of a piece of construction paper. Cut out and glue the words "Sustainable Aquaculture Practices" on one side. On the other, put "Un-Sustainable Aquaculture Practices." Have students glue the statements in the corresponding column.

### MATERIALS

- Photocopies of statements below (1 full set per student)
- Construction paper
- Glue



Using alternative energy to power aquaculture pumps

Releasing effluent water without a permit

Determining environmental impact before building facilities

Releasing non-native species into local water bodies

**Sustainable Aquaculture Practices**

Unfair wages and work conditions for farm workers

Clearing a mangrove forest to build your facility

Adopting Aquaculture Best Management Practices

**Un-Sustainable Aquaculture Practices**

Integrated farming

## WORKSHEET 3A

# Aquaculture Systems in the Pacific

Fill in the blanks using the words below.

*Hint: there are more words than there are spaces. Choose wisely!*

open ocean	maintenance
culturist	above-ground
increased	fingerlings
predation	wind
big	water quality
earthen	older fish
recirculating	harvest
space	in-ground
water	ocean currents
a pump	polyculture

- 1) \_\_\_\_\_ ponds are one of the most commonly found fresh or brackish water culture systems in the Pacific. They are in-ground ponds that are relatively easy and in-expensive to build, and they require less \_\_\_\_\_ than many other aquaculture systems. Culturists frequently use these ponds for \_\_\_\_\_ farming. A potential downside to this system can be an increased chance for \_\_\_\_\_ by birds and other animals.
- 2) \_\_\_\_\_ aquaculture Systems are fresh or salt water systems usually in the form of \_\_\_\_\_ tanks. They are closed systems in which the entire production process can be controlled by the \_\_\_\_\_. Depending on the scale of the operation, they require a small amount of \_\_\_\_\_ and can be kept either indoors or outdoors. A potential downside is \_\_\_\_\_ efforts in water management.
- 3) \_\_\_\_\_ aquaculture cages are large cages anchored, tethered, or floating in the open ocean. They are stocked with fish (usually \_\_\_\_\_), which are fed regularly and monitored for changes in health until they grow to harvest size. \_\_\_\_\_ is typically less of a concern with these systems, as they have a constant flow of water passing through them from \_\_\_\_\_. A potential downside to this system can be the high cost of capital investment.

# Choosing The Right Species

Anyone who wants to start an aquaculture farm, or start working with fish in a research capacity, needs to know as many details about that fish as possible to determine if it is suitable to work with.

Complete the following profile for the fish that you are growing in your system at school or at home, or any fish you choose. If you do not have fish, each student can select a different fish to profile. Combine together with classmates profiles to create a classroom fish database. *Hint: you can find helpful information on the website [www.fishbase.org](http://www.fishbase.org)*

Common name: \_\_\_\_\_

Scientific name: \_\_\_\_\_

Hawaiian name (if applicable): \_\_\_\_\_

Origin: \_\_\_\_\_

Size: \_\_\_\_\_

Desired pH level: \_\_\_\_\_

Temperature: \_\_\_\_\_

Place Your Fish Photo Here

Physical description: \_\_\_\_\_

\_\_\_\_\_

Reproduction characteristics: \_\_\_\_\_

\_\_\_\_\_

Feeding habits (wild and aquaculture): \_\_\_\_\_

\_\_\_\_\_

Stocking density: \_\_\_\_\_

\_\_\_\_\_

Polyculture: \_\_\_\_\_

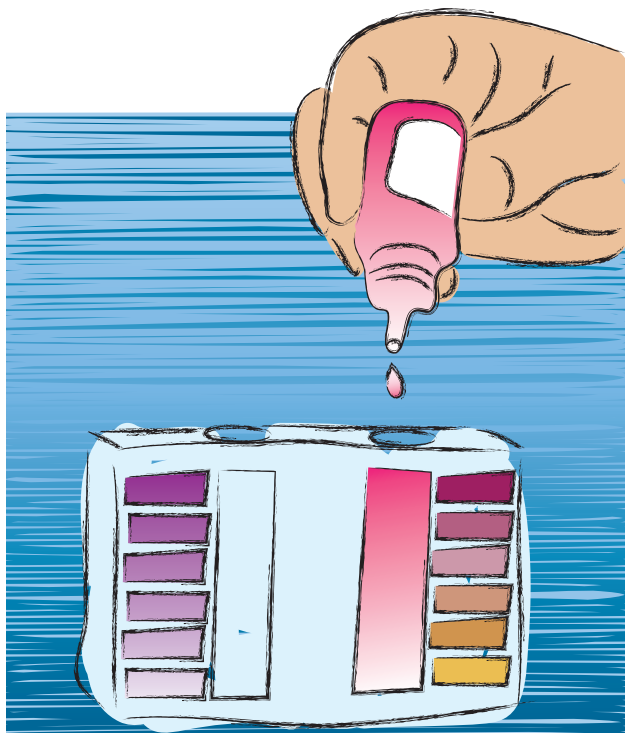
\_\_\_\_\_

Other comments: \_\_\_\_\_

\_\_\_\_\_



# Comparisons of Water Quality



Test the water quality of many different samples of water. Collect each sample and put it in a clean jar, clear cup, test tube, or beaker. Some examples of types of water you can test include:

- Aquaculture water (freshwater and/or saltwater)
- Water from a hose
- Rain water (capture some in a clean jar or cup at school or at home)
- Water from a sink at home
- Water from a sink at school
- Ocean water
- Stream water
- Water from a puddle
- Pond water

Complete the following chart for each sample of water you test. Compare the differences between "clean" water samples and "dirty" water samples. Use water test kits (obtained from pet and aquarium stores, or online) to find DO, pH, Ammonia, Nitrates, and Nitrite levels.

Water sample source: \_\_\_\_\_

Dissolved Oxygen (DO): \_\_\_\_\_

pH level: \_\_\_\_\_

Ammonia: \_\_\_\_\_

Nitrates: \_\_\_\_\_

Nitrites: \_\_\_\_\_

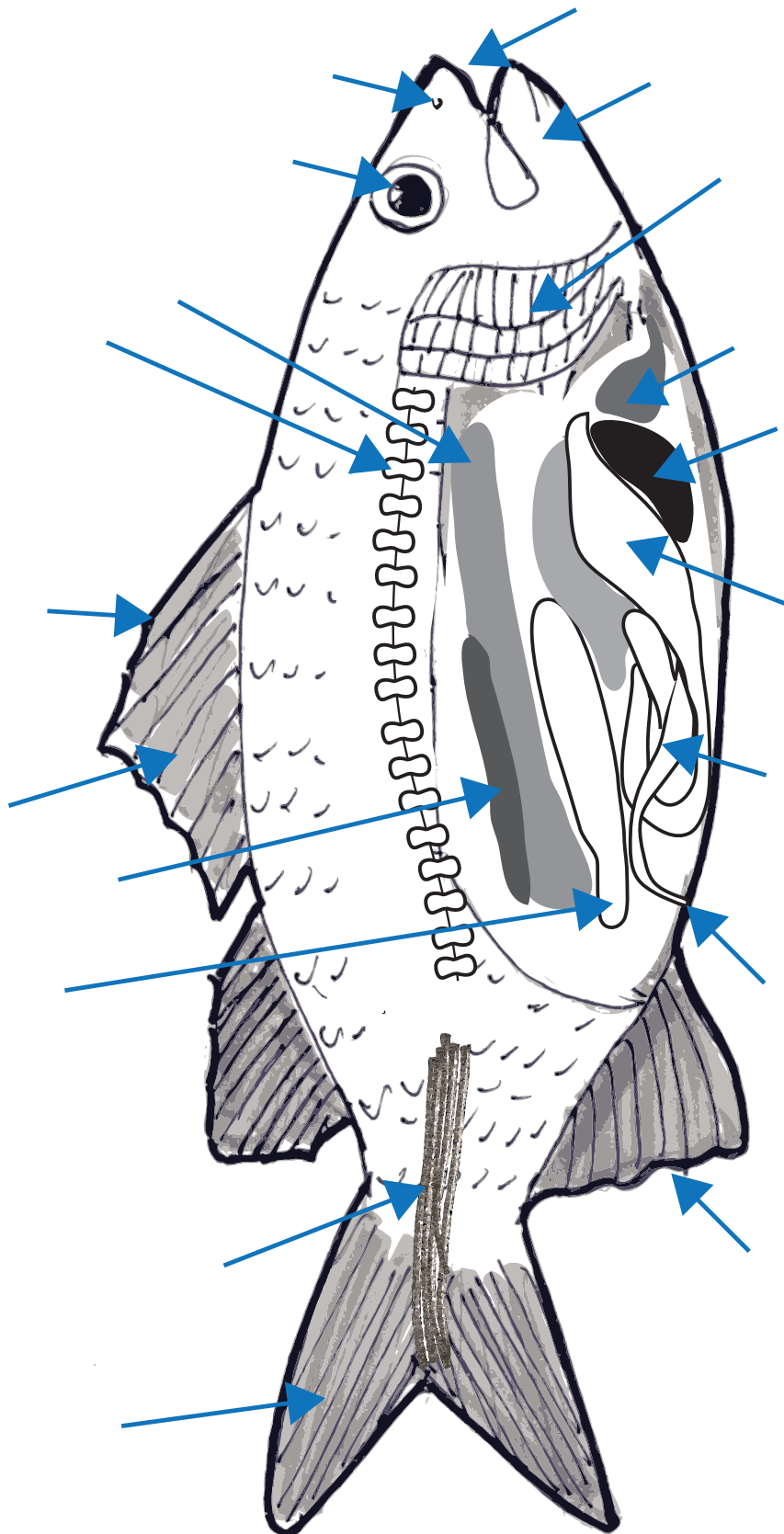
Describe what the water looks like: \_\_\_\_\_

Describe what the water smells like: \_\_\_\_\_

Does there appear to be any organic matter in the sample? \_\_\_\_\_

# Anatomy of a Fish

WORKSHEET 3D



## Fish Growth Experiments

**Determine if tilapia or other types of fish grow at various rates under different conditions!**

Using the Scientific Method, setup experiments to determine if fish grow at varying rates, depending on the specific conditions of the culture system they are in. These experiments can be conducted using your school aquaculture system (if applicable), or in individual aquarium fish tanks.



*Use the standard Experiment Data Log to record data from your experiment*

**Experiment 1:** Test a hypothesis about the effect of feeding behaviors on the growth of fish. For example, you can conduct an experiment to determine if fish grow at a different rate if they are fed the same amount of food twice a day, as opposed to only once a day. You can also test to see if different types of feed affect animal growth or water quality.

**Experiment 2:** Test a hypothesis about polyculture. For example, with the proper permissions and research, you can conduct an experiment on raising at least two different species in the same environment. Does it affect the growth rate of one or more animals? Does it affect their behavior? Does it affect water quality?

**Experiment 3:** Test a hypothesis about the effect of water temperature on fish growth rate. For example, you can conduct an experiment to determine if fish grow faster in warmer water or cooler water.

**Experiment 4:** Test a hypothesis about different stocking densities of fish. For example, do fish grow better with a larger or smaller amount of fish in the tank? Does density affect water quality?



## How Much Sunlight? Experiment




Photosynthesis is the process plants use to make food (glucose) from oxygen and carbon dioxide in the air. Photosynthesis starts when light hits the leaves of a plant, and cannot occur at night or on a cloudy day. There are many potential experiments you can do to illustrate this process. To start, do an experiment to determine how much sun a seed needs to sprout.

For this experiment, you will need three pots (or cups) with potting soil, bags of seeds, water, and a paper bag.



- STEP 1.** First, create a hypothesis about how much sunlight a seed needs to sprout. You can be more specific (examples: a seed needs ten hours, two hours, or no hours of sunlight per day to sprout) or less specific (examples: a seed needs sunlight all day, for part of the day, or not at all to sprout).
- STEP 2.** Setup a comparison trial to test your hypothesis. Plant three seeds in three different pots, and water them with the exact same amount of water.
- STEP 3.** Place one pot in a place where it will receive full sunlight. Place another pot in a place where it will receive partial sunlight, and place the final pot in a place where it will receive no sunlight (you might even consider placing a paper bag over the pot). Water all pots with the exact same amount of water for two weeks, and continuously observe them.
- STEP 4.** Chart the growth of each pot using the log on the following page. Every other day, closely observe the three pots. Record any changes you see using either words or drawings, or a combination of both.
- STEP 5.** At the end of two weeks, analyze your data and develop your conclusion. Complete an Experiment Data Log. Which pot(s) grew the best? What have you learned about the relationship between the sun and seeds?

HOW MUCH SUNLIGHT? LOG

DATE	POT 1 	POT 2 	POT 3 

# Nitrogen Cycle

## ACT OUT THE NITROGEN CYCLE AS A CLASS

### TEACHER INSTRUCTIONS

Cut strips of colored paper (equal size) and write the corresponding labels on each strip. Cut enough strips for each student to have only one piece of paper (you will divide students into groups, per below).

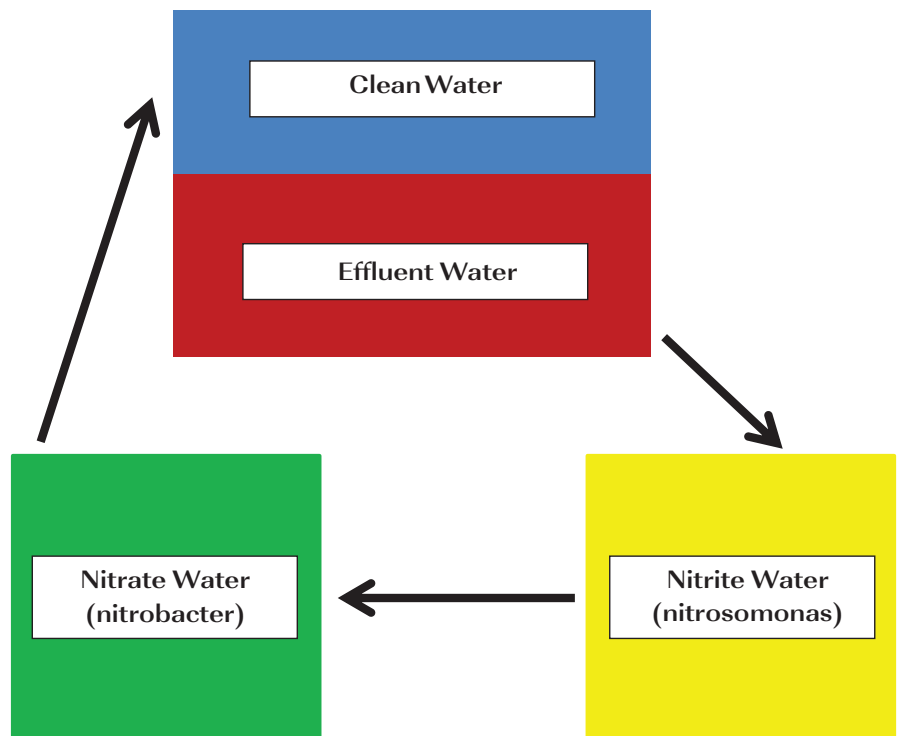
**Red paper = effluent water**

**Yellow paper = nitrite water**

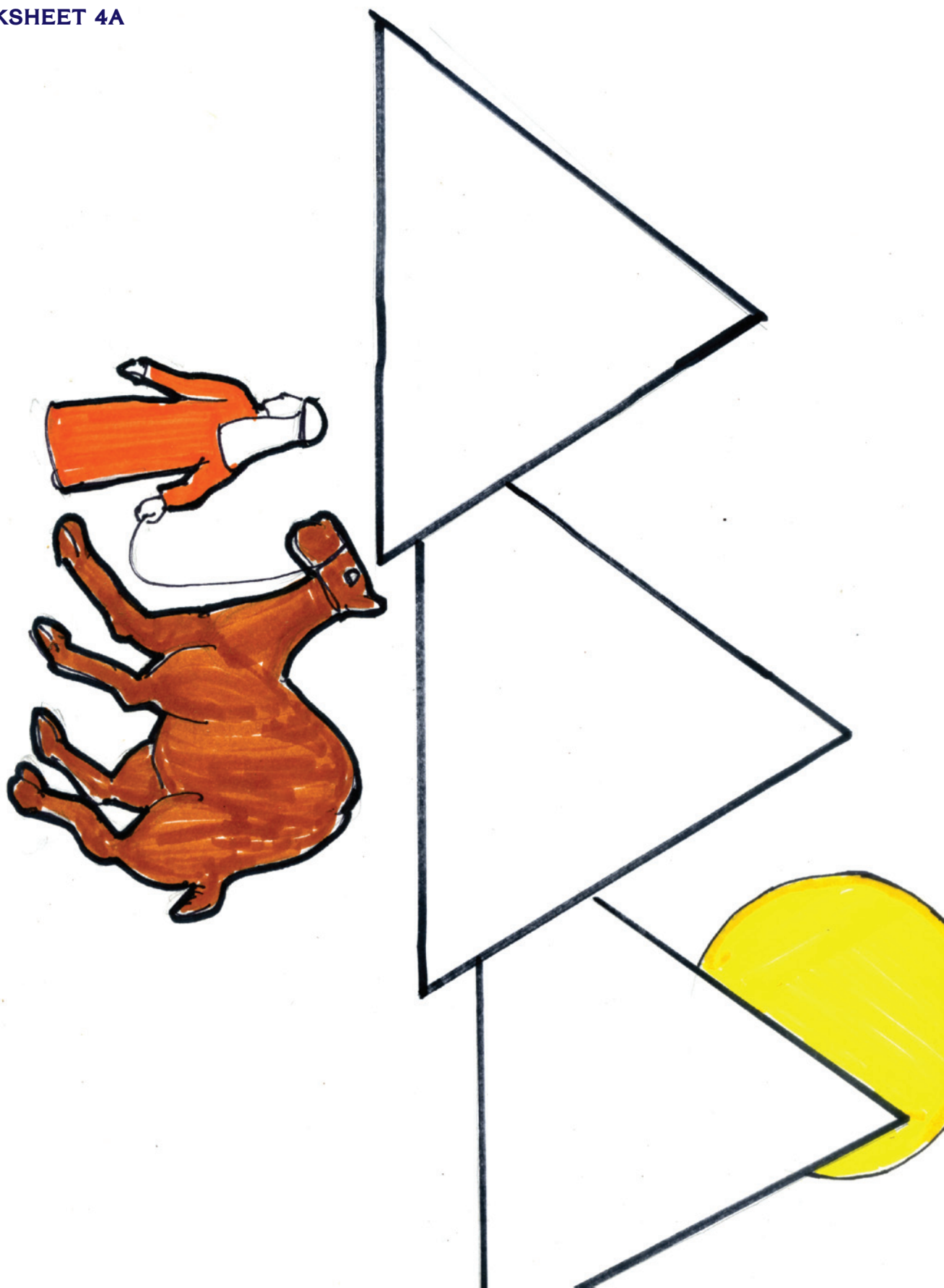
**Green paper = nitrate water**

**Blue paper = clean water**

- Using masking tape or other classroom items, create three boxes in a line on the floor. The first is the fish tank, the second is the biofilter, and the third is the grow bed. Assign students to different roles.  $\frac{1}{3}$  of the students will be fish in the tank.  $\frac{1}{3}$  of the students will be bacteria in the biofilter ( $\frac{1}{6}$  will be nitrosomonas bacteria,  $\frac{1}{6}$  will be nitrobacter).  $\frac{1}{3}$  of students will be plants in the grow bed.
- Give each "fish" a piece of red paper, each "bacteria" a piece of either yellow or green paper (distribute equal amounts of each color), and each "plant" a piece of blue paper.
- Ask the "fish" students to imagine they are fish living in a tank. Have them stand together and "swim" like fish. Ask the "bacteria" students to stand together based on the color of their paper, with yellow closer to the fish and green closer to the plants. Ask "plant" students to stand together and wave their arms like plants in the breeze.
- Explain to students that the papers they are holding represent stages of the nitrogen cycle in an aquaponics system. Explain that in aquaponics, waste water from fish goes through a biofilter, where Nitrosomonas bacteria converts ammonia ( $\text{NH}_3$ ) to nitrite ( $\text{NO}_2$ ). Nitrobacter then converts nitrite ( $\text{NO}_2$ ) to nitrate ( $\text{NO}_3$ ). Plants then suck up the nitrates, and clean water is returned to the fish tank. Then, ask students to act out the nitrogen cycle!
- Each fish, one by one, hands their red paper to a yellow (nitrosomonas) bacteria. The yellow bacteria crumples and discards the red paper, and hands their yellow paper to a green bacteria (nitrobacter). The green bacteria crumples and discards the yellow paper, and hands their green paper to a plant. The plant "uses up the nitrates" and crumples and discards the green paper. They then hand their blue paper back to a fish. Continue until all students have participated.
- Ask students to describe what took place, and to explain the nitrogen cycle and why it is important to both fish and plants.
- Using a large piece of butcher paper, draw the diagram to the right. Have students unfold the crumpled pieces of paper used in the activity and glue them into the appropriate places on the butcher paper diagram. Display diagram in classroom.







## Seafood Assessment Survey

Complete the following form. Ask your family questions as needed to fill in the blanks that you cannot answer.

1) How often do you eat seafood? \_\_\_\_\_

2) What are your favorite types of seafood to eat? \_\_\_\_\_

\_\_\_\_\_

3) Explain the way your favorite seafood smells, tastes, and feels in your mouth (texture): \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

4) What type of seafood do your parents and grandparents like to eat? \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

5) What type of seafood do your brothers and sisters (or cousins) like to eat? \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

6) Where does your family get the seafood you eat from (eg. fishing, the supermarket, a fish market, etc.).

\_\_\_\_\_

7) Seafood is an important part of many cultures, especially in the Pacific Islands. Explain the significance of seafood in your own culture's traditions (if applicable):

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

8) Draw your favorite seafood in the space below



## References

NOAA Fisheries Service:

[www.nmfs.noaa.gov](http://www.nmfs.noaa.gov)

NOAA FishWatch:

[www.fishwatch.gov](http://www.fishwatch.gov)

USDA:

[www.usda.gov](http://www.usda.gov)

NIFA:

[www.nifa.usda.gov](http://www.nifa.usda.gov)

FAO:

[www.fao.org](http://www.fao.org)

CTSA:

[www.ctsa.org](http://www.ctsa.org)

CTSA AQUA website:

[www.pacificAQUA.org](http://www.pacificAQUA.org)

Hawaii Aquaculture Development Program:

[hawaii.gov/hdoa/adp](http://hawaii.gov/hdoa/adp)

"Best Management Practices for Hawaiian Aquaculture" CTSA Publication #148:

[http://www.ctsa.org/files/publications/CTSA\\_1486316728532840802601.pdf](http://www.ctsa.org/files/publications/CTSA_1486316728532840802601.pdf)

"Keeper of the Moli'i Pond" by Vernon T. Sato and Cheng-Sheng Lee. Published in 2007 by the Oceanic Institute.

Contact CTSA to request a copy of the book.

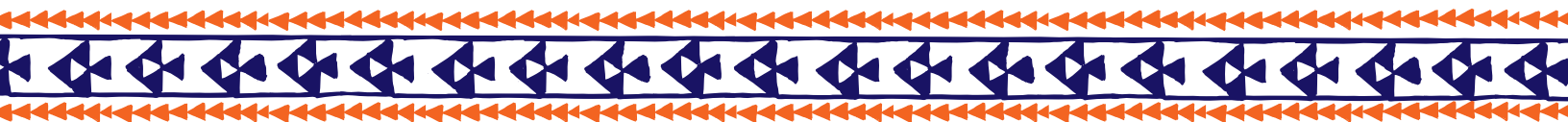
There are many other curriculums that go more in-depth into the study and practice of aquaculture. We recommend that you continue your quest to understand aquaculture with your students.

## Worksheet Answers

### Worksheet 1a

- 1) availability; access
- 2) billion; twenty
- 3) exploited
- 4) ten
- 5) shipped
- 6) aquaculture; seafood
- 7) sustainable

### Worksheet 3a

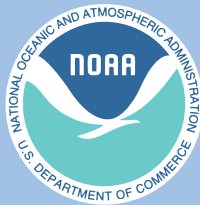
- 1) Earthen; maintenance; polyculture; predation
  - 2) Recirculating; above-ground; culturist; space; increased
  - 3) Open ocean; fingerlings; water quality; ocean currents
- 





A Quest to Understand Aquaculture

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AND  
SUBTROPICAL  
AQUACULTURE



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