TEACHER EDITION

Marine Aquaculture:
Raising Salt Water Fish in Your Classroom

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To the Teacher: Introduction

Marine Aquaculture: Raising Salt Water Fish in Your Classroom is designed as a means for reaching our shared goals of improving student inquiry skills and enhancing knowledge of the life, physical and earth sciences. What is special about this program is that it provides students and teachers with a special opportunity to interact with and learn about one of the key elements of marine resource management today: aquaculture.

This standards-based curriculum is designed to address the 6 - 8th grade-learning standards of inquiry, life, earth sciences, and technology/engineering (as spelled out in the recently revised Curriculum Frameworks for Science and Technology/ Engineering, 2000), as well as standards in mathematics (pending publication). Marine Aquaculture, adaptable to most classroom settings 6 - 8 and high school, provides an exciting opportunity for your students and you to experience:

- the biology of marine organisms, including survival needs that may be modeled for all organisms.
- the importance of posing scientific questions, making accurate measurements, collecting and recording data, mathematically interpreting that data and drawing conclusions from the data
- how technology and engineering interact to help us raise species of importance as food which are also important components in our coastal environment.

The goals, activities, and technology can be easily adapted to high school settings and can be enriched by increased emphasis on mathematics and modeling. In Appendix G, you will find the specific Science and Technology/Engineering and Mathematics standards and the activities of Marine Aquaculture, which address each of those standards. Assessment suggestions are presented. There are sample pre /post-tests in the appendix section that you might like to use as a model for determining your student's overall knowledge of the subject as a result of this series of activities.

The curriculum for Marine Aquaculture is organized into a series of units each with relevant activities. References to the specific Curriculum Framework learning standard(s) are in the Learning Standards and Activities Matrix at the beginning of the curriculum. Within each unit the materials are organized in the following manner:

- Teacher and Student Overviews
- Goal(s)
- Objectives
- Student skills
- Questions to be answered
- Background information on the subject for the activities
- Materials
- Procedure(s)
- Activity set-up and monitoring including suggested data recording sheets and other instructional materials
- Assessment Suggestion

A glossary is included at the end of the curriculum and words included in the glossary are in bold throughout the text. There is also a Resource Guide located in the appendix to give guidance and more detailed information for each unit.

Your comments on this curriculum are invited and encouraged.

Why Marine Aquaculture In Your Classroom?

Background Information:
Massachusetts has a historical connection to the sea, which began even before the first European settlement at Plymouth. The ocean waters off New England were rich with fish that were important enough for European fishermen to travel across the ocean to collect what they could and bring it back to Europe. This harvest included an amazing amount and variety of fish from the sea. Many of these species have been so important that we have named many places and roads after them: Cape Cod, Halibut Point, Alewife Brook Parkway and Herring Cove.

The ocean and the fish that live there are in jeopardy**. Pollution** from our cities and towns, and from individual homes, has increased the amount of chemicals and **bacteria** in our waters to levels that prevent swimming, fishing or shellfishing in these areas. Some of these materials cause changes in **habitat** so that animals and plants that once lived there can no longer survive.

At the same time, many habitats, such as **salt marshes** have been filled in and some **estuaries** have been completed closed off from the sea and become filled with fresh water. The Charles River in Boston, for example, was once an estuary but the dam at the Museum of Science closes off this river from the sea.

The amount of fish we **harvest** from the sea has declined, and some **species** of fish are in such low **populations** that we no longer can catch them in the ocean. Some species are at risk for extinction as they once were very plentiful. The fishermen cannot keep up with the demands simply because there is not enough seafood left in the ocean.

As these changes are taking place, we recognize the dietary benefits from fish consumption. More and more people want to eat fish. They are low in fat, high in protein and many have oils that are very good for our health.

What is Aquaculture?
Aquaculture is a process by which we are able to raise fish, shellfish and plants for people to eat or to release into the wild to help the wild stocks **recover**. People in aquaculture also raise fresh water species of fish. For example, catfish, a very popular fresh water fish, are raised using aquaculture methods in southern United States. Shrimp are raised in such places as the Philippines using tank and pond aquaculture. Some of the lobsters we eat in New England are raised in aquaculture nurseries in Maine and released into the sea. Much of the salmon that we eat in Massachusetts is aquaculture-raised on farms in Norway, Chile, Northeastern and Northwestern United States and Canada.

Our Role:
What can we do to better understand the oceans and the fish that live there? How can we raise some species to help rebuild the wild stocks of fish? What can we do to raise the fish that people want for food?

You will have a chance to answer these questions by being a part of this effort. Welcome to Marine Aquaculture: Raising Salt Water Fish in Your Classroom.

To the Teacher: Preliminary Instructions

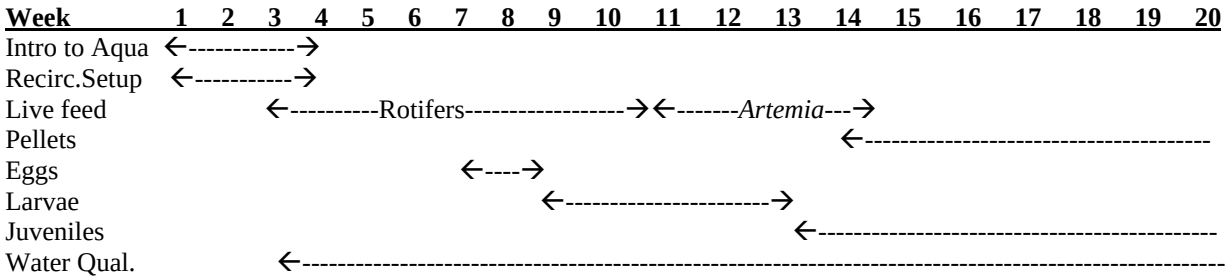
The set-up and rearing of saltwater fish requires attention to a number of details that will allow for a successful project for you and your students. Below is a list of the factors to consider and plan for implementing the Marine Aquaculture program.

1) **Timeline**: From the set-up of the recirculating system to the fingerling size fish (2-4 inches) is anywhere from 3-4 months, depending on the species of fish you choose. Warm water fish will grow much quicker than cold-water fish. The steps include:

A. Setting up the recirculating system (1week) and allowing for the appropriate bacterial colonies to develop (2-4 weeks).

B. Setting up the systems to raise food for the fish (different food for different stages) and having available food for the fish larvae (2-4 weeks). Note: rotifer populations take time to increase their number to the estimated level needed for the fish.

C. Acquiring and hatching fish eggs and raising larvae through the various development stages (3-4 months) to fully developed fingerlings.



You may want to allocate time for pre-set up instruction for the students in discussing why aquaculture is important, how salt and freshwater fish aquaculture are different from each other and the goals of this program. At some point you should discuss with the students how they feel about raising live food to feed the fish and how this relates to the food the fish eat in the wild.

As you can see from the timeline above, many of the activities overlap with each other. This shows how the units can be run simultaneously. It is important to plan each activity/action accordingly.

2). **Location and set-up**: There are three main components of the system that will need space.
a) Raising rotifers and *Artemia* requires an area of countertop with two electrical outlets.
b) The recirculating system for the fish, with the filters (biofilter and particle filter) and work area, will take up a space of approximately 6' x 6'.
c) Also required will be two electrical outlets for the pumps and filtration system.

Be sure to measure the doorways to make sure all equipment (tanks) will fit into the room. The main tank in the system, 100 gallons, is very heavy when it is full with water and is best if placed on the floor or on a very sturdy platform (preferably) and supported by blocks. When ever possible, place your culture tank and storage tanks on the first or ground level of the building.

This will minimize the amount of damage to other floors in the event that there is a spill or leak in the system. Area around the location should be well lit and access to the filters and tanks should be unobstructed.

If you do not have the funding or space to set up a 100 gallon recirculating system in your classroom, there are several other options to running this curriculum with smaller tanks. There are internet sites that will have set up instructions for smaller systems or you may contact MIT Sea Grant for other options.

As students become connected to the project and to the fish, keeping a cover (clear plastic or small mesh netting) on the system to prevent materials falling into the water is recommended. It is also very important to explain to the students that the fish are living creatures that can die. You want to avoid class depression when some of the fish do die because there was something poured in the tank that should not have been.

3) **MIT Sea Grant** will assist in identifying marine fish egg sources and other live organism that can be utilized with this curriculum. A permit is required to hold fish for any aquaculture project. MIT Sea Grant will submit the collaborating school's name onto the Northeast Massachusetts Aquaculture Center's educational permit that allows schools to hold fish thus, the school will not have to submit a separate application**.** To fulfill the permit requirements, the teacher must be able to supply accurate records, detailed student assessment information and evaluation of class projects.

4) **You must also have a plan** set up for what you are going to do with the fish at the end of the school year. MIT Sea Grant can help you with ideas/tank space to house/donate your fish. Plan ahead so there is a course of action for the end of the year. Suggested places for fish:

- Northeastern Aquaculture Center
- MIT Sea Grant
- Western Massachusetts Aquaculture Center
- Universities, colleges and/or community colleges conducting finfish research
- Local Aquarium

5) **Student assessment** is a critical component of this project. Please administer a pre- and post-test or a similar assessment strategy for your students during this project. We have provided ideas for such assessment instruments in this curriculum to be used or to be a tool for creating assessments tailored to a particular class. The results of the assessment work are very important to us. We anticipate compiling the information from the assessments and sharing the results with you and other participating teachers/classrooms.

6) We anticipate that several classrooms will adopt Marine Aquaculture each year. As students from other schools will have shared experiences, we will distribute information about how the schools can communicate with each other via email and other means. MIT Sea Grant anticipates creating a web page with the results from the various schools that will allow for sharing of information among MIT Sea Grant, the schools and the students involved in the project.

7) There are funding opportunities for teachers that are looking to try new curriculum in the classroom. Check with the Department of Education, State agencies, or local businesses that support education.

All questions, comments and concerns regarding the Marine Aquaculture curriculum are both welcome and invited. Please contact:

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Unit 1: Getting Started:
Building the Hatchery

Teacher's Overview:

This section focuses on the understanding of aquaculture and the different types of systems that are used to culture aquatic species. Recirculating systems are the main concentration of this lesson because of their broad application to a variety of subjects and compatibility with environmental regulations. The major components of a recirculating system will be discussed as well as a design and construction of a functioning table size model system. Included are steps on how to select a species to culture in your classroom and where to look for sources of eggs.

Student Overview:

To raise fish in your classroom, you will need to construct a hatchery for fish eggs and a system for helping the fish develop from eggs to a fully developed fish. We will use a hatchery and growout system that uses water over and over again. This is called a **recirculating system**. This system helps us comply with environmental laws meant to protect water quality while at the same time it provides a clean and healthy growing environment for the fish. Now let's develop an understanding of aquaculture and the different types of systems that are used to **culture** saltwater fish species.

Goals:

- To select a suitable marine finfish species to be cultured in the classroom
- To construct a recirculating aquaculture system that can support marine finfish larvae

Learning Objectives:

- Investigate the possible marine fish that could be selected as the cultured species
- Develop communication skills by discussing the identification of life-history requirements for the marine fish chosen by the class to culture
- Discuss and describe components of a recirculating aquaculture system
- Calculate tank size, water requirements, light requirements, salinity, etc.
- Design and construct a recirculating hatching system
- Trouble shoot any problems with the operation of the system
- Understand the importance of maintaining a recirculating system
- Develop a fundamental understanding of the natural life-history for marine fish
- Understand how the compact recirculating system mimics the chemical, physical and biological process of nature

Skills:

Describing	Creative thinking
Building	Cooperative problem solving
Calculating	Researching

Key Concepts/Terms:

- Recirculating systems
- Culture
- Life history
- Spawning
- Particulates
- Discharge
- Aquaculture
- Bottleneck

Questions To Answer:

- What species of saltwater fish are appropriate to culture in the classroom?
- What are the life histories of these species?
- What type of tanks, filtering, and water quality is needed to culture salt water fish in our classroom?
- What is a **recirculating system** and how will that work in our classroom?
- How is the recirculating system a **model** for what happens to the chemical, physical and biological processes of the ocean?

Background:

Aquaculture is a science that has been studied for thousands of years in Asia and Europe but did not begin in the United States until the mid 1800s. Eighty percent of aquaculture that is practiced in the U.S. is in freshwater. The main focus of aquaculture has been on the **growout** phase**,** which is when fish increase from a **fingerling stage** to **market size**. Due to the very small numbers of fingerling suppliers for saltwater fish, **marine fish** hatcheries are becoming more important in the United States. A **hatchery** is a place where fish eggs are hatched into larvae. The larvae continue growing and go through a developmental stage called **metamorphosis**. Once this stage has past, the fish are considered juveniles. Metamorphosis is the most difficult life stage for any species. This critical point during development, or **bottleneck**, causes high mortality in the larvae. Because of this delicate life stage, special notice must be given to the type of system that is developed to hold these fish.

There are several types of systems in aquaculture: tanks, recirculating systems, cages, pens and ponds. Recirculating systems are the most environmentally friendly method of aquaculture. This is because only a specific amount of water is needed and that water is recycled by the system's components. Only a small amount of water replacement is needed in a functioning system on a routine basis to control evaporation and nitrogen levels. Recirculating technology is a great technique to be used in any situation where there is a minimal source of quality incoming water and there is the need for minimal **discharge** from classrooms and demonstration facilities.

The system you will set up in class will allow you to focus on each of the bottlenecks that occur during larval rearing: egg holding, hatching, and rearing larvae through metamorphosis to juveniles. Raising food for the newly hatched fish, weaning fingerlings onto dry feed and raising the fingerlings to market size will also be learned.

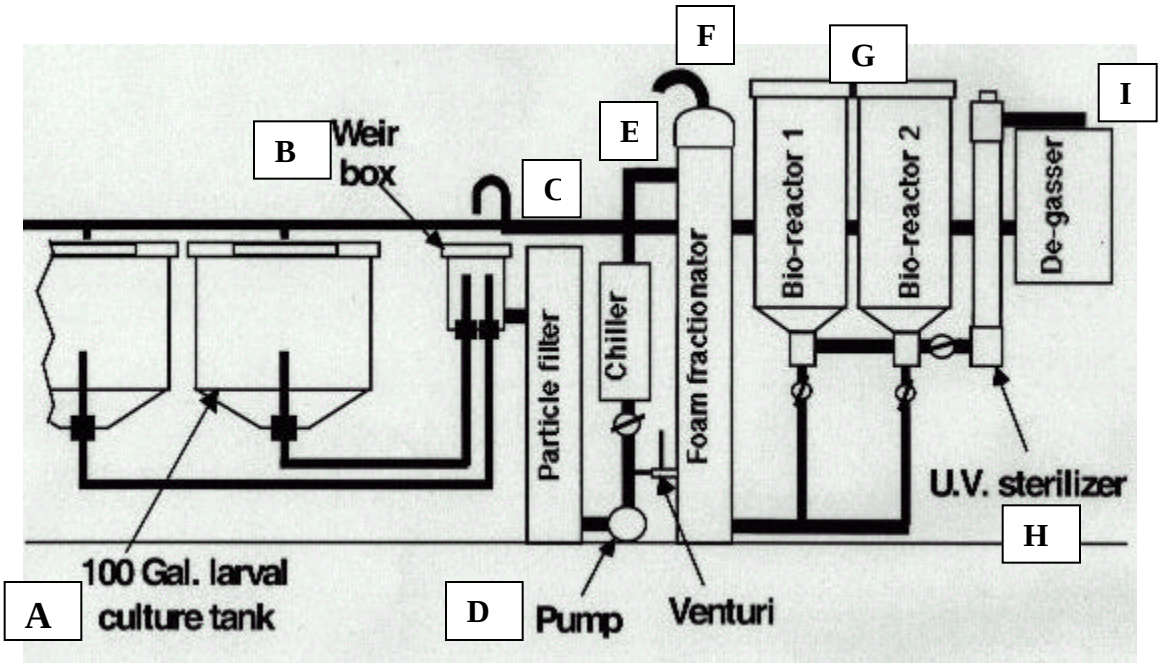
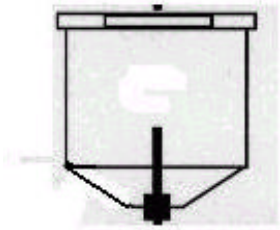


Figure 1: Schematic of a recirculating system.

Recirculating systems need to have the following components to allow for the maximum reuse of the culture water:

A. Tank

Figure 2: Tank in a recirculating system.



Tanks provide a living environment for the fish eggs/larvae/juveniles. Tanks can be any shape and size depending on the space available. Circular tanks are best because they encourage good water circulation and waste removal. Tanks must be dark in color (preferably black). The tank walls need to be smooth for easy cleaning and minimize the amount of available surface area for bacteria growth. A central drain in the bottom of the tank is needed for the waste to be flushed out of the tank. The size of the drain screen should be small enough to keep the larvae or fish in the tank and large enough to let out waste and debris.

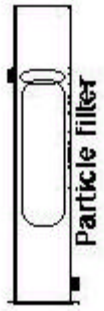
B. Weir Box/Settling Box

Figure 3: Weir Box/Settling Box

This box is used to collect large pieces of waste (excess feed, feces). The water flow slows down in this box which allows the larger particles to sink to the bottom. This box reduces the amount of particles that enter the filter bag. This is important in a large system with a lot of waste products.

C. Mechanical /Particle Filtration:

Figure 4: Mechanical/particle filtration for a recirculating system.



The larvae will eat live food that you will raise and eventually a dry pellet. The excess feed that is placed in the tanks needs to be filtered out of the water so the water can be reused. For hatchery systems, the filter must be capable of filtering the water down to 25 microns to ensure proper water quality in the sensitive larval stage. A felt or fabric bag that can filter is ideal for larvae that are feeding on live feed. Once the fish are feeding on dry pellets, the filtration can go up to 50 microns. It is important to design the system so that the filter is easily accessible because it will need to be cleaned on a routine basis.

D. Pump

Figure 5: Pump in a recirculating system.

A pump is needed to drive the water through the system. The pump is always located after the mechanical/particle filtration so that the water passing through is free of particles and will not clog the pump.

E. Chiller

Figure 6: Chiller

A chiller is used to control the temperature of the system. Chillers can be plumbed into the system or a titanium chiller coil can be placed in the bottom of the filter box.

F. Foam Fractionator

Figure 7: Foam Fractionator

A foam fractionator removes dissolved organics, proteins and small particulates out of the water. Water flows down the column as air moves up through the water column. As the air bubbles rise to the top of the water column, the particles and proteins bind to the bubbles and create a foam. The foam can be directed to exit the foam fractionator at the top by creating a directed opening such as an elbow. After the water leaves the foam fractionator, it should be free of all particles.

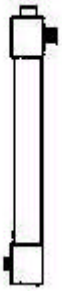
G. Biological Filtration

Figure 8: Biological filter in a recirculating system.

Once all the particles are removed from the water, the water can be pumped into a biological filter. This component of the system should be scaled to the amount of fish you are holding in your system because its purpose is to remove the ammonia and nitrite created by the waste of the fish and excess feed. A variety of plastic materials are available to be uses as bio-media. The bio-media provides surface area for the nitrifying bacteria to populate. The more surface area available for the nitrifying bacteria, the more ammonia it can break down.

H. UV Treatment

Figure 9: UV filtration in a recirculating system.



Ultraviolet light (UV) treatment assists in the control of "bad" bacteria and viruses in the system. Water passes through a UV light, which will minimize the amount of bacteria or viruses present in the water. This completes the cleaning process of the recycled water.

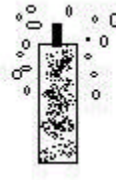
I. Degassing Column

Figure 10: Degassing Column

The degassing column is used to strip the excessive buildup of carbon dioxide and nitrogen that occurs in a continuously recycled system out of the culture water. The water enters the top of the column and bounces down through the large plastic media that is inside the column. As the water bounces through, it comes in contact with the air and the excess carbon dioxide and nitrogen dissipate into the air. The water becomes properly oxygenated and can be distributed back into the system.

Aeration for System

Figure 11: Airlines and airstones in a recirculating system.

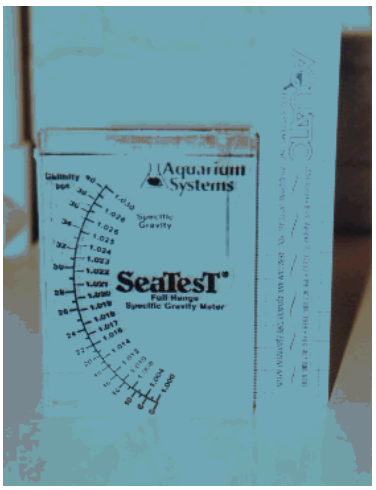


Each culture tank as well as the biofilter needs an airline with an air stone or perforated ring attached. Aeration is important to create an up-welling motion in the culture tank for the eggs and larvae. Also it helps maintain the system's dissolved oxygen level and agitation in the biofilter media.

Storage for Salt Water:

You should check with your water treatment plant to see if they treat the water with chloramine. **Aerating** the tap water for 24 hours will remove chlorine treated water, but not chloramine. To rid the water of chloramine, you need to add a water treatment to the water that will remove the chloramine. This can be purchase at any store that sells water quality test kits. After you have treated your water, you can then mix in sea salt to make up saltwater for your hatching system. One airline and air stone per storage tank is sufficient. Any plastic container such as a garbage can or vat can be used. Storage tank should be able to hold at least 50 gallons of mixed saltwater.

Hydrometer (salinity meter)



This tool has the ability to read salinity do the nearest 1.5 ppt (parts per thousand). A hydrometer measures the specific gravity of the seawater and tells us what the salt concentration is in the water. Open ocean seawater is approximately 34 parts salt per thousand (or 3.4%) but many fish can live in or tolerate higher and lower salinities.

Figure 12: Illustration of a hydrometer. Hydrometers measure the salinity of water.

<u>Activity #1</u> What species of marine fish can we culture in our classroom?

Objective:
To research and identify life history requirements for marine fish that are suitable for culture.

Materials:
Library and/or Internet access
Notebook
Fish for Aquaculture, Fish Descriptions Appendix B
Classroom space for the hatchery system

Key Concepts/Terms:
- culture
- life history
- spawning

Procedure:
You have been hired to start a marine fish hatchery research station. A space in the classroom has been set-aside for you to build this station and then to maintain it. You will be given a list of species of fish that might be good to culture in your hatchery. Choose one of these fish species and research its **life history** (where it normally lives, its **spawning** season, and what are its temperature, salinity, light, and feed requirements). Also find out if this fish has been raised previously in aquaculture.

Post all your information on the chart provided. Be prepared to discuss with your class why you think your fish is or is not a good candidate for aquaculture in **your** classroom.

Assessment Suggestions:
1) Have students choose a fish from the list and write down what they know about the fish and why they chose it to do research on. After researching the fish, have them complete the chart and compare their pre- and post-research knowledge of the fish.
Ask them why they thought their original choice would be a good candidate for aquaculture and find out how they feel after they have research their species and why.
2) Create a matching list quiz of fish species and requirements. Have students complete the quiz in a pre and post format (before and after doing the research and classroom sharing of information).

See fish descriptions in the Appendix B

Fish For Aquaculture:

Name of fish species (include scientific name)

Native home range

Spawning Season

Requirements for Survival

temperature	
light requirements	
salinity	
egg incubation time	
feed requirements	
life stages and life history	
other important information	

Activity #2 Where can you hatch a fish?

Objective:

The goal of this section is to construct a recirculating hatchery system for raising fish and to understand its components. This activity will guide the class through the process of building a marine fish culture system. A 100-gallon recirculating system will be the incubator for the **larval** production and can be used for later stages of fish growth.

Key Concepts/Terms:

- larvae
- recirculating systems

Specific instruction will be given by your teacher.

In general, you will need to:

1.) Gather materials needed. Order supplies if necessary.
2.) Set up a time line for the construction of your recirculating system.
3.) Designate teams for different parts of set up.

Only the teacher is provided with the supply/parts list and the instructions for the construction of the recirculating system. Students should be given specific tasks while assembling the system.

STEP-BY-STEP DIRECTIONS ON CONSTRUCTING A TABLE-SIZE RECIRCULATING SYSTEM

Materials:

Parts, Vendors and Price List for Table-Size Model

Item	Supplier	Stock #	Price
Culture Tank, black, 100 gal.	US Plastics	4157	200.27
Tank drain, 1-1/2 "	AES	CV4S	1.65
Tank bulkhead fitting, 1-1/2"	AES	BKF6	6.60
Filter bulkhead fitting, 1-1/2"	AES	BKF6	6.60
Celcon filter holder	AES	FBH	23.45
Filter tank, 15 gal. rectangle	US Plastics	10116	36.11
Filter bag, 25 micron	AES	FB25	5.25
Filter outlet fitting, 1"	AES	BKF4	5.85
Circulation pump, 6 gpm	AES	MD3	48.95
UV Sterilizer, 15 watt	Aquacenter	UV15	138.00
Bio-filter tank, 20 gal. rectangle	US Plastics	10117	42.96
Bio-filter drain, 1-1/2"	AES	CV4S	1.65
Bio-filter bulkhead fitting, 1 _"	AES	BKF6	6.60
Bio-media, 1 cu.ft.	Water Mgmt. Tech.	KMT/Purac	25.00
Aerator	TFP	QP0005	48.99
Hydrometer	TFP	AS0043	6.99
Water quality test kits	TFP	AO0076	22.49
6 - Air stones	AES	AS2	1.48
Airline tubing	AES	TP30-HD	12.00
Sea salt	TFP	ASO120	34.99
400-600 micron screen	Aqua. Supply	B-PES400	15.75
by the yard		B-PES500	15.10
		B-PES580	20.35
		Total	727.08

1 or 2 - Saltwater mixing/storage tanks, any type of 50-gallon container (barrel, garbage can, etc)

Find the following at any hardware store:
1 – _" x 2" threaded nipple
1 – 1" T with _" threading
1 - 1 _" cap
2 – 1" ball valve
3 – 1" bulkhead fittings
1 – 1" bulkhead fitting
6 – 1" male adapter
4 – _" – 1 _" hose claps
1 – 1 _" street elbow
1 – 1 _" male adapter
4 – 1 _" elbow
1 – 1 _" rubber connector

1 – 1” female adapter
1 – 1 _” crossover
2 – 1 _” to 1” bushing
2 – 1” – _” bushing
1 – _” ball valve
2 – 1” elbow
10” of 1 _” I.D. tubing

PVC
3 feet of 1” PVC pipe
7.5 feet of 1 _” PVC pipe
1 feet of _” PVC pipe

Tools Needed
Hole saw bits 2 3/8” and 1 5/8”
Utility knife
Wrench
Drill with 3/8” bit

Hints: always put 2 layers of Teflon tape around any threaded fittings before connecting to ensure a tight seal.
Always sand down edges of PVC before gluing with PVC glue to make sure the glue sticks to the surface.

Step by Step:

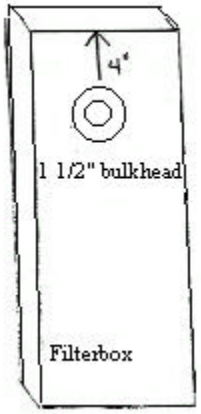
Tank:

1.) Drill a 2 3/8" hole in the center of the bottom of the tank with a hole saw.
2.) Trim around the hole with a utility knife, inside and out. This will remove rough edges created by the saw that might prevent the bulkhead from fitting correctly.

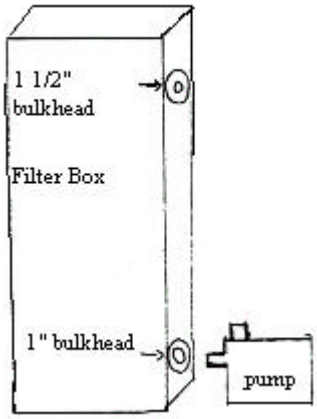
3.) Put the 1 _ " bulkhead fitting in the hole with the rubber gasket inside. Tighten with a wrench.
4.) Put the tank on blocks of wood or cement so the connection from the tank is the same height as the filter box. Support the tank evenly around the perimeter of the tank.

Filter Box:

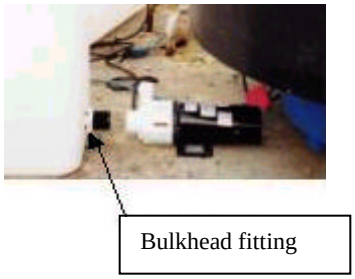
5.) Measure 4" down from the top of the filter box, mark. Center a 1 _ " bulkhead fitting, mark. Use a hole saw with a 2 3/8" bit to drill a hole on the mark. Cut out the rough edges inside and outside of the hole with a utility knife.



6.) Put a 1 _ " bulkhead fitting with gasket inside the filter box. Tighten with a wrench.



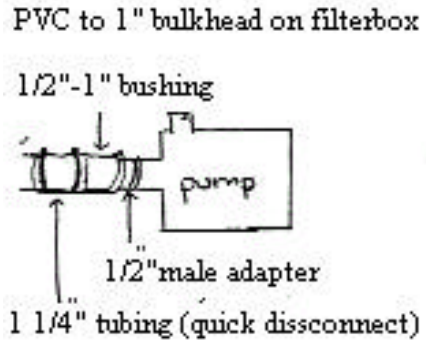
7.) Place pump on the ground and measure where the outlet hits the filter box. Center the mark and use a hole saw with a 1 5/8" bit to drill a hole for the 1" bulkhead fitting. Again, use utility knife to cut out the rough edges inside and outside of the hole. Put the 1" bulkhead fitting in the hole with the rubber gasket inside the box. Wrench tight.



Connection:

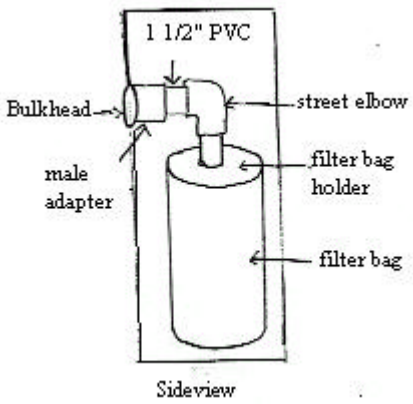
8.) Connecting the pump to the filter box:

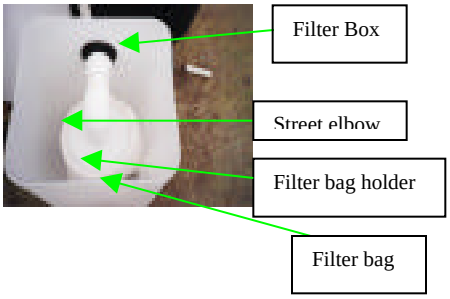
- Cut two 2 _ " pieces of 1" PVC
- Connect the two PVC pieces with a 1 _ " inside diameter (I.D.) tubing cut to 4 inches in length. This will create an easy disconnect to maintenance the pump or disassembly for storage. This is also called a homemade rubber coupling.
    - Use _ -1 _ " size hose clamps to create a tight seal around the tubing and the PVC. Tighten with screws facing up.
    - Screw a _ " male adapter into the intake of the pump. Glue a _ " x 1" bushing to the _ " bushing.
    - Attach the 1" PVC homemade rubber coupling to the 1" male adapter from the pump and to the 1" bulkhead fitting on the filter box.



Filter Bag:

9.) Attach a 1 _ ” street elbow to a 1 _ ” male adapter. The male adapter screws into the filter bag holder. Now attach a 4” piece of 1 _ ” PVC to the elbow. Glue this connecting with PVC glue. Screw a 1 _ ” male adapter into the bulkhead fitting that is in the inside top of the filter box. Attach the 4” piece of PVC of filter bag holder to the male adapter. Glue these parts together with PVC. 25-micron bag fits around the filter bag holder and hangs within the filter box.

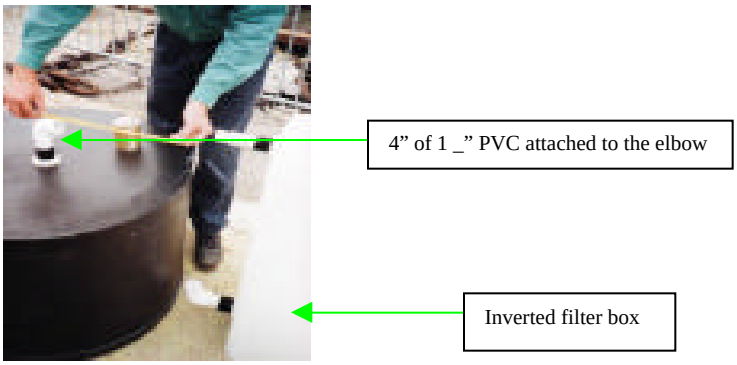




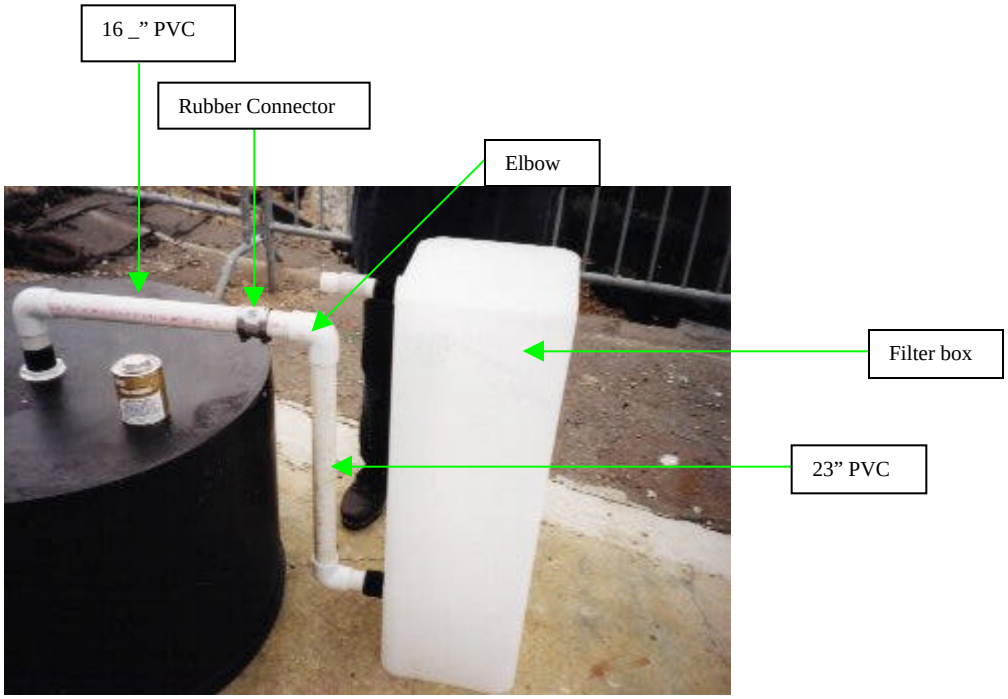
Connection:

10.) To attach the filter box to the tank:

- Turn the tank and filter box upside down and set them on a level surface.
- Glue a 4” piece of 1 _ ” PVC into the bulkhead on the bottom of the tank.
- Glue a 1 _ ” elbow to the 4” piece of PVC



- Glue a 16_ ” piece of 1_ ” PVC to the elbow horizontally out to the edge of the tank.
- Attach a 1 _ ” rubber connector to the end of the 16 _ ” PVC
- 4” piece of 1 _ ” PVC attaches to the end of the rubber connector
- Glue a 1 _ ” elbow to the end of the 4” PVC
- Attach a 23” piece of 1 _ ” PVC to connect the tank and the filter box. Glue.



Setting up:

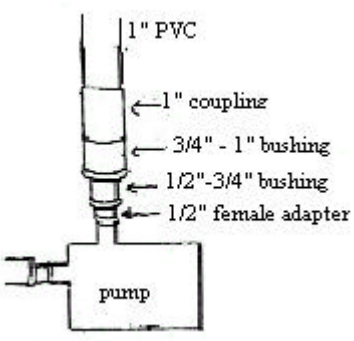
11.) Disconnect the rubber connector and turn tank and filter box right side up. Reconnect the connector once the tank and filter box are upright and stabilized.

12.) Put the tank on blocks/table so that it sits 10 _" off the ground.

13.) Tighten rubber connector, screws facing out. This is another quick disconnect for the system.

Pump:

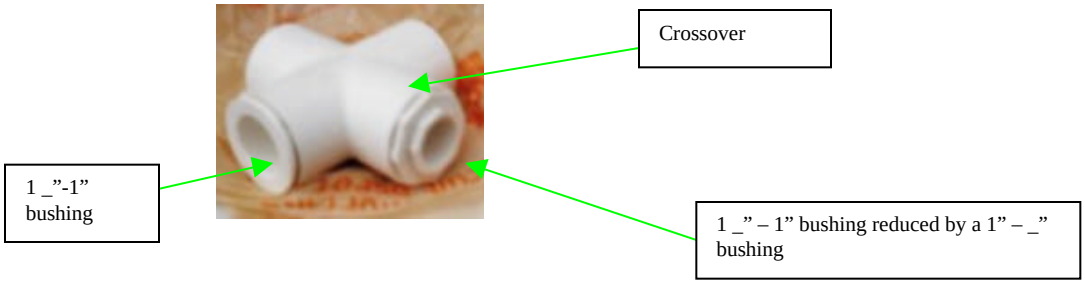
14.) Screw in a _ " female adapter to the vertical discharge of the pump. Glue a _ " x _ " bushing to the _ " female adapter. Then glue a _" x 1" bushing to the _" x _" bushing. Now attach a 4" piece of 1" PVC to the coupling.



Crossover:

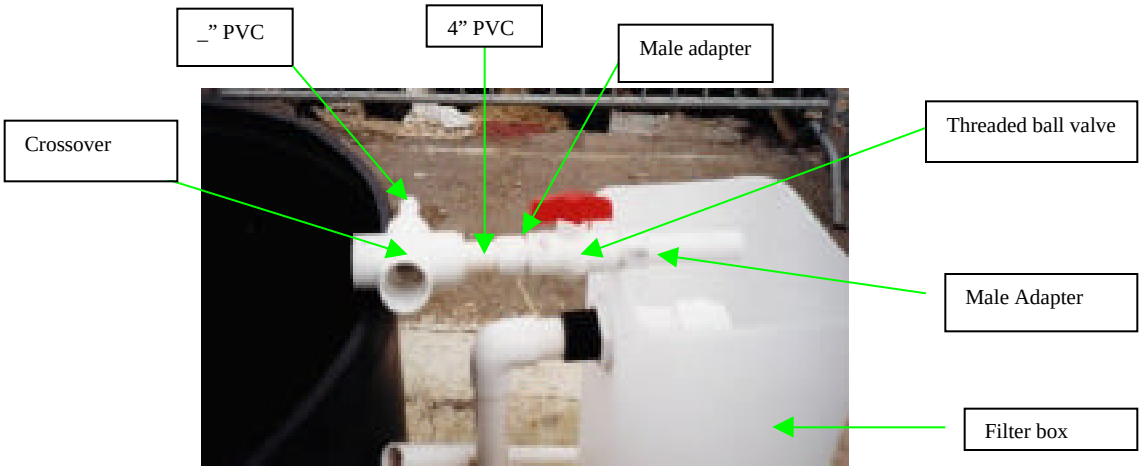
15.) Assemble a 1_ crossover

- Reduce one end to 1” by adding a 1 _” to 1” bushing. Glue these fittings.
- Reduce another end that is next to the one you just reduced to a _” by adding a 1 _” to 1” bushing inside the crossover. Glue. Then add a 1” to _” bushing inside that. Glue.



16.) Connect a 4” long piece of 1” PVC to the 1” outlet of the crossover. At the end of the PVC, attach a 1” male adapter. Glue. Connect a 1” threaded ball valve to the end of the PVC. A 1” male adapter screws in on the other side of the valve. Attach a 2” piece of 1” PVC onto the other end of the male adapter. This will be an overflow back into the filter box. Attach a 1” elbow to the end of the PVC and direct it into the box.

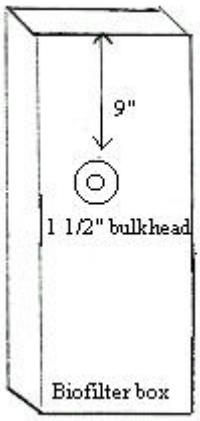
Connect a 4” piece of _” PVC to the _” outlet on the crossover. Glue.



Biofilter Box:

17.) Preparing the biofilter box:

- 9” below the top of the biofilter box, drill a 2 3/8” hole with a hole saw. Cut out rough edges with a utility knife. Attach a 1 _” bulkhead fitting, gasket inside the box.
- Attach a 4” long piece of 1 _” PVC to the outlet of the bulkhead on the biofilter box. Glue.



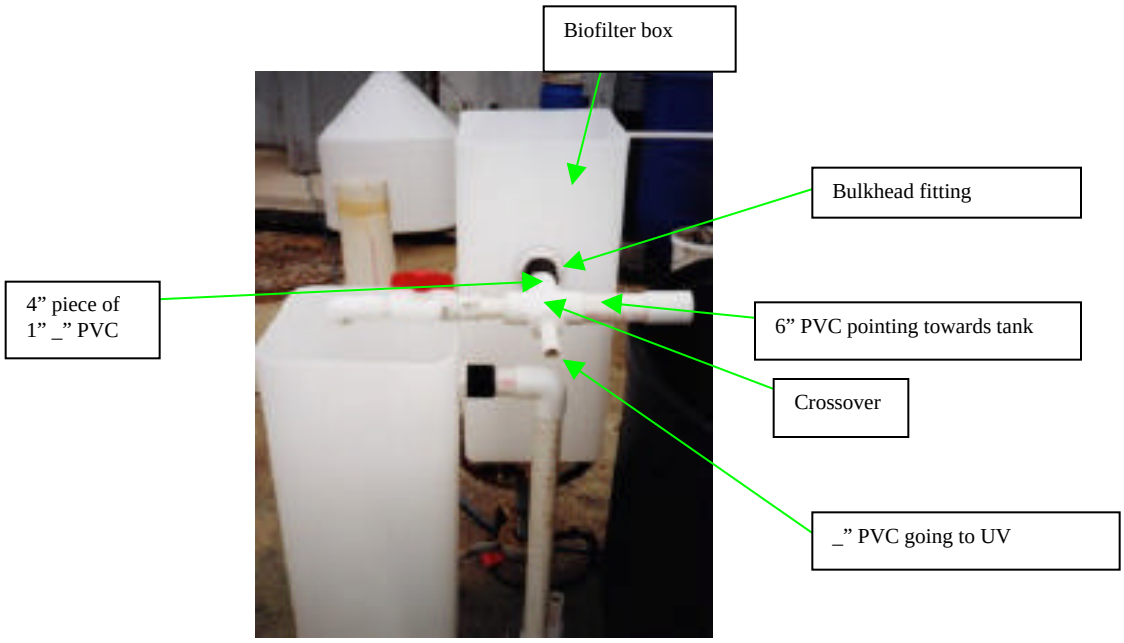
Connection:

18.) Attach the crossover to the biofilter box

- Attach the 4” piece of 1 _” PVC to the crossover (opposite side of the _” outlet in the crossover). Glue.

19.) Biofilter box should be supported 18” off the ground. Use a table or stool.

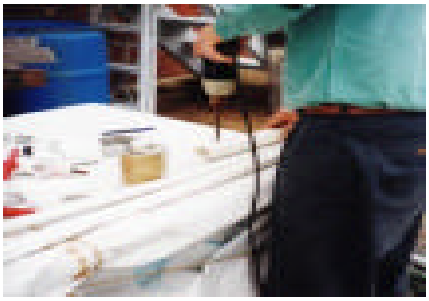
20.) A 6” piece of 1 _” PVC attaches to the crossover that points to the tank. This is your flow to the tank. Put a 1 _” elbow at the end of the PVC and use this to direct/control the flow to the water into the tank.



Spray Bar:

21.) How to make a spray bar:

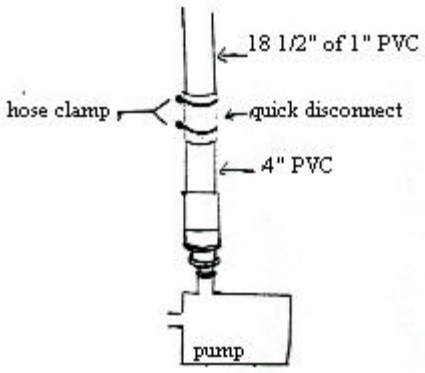
- Use a 4” piece of 1 _” PVC with a 1 _” cap on the end. Use a 3/8” drill bit to drill holes every _”. Scrap out rough edges. This spray bar can be attached to the end of the crossover that is pointing toward the tank instead of the elbow when the fish are feeding live feed. The spray bar will be beneficial in two ways; as the water sprays, it comes in contact with the air creating more oxygenated water and it creates less turbulence in the water column. This is important to during the larval stage because the fish cannot tolerate a lot of movement.



Connection:

22.) Pump outlet to biofilter box and UV:

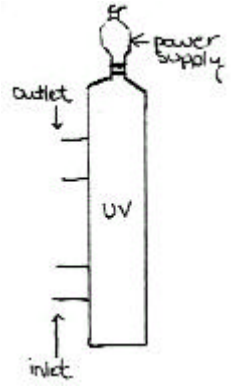
- Cut a 4” piece of 1 _” (ID) tubing for a quick disconnect. Put tubing on the end of the 4” piece of PVC coming out of the vertical discharge of the pump. Use hose clamps to tighten the fit.
- Attach a 18 _ ” piece of 1” PVC to the top of the tubing. Use hose clamp to secure the fit.

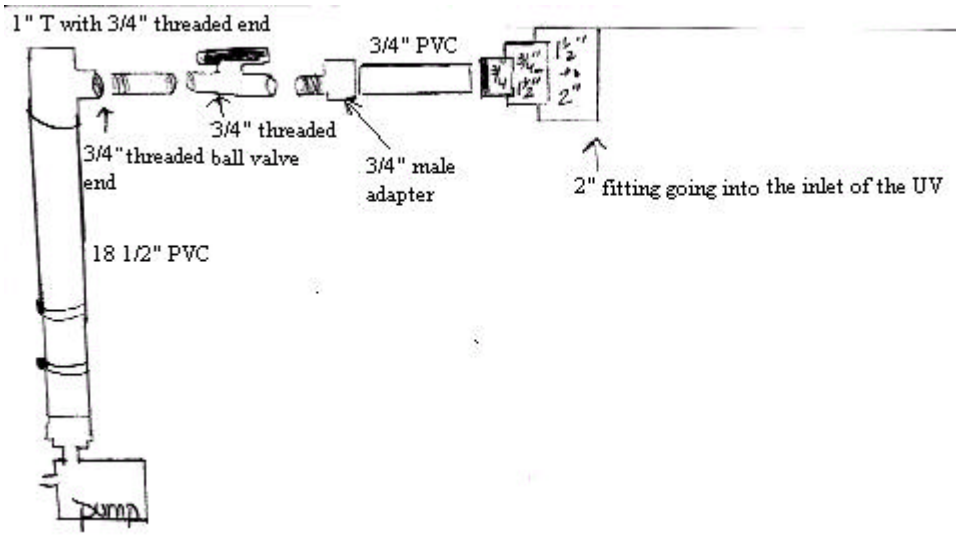


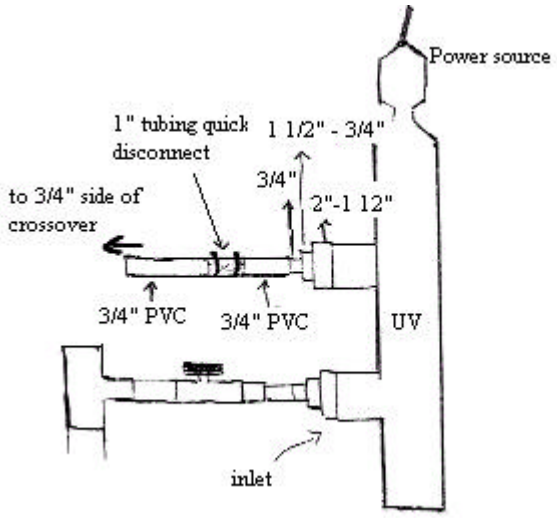
UV:

23.) To the UV:

- Attach a 1” T with a _” threaded end to the 18 _” PVC coming out of the vertical discharge of the pump. Screw a _” x 2” long threaded nipple into the T. Now screw the other end of the nipple into a _” threaded ball valve. A _” male adapter screws into the other end of the valve.
- Cut a 2” piece of _” PVC to slip into the inlet of a 3/4” bushing. Now attach that to a _ ” x 1 _ ” bushing. And finally attach that to a 1 _ ” x 2” bushing. The 2” adapter will now fit into the inlet of the UV. Be sure to glue all fittings.
- Attach another series of bushings to the outlet of the UV: 2” x 1 _ ” bushing to a 1 _ ” x _ ” male bushing to a _ ” bushing. Glue all fittings.
- A 3 _ ” piece of _ ” PVC is glued to the male adapters outlet of the UV.
- Create a quick disconnect by using a 2” piece of 1” ID tubing and attach to the PVC coming out of the outlet of the UV. Use a hose clamp to secure.
- Connect a 4” piece of _ ” PVC to the other side of the tubing and connect to the outlet of the crossover.


power supply
outlet
UV
inlet

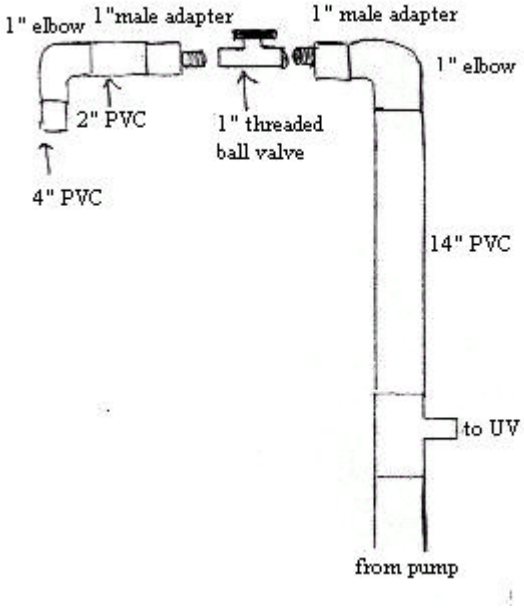

1" T with 3/4" threaded end
3/4" PVC
3/4" threaded
3/4" threaded ball valve end
3/4" male adapter
2" fitting going into the inlet of the UV
18 1/2" PVC
pump


Power source
1" tubing quick disconnect
1 1/2" - 3/4"
3/4"
2"-1 12"
to 3/4" side of crossover
3/4" PVC
3/4" PVC
UV
inlet

Connection:

24.) To Biofilter box:

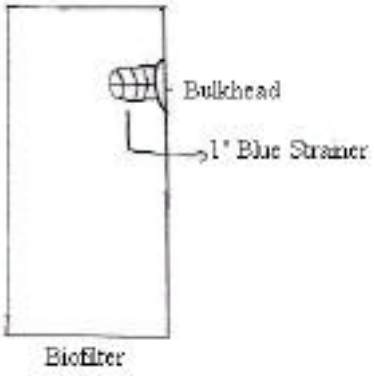
- Connect a 14” piece of 1” PVC to the top of the T that is connected to the pump vertical discharge and the inlet of the UV. Glue.
- Attach a 1” elbow to the top of the PVC.
- Attach one end of a 4” piece of 1” PVC to the elbow and the other end to a 1” male adapter. Screw male adapter into a 1” threaded ball valve.
- On the other end of the valve, screw in a 1” male adapter.
- Connect a 2” long piece of 1” PVC to the male adapter.
- Attach a 1” elbow and direct into the biofilter box.
- Attach a 4” piece of 1” PVC to the
- end of the elbow to direct water down.

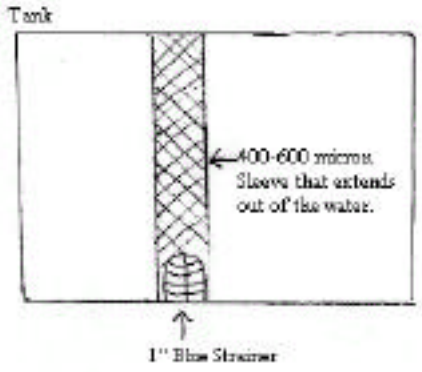


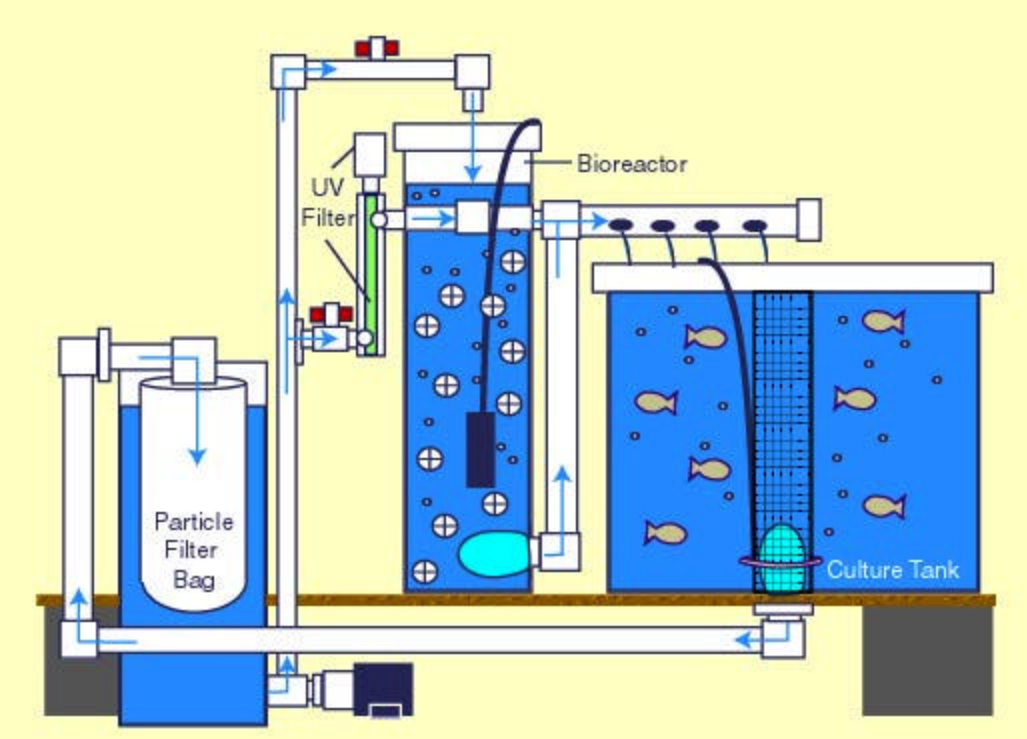
Final Steps:

25.) Screw in 1” blue strainers into the bulkhead in the bottom of the tank and inside the biofilter box’s bulkhead fitting.

26.) Put a 400-600micron sleeve over the strainer in the tank. This will prevent larvae from getting flushed out of the tank. Once the fish are large enough to not slip through the 1/8” slots of the blue strainer, the nylon sleeve may be removed.







Schematic line drawing of table top system

System for Travel/Storage:
The table size system can easily be broken down into 4 manageable parts. Disconnect each "quick disconnect" connection by loosening the hose clamps and taking the PVC out of the tubing. All parts of the system fit nicely inside the 100-gallon tank. This lends itself to easy storage and transferability.

Filling the Tank:

When you fill the system, start with filling the tank first. Fill the tank just to the lip of the tank or 2 inches below the top of the tank. Next, fill up the filter box to just above the elbow. Then fill the biofilter box to just above the blue strainer. The system should now contain enough water to allow the pump to work effectively. Plug in the pump and the UV. If the filter box starts to get drained of water (below bag holder ring), add water to the filter box.

Test the water level of the system by unplugging the pump. If the tank overflows, you need to remove water from the system. You want to be able to maintain your water level in the tank if you have to unplug your pump.

Assessment Suggestions:

1) Given pictures of each of the modular elements in the recirculating system, students will place the pictures in the proper order and describe the function of each section of the system.
2) Given a list of each of the modular elements of the recirculating system, students will draw the proper sequence of steps in order and label what happens at each step.

Unit 2: Getting Your Hatchery System Up And Running: Instructions On Maintaining Your Recirculating System

Teacher Overview:
This section provides guidance on setting up and maintaining the constructed table top hatchery system. The main focus is conditioning the system and the importance of distinct culture methods for different developmental periods.

Student Overview:
The next component of marine aquaculture is to set up and maintain the table top hatchery system. Our first step is conditioning the system. We also need to explore how each stage in fish development is distinct and what we need to do to culture the fish at each stage in its development.

Goal:
To maintain a system which can support the lives of fish from eggs to adults and balance the physical, chemical and biological factors necessary for fish to thrive.

Learning Objectives:
· Gain experience in conditioning and maintaining a recirculating hatchery system
· Measure flow rates
· Measure salinity and chlorine levels

Skills:
Calculating	Estimating
Measuring	Observing
Communicating	Cooperative problem solving

Key Concepts/Terms:
- conditioning
- salinity
- flow rate
- larvae

Questions to Answer:
· What environmental conditions can we control using a recirculating system for raising fish?
· How do we set up a recirculating system that is best for the progression from larvae to fully developed fish?
· What care and environmental factors are necessary when we first receive fish eggs?

<u>Activity #3</u> How do we condition the tank to prepare for fish eggs?

Objective:
To prepare the tank to receive the fish eggs.

Materials:
Completed set up of recirculating system
Biomedia
Fresh water
Sea Salt (Instant Ocean)
Hydrometer
Chlorine Test Kit
Thermometer

Key Concepts/Terms:
- condition
- salinity
- chloride levels
- bio-media
- siphon

Procedures:
Once you have built your recirculating system, be sure the tank is completely supported by blocks, table, and that the biofilter is on a secure platform. This precaution is necessary because when you add water to your system, you are also adding a lot of weight. You must make sure that the system will not be unstable and break.

Once the recirculating system is set up in the classroom it is time to clean out any dirt and get the saltwater ready to support the eggs and larvae.

<u>Cleaning the System:</u>
1) Fill the tank, biofilter box and filter bag box with freshwater from the tap. Be sure to put the 25-micron bag on the filter ring in the filter box; this will collect any debris that is present in the system as a result of construction.
2) Plug in the pump. Do not plug in the UV light. There is no need to UV the freshwater you are running through your system because you are only trying to clean out the tank, pipes and compartments. Let the system run with freshwater for 24-48 hours so you can clean out any debris and observe any potential leaks or mechanical failures. Once you have tested the system and are sure it is functioning properly, unplug the pump and drain the freshwater into a bucket or siphon it into a sink. Remove the 25-micron bag; turn it inside out and rinse it clean. Place bag back in the system.

<u>Preparing Your System:</u>
3) Measure the amount of salt mix and freshwater needed to create the proper salinity for the fish. Mix them together well so the salt dissolves in the water. This should be done in a separate

clean storage container. Add an airstone to the water and aerate for at least 24 hours. Be sure to test the **salinity** and the **chlorine** level before adding the seawater to the system. If your water treatment center uses chloramine to treat the water, you will need to condition the freshwater by adding a chloramine remover. Both of these water conditioners can be found at any aquarium supply store where water quality kits are sold. Follow the manufacture directions for each product. Chlorine and chloramine should be absent in your make up water and the salinity should match the life history requirement of the fish. Add more freshwater and/or salt mix to gain the appropriate salinity for your fish.
4) Add the biomedia to the biofilter box.
5) Transfer the seawater over to the hatchery system by buckets or by siphoning. Fill the tank to 2 inches below the top; fill the filter bag box to 1 inch above the plastic ring; and fill the biofilter box to 1 inch above the blue strainer. Turn on the pump and the UV. Add water, if needed, to the filter bag box until the water is flowing properly through the whole system.
6) Be careful not to overflow any compartments of the system. If this occurs, remove a few liters of water from the tank until the overflow stops. Put two (2) air stones in the biofilter box and turn on full power. The air will create an upwelling motion and keep the biomedia agitated within the box. If the aeration is not high enough, the media will just float in the box and its surface area and performance will not be maximized. If you cannot get the movement of the biomedia that is necessary, remove some of the media until it is in motion. Do not take out more than one third of the media. You can also add another airstone to the box to provide more aeration for the upwelling motion.

Conditioning the Biofilter

7) Before adding any marine animals to the hatching system, you must condition the system. The first step in conditioning your system is to get nitrifying bacteria to grow on the biofilter media in the biofilter box. When the bacteria population establishes itself on the media, it will break down the ammonia that will be produced in the system once the eggs are introduced. This nitrifying bacteria population is the main why the original culture water can be continuously recycled. This is the reason why this system is called a recirculating system. See Unit 6: How's The Water? to monitor the growth of the nitrifying bacteria and understand the nitrogen cycle.

Once the system is running with saltwater, and at least 2-4 weeks before adding eggs, add the recommended amount of bacterial starter to the system to maintain the proper population of bacteria. The bacteria need an ammonia source to feed on which will allow them to colonize; therefore, you can add household ammonia to the system by the capful (up to _ cup). Be sure to test the water before you put the eggs in the tank. If the ammonia levels are high, you must do water changes to get the water quality to an acceptable level for the health of the eggs and larvae.

Unacceptable Ammonia Level	Acceptable Ammonia Level
> 0.50 ppm	< 0.2 ppm
* water change necessary	* good water, **no** water change

Water changes

8) When water quality is poor (ammonia level > 0.05ppm), you must remove some of the bad water and replace it with clean saltwater. Do this by siphoning out 10-20 % of the culture water. Replace that water with clean saltwater from your storage tanks. This water change should only happen once per day. Never replace more than 50% of your culture water per day. Limiting

your water exchange to 50% per day will ensure that the nitrifying bacteria will have an ammonia source to feed on and that the system temperature will not change quickly in a short period of time.

IMPORTANT NOTE:
If you cannot or do not have the time to colonize the bacteria in the system before the eggs arrive, the biomedia will begin to establish itself over time. As the eggs/larvae/juveniles grow, the nitrifying bacteria colony should grow with the fish. But it will be necessary to monitor the water quality more carefully and add nitrifying bacteria on a regular basis. If the water quality parameters get too high, water changes must be done once a day until the nitrifying bacteria populations are stable and the parameters return to normal.

Always remember that if you are adding a bacteria enhancer or starter (ex. BactaPure) to your system, you should do so **AFTER** you have conducted your water exchange because you do not want to remove the new bacteria that was just added to the water. This bacteria enhancer will boost the nitrifying activity within the biofilter.

Maintenance Section:

Temperature

9) You must maintain a constant temperature for the eggs/larvae/juveniles. For most fish species, constant room temperature will be a sufficient. To monitor temperature, hang a thermometer in the culture tank. Be sure to set the tank temperature to the optimum temperature that is appropriate for the species you are raising (refer to your life history notes on the fish). If you need to heat the water above room temperature, use aquarium heaters. Place one heater in the biofilter and one in the tank. If you need to chill the water, you can put a chiller coil in the bottom of the filter bag box.

Lighting

10) Lighting is very important to the development of the larvae, but not for the development of the eggs. Direct and intense light can have a negative impact on the developing eggs. Therefore, your system should not receive intense, direct light. Overhead fluorescent lights are acceptable. Once the eggs hatch, the yolk sac larvae require light to see their prey (See Unit 4 for information on yolksac larvae). Overhead lights should be on while there is food in the water column of the tank. Lights can either be on 24 hrs. during the larval period or try to keep them on a specific pattern with a minimum of 12 hours on.

Particle Bag Filter

11) The 25-micron particle filter bag must be cleaned every day. Remove the bag from the mounting holder, turn inside out and rinse clean. Place bag back onto the holder. By cleaning this bag daily, you will be able to monitor the amount of excess feed that is getting flushed from your system but seeing how much feed gets trapped in the bag. The filter bag can be rinsed with freshwater, and the waste can be disposed of in the municipal sewage system. Eventually the bag will not rinse clean and will stay a brownish color. When this happens, replace the bag with a new one. The dirty bag can be bleached and reused again. After bleaching the bag clean, be

sure the rinse the bag in freshwater for at least 10 minutes. You do not want any chlorine left on the bag. **Chlorine is fatal to the fish.**

Tanks

12) The tank should be siphoned at least once a week to maintain tank cleanliness. Use airline tubing attached to a 3 foot piece of 1/2" PVC with duct tape. This PVC creates a handle for the siphon tube to help guide the tube around the bottom of the tank. Carefully siphon the debris off the bottom of the tank into a bucket. This way you can collect any larvae you accidentally suck up. Return any live larvae to the tank by scooping them out with a small beaker. Count dead larvae that were siphoned from the bottom of the tank for your records. See Unit 4 for logging the survival of the larvae. If the tank is relatively clean, do not siphon. You want to wait as long as possible to siphon, so you reduce the chance of siphoning up live larvae. By the time the larvae are feeding only on *Artemia*, the fish are bigger and tend to avoid the siphon. This makes cleaning the tank much easier.

Water Quality

13) The water quality of the system needs to be tested every other day initially and twice a week once the parameters are stable. See Unit 6: HOW'S THE WATER for details on how to test the water and the safe limits for the water quality parameters. When the parameters are high, you must replace water. To replace water, siphon out 25% of water and replace with saltwater from your mixing storage tanks. Continue this replacement every day until the water quality parameter are within the safe limits. Be sure to add BactaPure to the biofilter after you do the water replacement. Never replace more than 50% of saltwater a day.

UV

14) The UV bulb should be changed every 6-9 months depending on manufacture recommendation.

NOTE TO TEACHERS: System Maintenance

You must define a maintenance schedule to ensure the upkeep of your hatchery system. By having to maintain the system, the students will gain a sense of responsibility and pride in their project. Using a maintenance log will allow for systematic record keeping and data analysis.

Activity #4 What do you do when the eggs arrive?

Objective:
To care for the eggs to maximize hatching and growth

Key Concepts/Terms:
- Acclimate

Procedures:
Eggs

The eggs you receive will most likely come in plastic bags.

1) Acclimate the eggs: Float the bags inside your culture tank until the temperature inside the bag is the same as the temperature in the culture tank. Allow 20-30 minutes for this to happen. Using the Fish Culture Log (See appendix) note the date, time, source and developmental stage of the eggs upon arrival (See Unit 4).

2) Add an airline to your culture tank. You should make a ring of tubing that is big enough to fit around the strainer/screen. Connect both sides with the airline T and then connect the main airline to the T. Using a tack or nail, poke small holes in the topside of the tubing ring to create multiple places where the air would escape and create bubbles. The air ring should sit at the bottom of the culture tank. If the airline floats, you can add stainless steel bolts around the airline tubing at the top of the T. Turn up the aeration high enough so that the bubbles pop before they hit the walls of the tank. This will keep the turbulence down in the water and keep the eggs and larvae from bouncing into the walls of the tank.

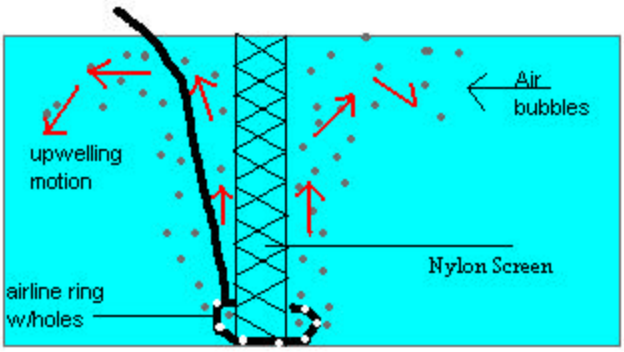


Figure 13: Illustration of the upwelling motion created in the tank by the aeration ring around the standpipe.

3) Over a sink or bucket, carefully pour the eggs out of the bag and into the 55-micron sieve. Carefully rinse off the eggs by pouring a few gallons of your system water over the eggs in the sieve. The rinsing will remove any contaminants that might have come with the eggs from the place where they were collected. **Important note: Discard the water in which the eggs were shipped as well as the water used to rinse the eggs to prevent contamination to the new system.** Take the eggs in the sieve and place them in your culture tank. Be sure to get all the eggs out of the sieve and into the culture water. Use caution when handling the eggs because they are very sensitive and cannot be left out of water or handled roughly.

Water Flow

1) Regulate the water flow into the system by adjusting the red ball valves that are coming from the biofilter box and the UV. **Be sure not to turn either valve off completely**, or the water flow of the system will not be uniform through the right components. The water flow into the culture tank should be approximately 0.5 liters per minute (L/min) when you have eggs and larvae in the tank. To test this, use any beaker and a stopwatch to calculate the flow. Use the equations below to calculate flow rates:

$$\text{Amount of Water in Beaker in ml} \times \frac{1\text{L}}{1000\text{ ml}} = \text{Liters of water}$$

$$\text{Time to fill the beaker in seconds} \times \frac{1\text{ minute}}{60\text{ seconds}} = \text{minutes to fill the beaker}$$

$$\frac{\text{Liters of water}}{\text{Minutes to fill the beaker}} = \text{Liters per minutes (flow rate)}$$

2) Keep a good flow through the bag filter and the biofilter by opening the bypass valve.

As fish grow in length and weight, their body proportions change as well. The mouth, or **gape** size, or a fish will get larger with age. This allows the fish to consume bigger feed as it grows. The newly hatchery larvae have a very small mouth and can only consume small particles of food. Rotifers are offered to the larvae at this stage. When the larvae increases in size, its mouth is big enough to consume *Artemia*. When this feed change occurs, the flow rate of the system should increase to 1 L/min. This increase is due to the fact that the fish are going to produce more waste and ammonia, therefore, the water in the tank will need to be passed through the biofilter more frequently. Turn up the flow rates after the fish have been on *Artemia* for two weeks to 2 L/min. The larvae will be strong enough to handle the added turbulence in the water column of the tank as this time. Once you wean the juvenile fish onto dry formulated feed, adjust the flow rates to the point of keeping good water quality but not so high as to push the fish around the tank. Flow rates should never exceed 3L/min.

Flow Rates for Different Life History Stages

Eggs/Larvae feeding on rotifers	**Larvae feeding on *Artemia***	**Fish on dry feed**
0.5 – 1 L / min	2 L/min	Adjust for good water quality, not to exceed 3 L/min

Assessment Suggestions:

1) Have students either define or match the bold terms to their definitions as included above and in the glossary.

2) Have students write, pre and post, why each of the following is important to the raising of fish in a recirculating system. The post-test should show a better understanding of the components of the recirculating system.

biofilter	
UV light	water flow
sea salt	ammonia
chlorine	water quality monitoring
biomedia	temperature
airstones	nitrifying bacteria

Unit 3: What Do Larval Fish Eat Anyway?
How Do I Raise Food For My Larvae To Eat?

Teacher Overview:

This section explains that rotifers and *Artemia* are zooplankton and that they can be cultured and fed to the larvae. Procedures on how to culture the live zooplankton (rotifers and *Artemia*) are included. The main highlights are how to build a live feed culture system, how to maintain cultured live animals and how to determine live feed population sizes.

Student Overview:

This section outlines how to culture live **zooplankton** (rotifers and *Artemia*) that will be used as feed for the larvae. The main highlights are how to build a **live feed** culture system, how to maintain cultured live animals and how to determine live feed population sizes.

Goals:

- Understand that the feeding requirements change for larvae as they mature
- Perfect the techniques on how to raise live feed (rotifers and *Artemia*)
- Construct a live feed system.

Learning Objectives:

The following objectives will be addressed in this unit:

- Understanding that the larval fish feeding requirements change as the fish mature
- Gain techniques on how to raise and harvest live feed (rotifers and *Artemia*)
- Calculate, monitor and understand the feeding densities that larvae require
- Learn how to count rotifers
- Define group responsibilities to ensure proper maintenance of the live feed systems
- Learn to change between metric and US units
- Communicate among class on the process and construction of live feed production units

Key Concepts/Terms:

- zooplankton
- live feed
- larval fish

Skills:

Monitoring
Metric conversion
Predicting
Sorting
Observing

Questions to Answer:

- Why do fish larvae need different foods at different stages of development?
- What types of food do larvae eat and what are the requirements for producing and raising that food?
- What are the systems that need to be created and maintained to raise the variety of live foods that developing fish need?

Background:

When fish eggs hatch and become larvae, they are very basic in their body structures. Their eyes are not fully developed, their mouths are small and their digestive system is underdeveloped. Because the larvae need to be fed, the available food (**prey)** needs to be very small, mobile and simple. The small mobile creatures stimulate the larvae to feed. **Live feed** is a term used for any live microorganism that is fed to the larvae until they have developed enough to fed a dry pellet. **Rotifers** and ***Artemia*** are two types of zooplankton that have been found in a larval fish gut that can be successfully cultured in the laboratory. They are also the key element to a successful hatchery. The quality and quantity of the cultured live feed will determine the survival of your larvae.

As the larvae grow in length, so does the diameter of their mouth. This growth allows the fish to ingest a larger food item throughout their life. Cultured larvae are usually offered rotifers as a first feed.

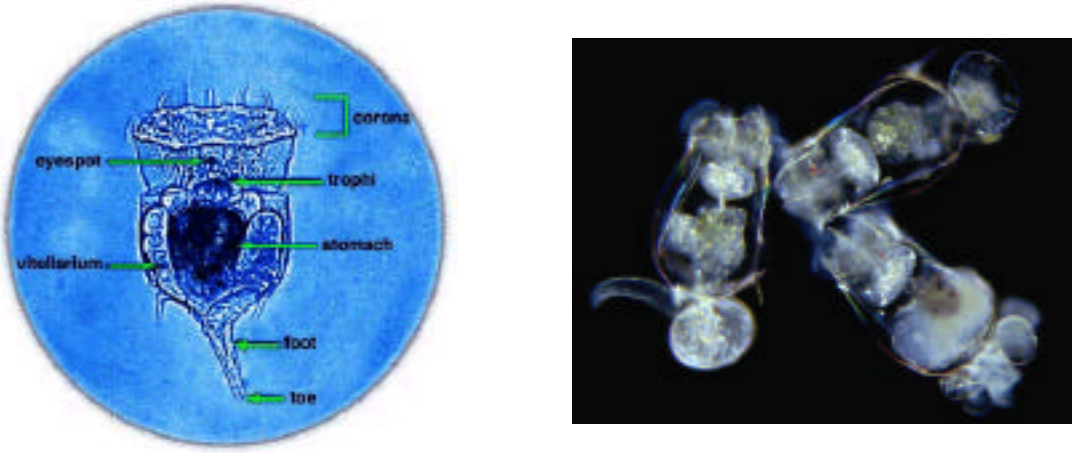


Figure 14: Illustration of a rotifer (anatomy and live).

Rotifers are a zooplankton that naturally occurs in the ocean and are 120-300 **microns** in size. These animals are **asexual.** Female rotifers continuously produce eggs without any male fertilization. Because of their reproduction style, rotifers are prime candidates for culture. One female rotifer can produce eggs every 4-6 hours for up to five days. The average lifespan for a female rotifer is 6-8 days. Therefore, long-term cultures of these animals can repopulate over time. Once the larvae further develop, *Artemia* are offered.

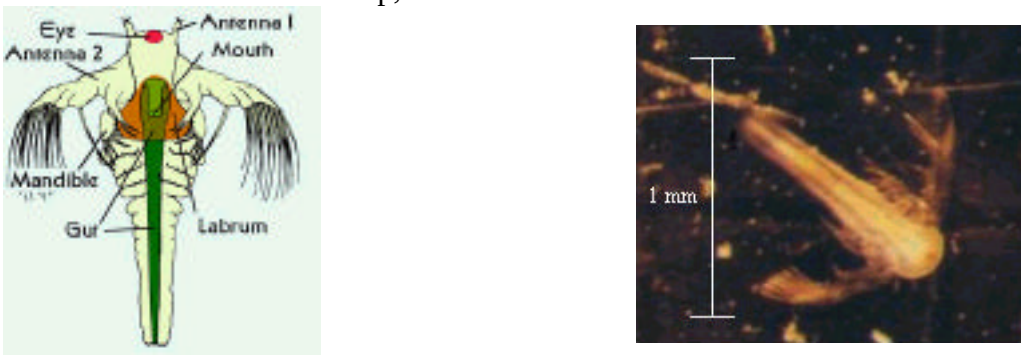


Figure 15: Illustration of an *Artemia* (anatomy and live)

Artemia are also zooplankton but range in size from 400 microns at hatch to 1000 micron for adults. The benefit to using these animals for a live feed culture is that you can buy dehydrated *Artemia* cysts in a can and hatch them out 24 hours before you need them in a hatching container.

Because culturing live feed is expensive and time consuming, **weaning** the larvae onto dry feed is the next important step. This allows the fish to be automatically fed by feeders and cuts down on the maintenance of the live feed and recirculating systems. As the fish grow, the size of the dry feed can be increased from a fish meal (<600 microns) to pellets (800 microns to 6 mm) of all sizes. Each time a new feed is introduced, a period of **co-feeding** occurs. Co-feeding is when two feeds are simultaneously offered and the original feed amounts are cut back gradually over time until all fish are feeding solely on the new feed.

Live feed is a great carrier of nutritional matter. **Enrichments** are added to the culture water of the rotifers and the *Artemia* 12 to 24 hours before feeding them to the larvae. These enrichments are a nutritional boost, which contain vitamins, amino acids and protein. The zooplankton feed on these enrichments, accumulate additional nutrients and then are fed to the fish larvae. When the larvae feed on the live feed, they benefit from their high nutritional value.

Example of a Life History Timeline for Aquaculture Production

Tautog Tautoga onitis

Spawn: July 15, 1998 Light Cycle: 20:4 Temperature: 20 °C +/- 1 °C
NMFS Milford, CT Stocking Density: 50/ml

Weeks
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Length in mm
4.4 5.8 6.6 9.4 12.3 14.2 16.5 20.5 22 25 30 34.1 38 41.2 43.2

Flow
<-----0.5L/min--------><---------- 1.0 L/ min ----------

Feed
<-- Rotifers ------>
<---------- Artemia -------->
<------<600 microns weaning diet ---->
<---------- 700 microns --------

Life History Stage

YS
<-- Larvae ------->
<- M ->
< ---------- Juvenile ----------

YS = yolk sac larvae: small mouth, under developed eyes and digestive system
Larvae = must be feed a live feed (rotifers then Artemia). Become efficient feeders and further developed.
M= metamorphosis: fin development, full organ development.
Juvenile: fully developed fish.

Activity #5 - How many rotifers do I need?

Objective:
To calculate the population of rotifers needed to successfully feed the larvae.

Materials:
Paper
Calculator
Size of tank used in the recirculating system

Procedures:
Your class needs to develop and maintain a live feed culture for your hatchery. To do this, you must know approximately what size tanks will be used for the fish culture. One step in developing a live feed culture is to know how many rotifers you are going to need to feed your larvae. After you determine that number, you need to calculate the amount of volume and space in your rotifer culture that is necessary to produce enough rotifers for your fish.

Hints:
- Larval feeding density: 3 rotifers/ml (minimum)
- 1 L = 3.8 gallons; 1 L = 1000 ml
- Predict rotifer amounts per day then multiply by number of days the larvae will need to be fed rotifers based on the class research of the life requirements and culture information. (Minimum 20 days, depending on the species).
- Steady rotifer cultures can be held at densities up to 500 rotifers/ml

1) Start with calculating the total number of rotifers you need for your culture tank. Use the average feeding density of 3 rotifers/ml:

$$\frac{3 \text{ rotifers}}{\text{ml}} \times \frac{1000 \text{ ml}}{1 \text{ L}} \times \text{vol of culture tank (L)} = \text{total \# of rotifer needed per fish culture tank}$$

2) Now take the total number of rotifers need to feed a culture tank and multiply by the number of culture tanks you have for the fish:

(total # of rotifers needed per fish culture tank) x (# of tanks for culture) = total # of rotifers per day

3) To ensure you will have a high enough population of rotifers to feed your larvae, it is a good practice to raise 2 times the amount of rotifers needed to feed the larvae. This allows for fluctuation in the rotifer populations as well as room for error.

$$\frac{\text{Total \# rotifers}}{\text{day}} \times 2 = \text{total \# of rotifers needed for feeding larvae for 1 day plus enough rotifers to double your population in 4 days so you can harvest it again for feeding}$$

4) Now you want to estimate the total number of rotifers needed for approximately 20 days of feed:

Total # rotifers needed x 20 days = total # of rotifers needed for feeding larvae until *Artemia* feeding begins

5) To calculate the volume of rotifers needed to harvest to feed the fish, use the number of rotifers per ml you counted for each rotifer culture tank. The average stocking density for rotifer culture is used below as an example. By plugging in the amount of rotifers needed for one day worth of feeding (see equation above), you will find out the volume you will need to harvest from a rotifer culture tank for the day:

$$\text{(Example density average for a rotifer culture tank)} \quad \frac{300 \text{ rotifers}}{1\text{ml}} = \frac{\text{total \# rotifers needed for 1 days worth feeding}}{\text{total ml of culture volume needed}}$$

Planning for volume of one culture cycle is assuming that the populations will double over that time period of the cycle. If you do not think you can at least double your population of rotifers in one week, consider doubling your days of your cycle in the equation.

Assessment Suggestions:

See Activity #8

1) Have students' estimate the number of rotifers needed for a single feeding for a 100-gallon tank based upon the information that they would use to feed the tank at a density of 3 rotifers per milliliter of water.

Activity # 6 - Rotifer Production

Objective:
To set up and maintain a rotifer culture.

Materials:
1 to 3 vials - Rotifer cysts or Live Rotifers
3 - petri dish (if using cysts)
55-micron sieve
1 ml x 1 mm ruled grid slide (Sedgewick)
Roti-rich
12 - 1mm plastic pipettes
1 box - air line tubing
Aquarium aerator
3 - Manifolds for up to 4 air lines ea.
4 - 100 ml glass beakers
Salt water
Microscope
Counter space for set up
10% bleach solution in a squirt bottle
10-12 soda bottles, cut off bottoms
Stand to hold up inverted bottles
Stainless steel bolts or washers to weigh down the airline tubing
Log sheets to track live feed production

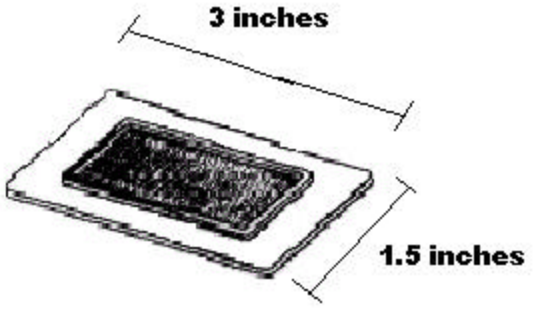


Figure 16: Picture of a Sedgewick slide.

Procedures:
1) Order rotifers live or as cysts or buy from a local pet shop at least 2 month before you plan to get eggs.
2) Set up rotifer culture tanks.

a) A water jug, soda bottle or small tank will be sufficient for the culture tank. Tanks can be any color. If using soda bottles, cut 1 inch off the bottom of the bottle. Put the cap on tight and stand on the cap. A stand should be made to keep all the bottles upright and stable. Suggestion: line a box with plastic and make a grid out of heavy cardboard to be the stand. Put bottles inside grid box for support.

b) Aeration should be suspended in the water column (not on the bottom of the bottle) to allow excess feed to settle to the bottom of the tank. See figure 17.

c) Light should be provided at least 12 hours a day and the culture should be maintained between 18-22°C.

d) When harvesting the rotifers, you must pour the culture by hand into the 55-micron sieve.

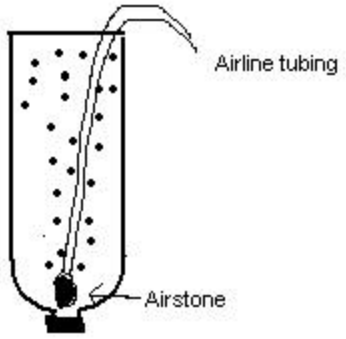


Figure 17: Illustration of the rotifer culture set up utilizing a soda bottle and aeration.

3) If you are starting with cysts, be sure to read the directions that come with them to hatch the rotifers and start your culture.

Figure 18: Live feed room at the MIT Sea Grant Marine Finfish Hatchery.

Start rotifer culture at least 6 weeks before you get fish eggs to ensure that you can conduct the procedures properly before you are dependent on the rotifers for feed. As you begin culturing the rotifers, they need to be counted and maintained 2-3 times a week to monitor their population. Once you have larvae and need the zooplankton as feed, the rotifers must be counted every day to determine how many can be fed to the fish and how many you need to repopulate in a given time frame. Rotifers should be fed to the larvae at the density of 3 animals per milliliter of tank culture water. A maintenance schedule should be set up for the class to keep a healthy population of rotifers growing.

Activity #7 Maintenance and harvesting of rotifers

Goal:

To maintain the rotifer culture until fish no longer need this food supply**.**

Procedures:

To maintain a rotifer culture, you must be certain to not over feed the animals and cause poor water quality. Also be sure to keep cultures in clean salt water and free of large particles of debris.

You should put your rotifers on a weekly production schedule. By doing this, you will always have a batch of rotifers up to population so that they can be harvested and fed to the fish. When you harvest a tank, it is either a tank that is older than 4 days or a tank you had enriched to use as feed for the fish.

To harvest rotifers, pour the culture through a 55-micron screen over a sink or over a bucket. This screen will collect the rotifers and allow smaller particles to get rinsed out. Rinse with 3 liters of saltwater. Concentrate clean rotifers into a 1L beaker. Clean the culture tank. Do not use any detergents. You may use a brush or scouring pad to remove the film on the inside of the bottle. Rinse well. Fill 1/3 of the clean bottle with saltwater and pour rinsed rotifers into the clean culture tank, top off with saltwater until the water is 3 inches from the top of the bottle. Aerate the culture by putting in an airline with an airstone 2 inches above the bottom of the bottle. You do not want to have the airstone on the bottom of the bottle because it would continuously stir up the settled debris in the rotifer culture. After you have moved the rotifers to a clean tank, you must feed them again and continue to aerate.

Figure 19: Demonstration of harvesting rotifers.

Feeding the rotifers

Daily feedings: Follow directions for Roti-rich on the package. Divide into 3 feedings daily. Pour into tank.

*Culture water should be clear or semi-clear of feed before you add another feeding portion. That means that most of the feed has been eaten by the rotifers. If you sample the water in a glass beaker and the water is still very cloudy from the previous feeding, skip a feeding. Do not overfeed the rotifers because if the rotifers do not eat all the food provided, it will settle to the bottom of the tank and create bad water quality. Bad water quality can kill the rotifers. Record on your log sheet.

Counting the rotifers
Using a 1ml pipette, take a sample of rotifers from the middle of the water column. Add this sample to your grid slide. Observe and record in your log any rotifer movement and water clarity. Add 3-4 drops of a 10% bleach solution to the slide to kill the rotifers. Count the total number of rotifers and the number of rotifers carrying eggs on the slide and record. Take three (3) counts from each culture sample. Record the average counts on the data sheet. Perform a count on all the tanks of rotifers.

Calculate the average of the total number of rotifers per ml in your culture tank and enter it in this equation:

$$\frac{\text{Count of rotifers}}{\text{ml}} \times \frac{1000\text{ ml}}{1\text{ L}} \times \text{vol rotifer culture tank in L} = \text{\# of rotifers in culture tank}$$

Now you want to monitor the rate of re-population of the rotifers:

$$\frac{\text{\# of rotifer carrying eggs per ml}}{\text{total number of rotifers per ml}} \times 100 = \text{\% of rotifer population that is reproducing}$$

This number tells you how well the population is going. The average repopulation rate for rotifers in approximately 20% per day.

How to calculate volume of rotifers needed to feed the fish?
If you are going to feed your larvae at the concentration of 3 rotifers/ml in your culture tank:

$$\frac{3\text{ rotifers}}{1\text{ ml}} \times \frac{1000\text{ ml}}{1\text{ L}} \times \text{vol of culture tank in L} = \text{\# of rotifers needed}$$

Now you need to determine how many rotifers per L of culture water there are. This will give you information to help you to determine how much to harvest to obtain the # of rotifers needed to feed your fish (equation above):

$$\frac{\text{total rotifer population}}{\text{vol of culture tank in L}} = \text{\# of rotifers / L of culture water}$$

To calculate the amount of the rotifer culture to harvest, use the following equation:

$$\frac{\text{\# of rotifers}}{\text{L of culture water}} = \frac{\text{\# of rotifers needed}}{\text{(x) number of liters to harvest}}$$

Harvest the amount of culture water you will need to get the number of rotifers needed to feed your larvae. **Never harvest more than 2/3 your original rotifer culture to feed your fish. You need to have a third of your population of rotifers left in the culture tank, so that they can repopulate to the densities needed in 4 days.**

Assessment Suggestions:

1) Have students estimate the number of rotifers needed for a single feeding for a 100 gallon tank based on the information that the feeding density is 3 rotifers per ml of water.

Activity # 8 *Artemia* Production

Objective:
To hatch and maintain an *Artemia* culture

Materials:
1 can - *Artemia* cysts
1 box - airline tubing
Aquarium aerator
Manifolds for up to 4 air lines
55-micron sieve
Microscope
Log sheets to track live feed production
Salt water
10-12 soda bottles with cut off bottoms
Stand to hold up inverted bottles

Procedures:
1) You will need a hatching system for the *Artemia*. The same 2 L bottle system used for the rotifers can be used here.

**Practice hatching out *Artemia* a week ahead of the needed date to ensure you know how to follow the procedures. * Newly hatched *Artemia* do not need to be fed or enriched because they cannot physically feed for 24 hours after they hatch.

2) Begin the hatching process for the number of *Artemia* you need to feed the larvae the day before you need them as feed.
- You can hatch up to 5 g of cyst / L of seawater
- There are approximately 280,000 *Artemia* cysts in 1 gram although this varies by different brands. Refer to the can of *Artemia* for exact amount.
- Temperature needs to be kept between 18-22°C and during hatching; the lights should be on for 24 hours straight. You can hang a light bulb over the bottles to get continuous light.
- You should feed your larvae at the densities of 2-3 *Artemia* / ml
- Aerate your containers of growing *Artemia*

This equation is used to estimate the # of *Artemia* needed to feed the larvae (2 Artemia per ml is an average feeding density):

$$\frac{2\ \textit{Artemia}}{1\ \text{ml}} \times \frac{1000\ \text{ml}}{1\ \text{L}} \times \text{vol of culture tank in Liters} = \#\ \text{of}\ \textit{Artemia}\ \text{needed}$$

To determine the amount of cysts to weigh out to start with, use this equation:

$$\frac{280{,}000\ \textit{Artemia}}{1\ \text{g}} = \frac{\#\ \text{of}\ \textit{Artemia}\ \text{needed}}{(\text{x})\ \#\ \text{of g to hatch}}$$

Hatching *Artemia*

Weigh out appropriate amount of cysts needed for one day worth of feeding and place in hatching cone. Use the 2 L soda bottle set up for the rotifers for the hatching and culturing of the *Artemia*. Fill hatching container with saltwater up to 1 inch from the top of the bottle. Place an airline with an airstone attached into the bottom of the bottle in the cap. Turn aeration up high. Aeration keeps the cysts suspended and allows them to hatch. Cysts that settle out on the bottom of a tank will not hatch. Keep a high light intensity on them for 24 hours. *Artemia* will hatch in 18-24 hours.

Figure 20: *Artemia* hatching container used at hatcheries.

Harvesting *Artemia*

1) Remove the air stone and let the culture settle. The unhatched cysts will settle to the bottom, the hatched shells will float on the top and the hatched *Artemia* will be swimming in the middle. You can concentrate the *Artemia* in a specific area by pointing a light in the middle of the water column and covering the top and bottom of the bottle with black paper or plastic. *Artemia* are attracted to light (ie. **Phototactic)**. Scoop off shells. Pour the "good" part or live *Artemia* through 55 or 100-micron screen and rinse well with freshwater. **Do not feed brown unhatched cysts or shells to the fish larvae.** If the larvae ingest the cyst shells, they will get lodged in their throat or digestive tract and kill the fish. After rinsing the *Artemia* well, they can be fed to the larvae.

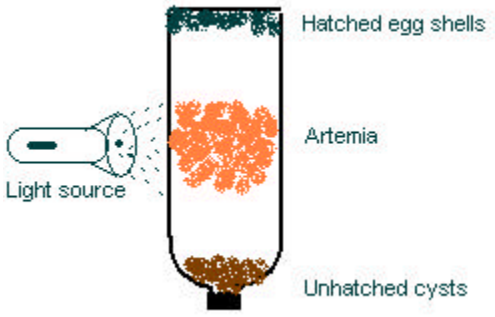


Figure 21: Illustration of *Artemia* separation from shells and unhatched cysts.

Assessment Suggestions:

1) Have students estimate the number of *Artemia* needed for a single feeding for a 100-gallon tank based upon the information that the feeding density is 3 *Artemia* per milliliter of water

Unit 4: Watching Your Fish Grow:
The Developmental Process of Marine Finfish

Teacher Overview:
The goal of this section is to use marine finfish as an example of developmental biology. A brief summary of the developmental patterns of marine finfish is included. The process on how to track the growth and survival of the larvae in the hatching system is also incorporated.

Student Overview:
Marine fish go through a variety of stages from the egg to the larvae to the adult fish. The process of growth and survival of the larvae in the hatching system is called development and the field of study is called developmental biology.

Goals:
- To use marine finfish as an example of developmental biology.
- To track the growth and survival of the larvae in the hatching system

Learning Objectives:
- Identify the developmental process of a marine finfish egg
- Distinguish the differences between each life stage of a marine finfish
- Recognize when fish go through metamorphosis
- Collect data to monitor hatch, growth and survivability rates

Skills:
Describing
Identification
Observing
Sorting
Measuring
Data collection
Communication
Estimating
Predicting
Drawing conclusions
Analyzing

Key Concepts/Terms:
- Metamorphosis
- Broodstock
- Chorion
- Eye spots
- Pigmentation
- Embryo

Questions to Answer:
- What are the observable changes in a fish as it develops from an egg to larvae to juvenile/adult fish?
- How do the stages of fish development differ between the wild and our classroom system ?
- What are the factors that effect fish egg hatching and survival?

Background:

To successfully raise fish, we need to understand the life stages of fish and how fish change through the process of metamorphosis. It is essential to understand this developmental process of marine fish in order to successfully culture fish. From egg to larvae to juvenile, the food and environmental requirements for each species changes.

Figure 22: Adult haddock.

Adult, mature fish that are held in captivity at an aquaculture facility for the purpose of producing eggs are called **broodstock**. These male and females will pair up and spawn. Different species of fish breed at different times of the year: **multiple** times per year, **bi-annual** (twice a year) or **single spawners** (once per year). The female will release her eggs into the water and the male will pass by and fertilize the eggs with his sperm. Once fertilization occurs, the developmental process begins.

The development of marine finfish eggs is temperature dependent among all **teleost** (bony fishes). Once the sperm enters the egg, the **chorion**, the outer layer of the egg, hardens to maintain the shape and volume of the egg. When fertilization occurs, cells begin to grow and divide. Cells continue to divide until the early **embryo** forms.

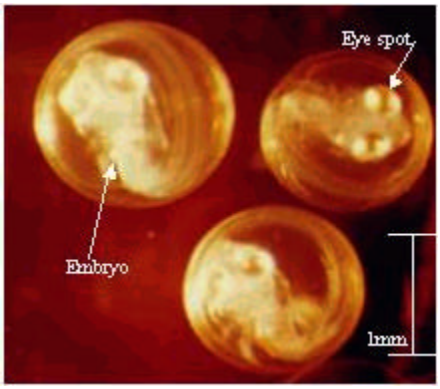
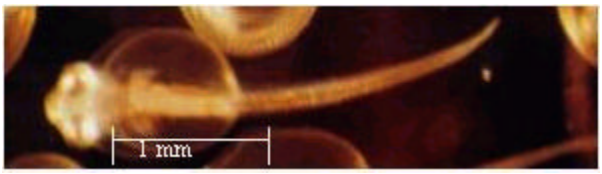


Figure 23: Developing fish eggs. Notice the eye spot formation and the tail curving around the inside of the egg.

The embryo will begin to move around inside the egg and will begin developing organs. The embryo develops around the egg and pigmentation spots occur on the body. **Eyespots** will develop on the sides of the head, followed by the development of the lenses. Over time, the embryo **pigmentation** becomes more numerous. The tail grows and wraps around the egg to the head. Eyes become pigmented and the heartbeat is evident. Once the body and eyes are fully pigmented, hatching occurs. The tail of the embryo will break out of the shell and the embryo becomes a free-swimming larvae.



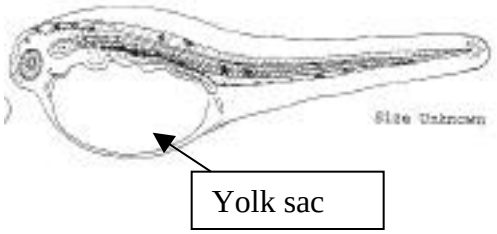
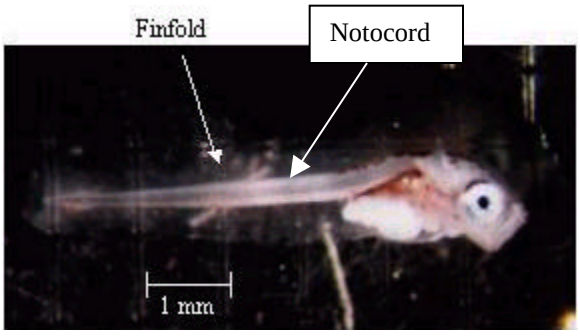


Figure 24: Yolk sac larvae.

The newly hatched larvae have a yolk sac that is a source of nutrition for the larvae. They absorb their yolk sac for several days until they are developed enough to feed on live prey.

Yolk sac larvae can survive for 2-4 days by feeding off their yolk sac food supply. This is called **endogenous** feeding. The length of the yolk sac period for larvae is dependent on the culture temperature and species of fish. The warmer the water, the faster the fish will use up their yolk reserves. The colder the water, the slower the fish will use up its reserves. Once the larval mouth has formed and eyes are partially developed, the larvae can be offered a live feed. Feeding on organisms or particles in the water column is called **exogenous** feeding. Live feed is essential to the early life stages of developing larvae. Because their eyes are underdeveloped at hatch, the larvae need to be offered a feed that is moving around to help stimulate a feeding response. Mobile live feed creates a shadow figure for the larvae to focus on and begin feeding. First feeding larvae have very simple digestive tracts and underdeveloped organs, which is why they need to feed on very simple organisms. As the larvae grow, the gut begins to coil creating more surface area. This allows the larvae to process larger, more complex feeds.

When the larvae hatch, they have a finfold around its whole body that looks like an outline when looking at the larvae under the microscope. This fold will eventually develop into fins beginning the process of metamorphosis.



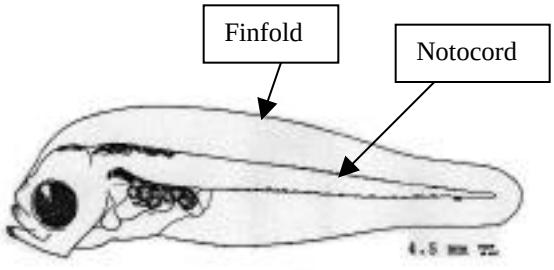


Figure 25: Larval finfish. Notice the finfold surrounding the notochord of the fish.

Metamorphosis is the process that signifies the end of the larval stage. After metamorphosis, the fish are considered juveniles and will acquire characteristics of an adult fish: body features, coloration, fins, etc. It also denotes full organ development. Metamorphosis occurs at different times for different types of fish. For example, some fish will metamorphose in 20 days whereas some will not go through the process until 4 months of age. Metamorphosis is a very stressful time for the fish and as a result, a point of high mortality i.e. bottleneck. During this time period, the type of feed the larvae are offered will change since they are now juvenile fish. Weaning fish to a new diet also is a stressful part of the culture process.

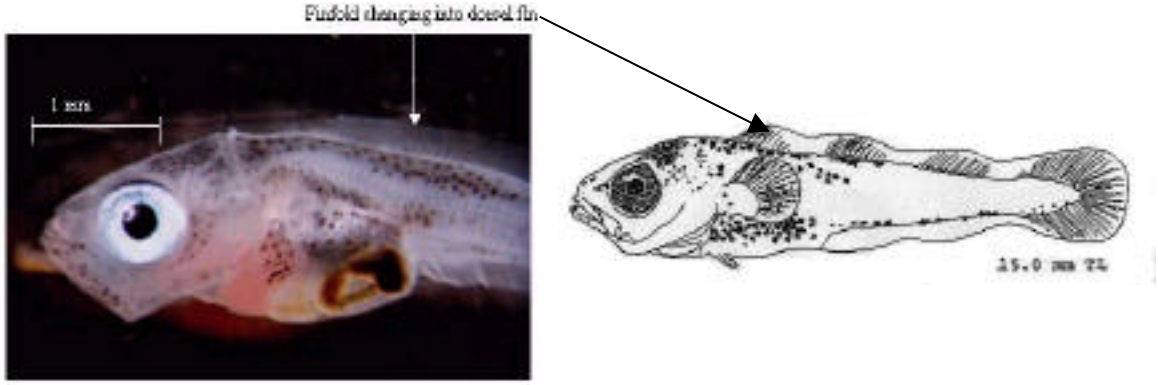


Figure 26: Larval fish going through metamorphosis. Notice the finfold is changing into fin rays.

Juveniles are usually resistant to stress (temperature, water quality, etc.) over time. As long as the culture environment remains healthy, the fish should thrive on dry feed and show significant growth rates. Juveniles are not considered adults until they become sexually mature. The developmental cycle is complete once spawning to egg and larvae to juvenile and adult has been accomplished.

Juveniles:

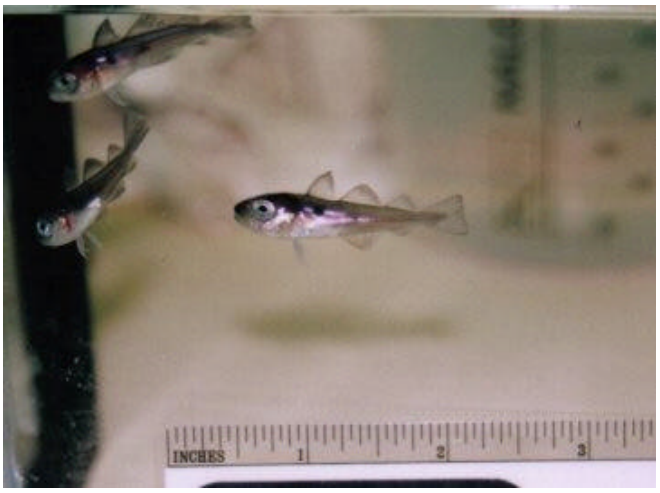


Figure 27: Juvenile haddock.

Activity #9 - What are the stages in the development of a fish?

Objectives:

- Identify the developmental process of a marine fish egg
- Distinguish the differences between each life stage of a marine fish
- Recognize when and why fish go through metamorphosis
- Collect data to monitor hatch rates, growth and survivability
- Present data by using computer software or graph on paper

Procedures:

Students will be asked to choose a fish species that is appropriate for marine aquaculture (as in Activity #1, above). For each species, students will need to review the life history information presented in Activity #1 and prepare a brief summary that documents the life history of the species. This work should be presented graphically with teams of students working together (ex. picture or diagram of egg, larvae and adult). Comparisons between the documented life history and the observed changes should be discussed.

Assessment Suggestions:

Have students identify the different developmental stages of eggs and larvae based on the information in this section.

See Appendix D for worksheets and example figures

Activity #10 How Long Until The Fish Hatch?

Objective:
To observe and predict the hatching rate of the eggs.

Materials:
1 ml x 1mm Sedgwick Slide (PIC)
55-micron sieve
12 - 1mm plastic pipettes
Microscope
Thermometer
4 - plastic beaker of at least 500 ml
Paper
1 - Class logbook

Procedures (see Activity #4 also):
1) The eggs will usually come in a plastic bag full of water. Egg bags should be left to float in the culture tank until the temperatures are the same inside and outside the bag(i.e. acclimation). This process will acclimate the eggs to your system. This should take 30-60 minutes.
2) Pour eggs into a 55-micron sieve over a bucket or a sink. Discard water in which the eggs were shipped.
3) Rinse the eggs with 3 liters of your culture water. Discard that water. Dip the sieve into the tank and then remove. Most of the eggs should now be in the tank. Using a beaker, pour saltwater over the back of the 55-micron screen over your culture tank. This will rinse any of the eggs that are sticking to the sieve into the tank. DO NOT LEAVE EGGS OUT OF WATER FOR MORE THAN 45 SECONDS!!!
4) Once you have placed the eggs into your culture tank, record the time, date and origin of the eggs in your Fish Log Book.
5) Examine the eggs immediately upon their arrival to the classroom. Scoop a sample of eggs out of the culture tank. Using a pipette, take five (5) eggs out of the beaker and place them on a petri dish. Observe the eggs under the microscope.
6) By using your knowledge of the developmental process for marine eggs, look at the eggs under the microscope and hypothesize when they are going to hatch. Record your hypothesis in the Fish Log.
7) Continue to observe the eggs under a microscope 2 times a day and draw the stages of development in your Fish Log.
8) When the eggs hatch, compare the individual hypotheses and display the different times on the board. Determine which hypothesis was the closest to the actual hatching date/time and why.
9) Discuss why the eggs hatched when they did and why some of the hypotheses were incorrect. Please note that warm water species will hatch sooner (2-3 days)than cold-water species (5-10 days).

Activity #11 - How do we monitor larval growth and development?

Objective:

To set up a continuous **monitoring** program to document the development, growth and survivorship of the eggs, larvae, and juveniles.

Materials:

Microscope
1 mm x 1 ml Sedgewick Slide
4 - plastic rulers with mm markings
4 - plastic beaker of at least 500 ml
1 - Fish Log
Graph paper or computer software for graphing (Excel)
1 or 2 - scale with capacity up to 200 g
Box of plastic pipettes
1- class log book

Procedures:

1) Calculate hatching rate/percentage: To obtain the hatching numbers, one must conduct a count of how many eggs, embryos or larvae are found in a specific volume of water, this is called a volumetric count. To calculate a hatching rate, first you must determine the number of eggs at the start of the project. To do this, be sure that the tank has good circulation to insure a uniform sample. Use a beaker to take a random, uniform sample from the culture tank. Count the number of eggs in the beaker and pour the eggs back into the tank.

After hatching occurs, conduct the same volumetric count. Use a beaker to scoop out a sample of water and larvae from the culture tank. Take at least 5 separate counts of eggs and again of larvae after they hatch. Average the samples to get a number to record on your log sheet. Now you can do the following equation:

$$\frac{\text{\# of egg or larvae}}{\text{vol of beaker}} = \frac{\text{(x)total number of egg or larvae}}{\text{total volume of culture tank}}$$

This equation gives you the total number of eggs and larvae in the tank. Now you can calculate the hatching percentage:

$$\frac{\text{total \# larvae}}{\text{total \# eggs stocked in tank}} \times 100 = \text{\% hatch}$$

2) Growth Measurements: Measure and weigh fish on a weekly basis by scooping 5-10 larvae out of your culture tank with a beaker. Place one larvae on the grid slide at a time. Observe and measure their total length (TL) (from the tip of the nose to the tip of the tail) to the nearest millimeter under the microscope. Standard length (SL) is also a type of measurement that can be taken of the larvae. SL measurement is from the tip of the nose to the tip of the notochord or spinal cord. Once the larvae outgrow the microscope-viewing field, carefully net out the fish and

place on a plastic ruler and measure. Then take a wet weight of the fish. To do this, fill half of a small beaker with saltwater and weight it. Place your fish in the beaker of water and record that weight. Subtract the numbers to get the weight of the fish.

weight of beaker of water + fish - weight of beaker and water = weight of fish

Return the fish to the culture tank immediately. Record the data in your Fish Log. Also, calculate the average length and weight of the fish measured for each week and log that data. This will allow you to follow the growth rates of your fish.

3) Survivorship: For maintenance and for keeping track of dead larvae and live larvae, the tanks need to be cleaned weekly and the larvae need to be assessed. Culture tanks should be "picked" on a daily basis by removing dead eggs and larvae floating at the surface by using a pipette and then counting them. Dead eggs and larvae are white in color. **The bottom of the culture tanks should be <u>carefully</u> siphoned once a week to ensure cleanliness in the tank. Using airline tubing attached to a piece of PVC, slowly siphon debris into a bucket. Return all live larvae to the tank**. **This can account for a partial water change on the day siphoned.** Count all dead larvae in the bucket. A volumetric count of the live larvae/fish should be conducted on a weekly basis. To do this, take a 1000 ml or bigger beaker (depending on your culture tank size) and sample the culture tank. Try to get a uniform sample. Count the number of larvae/fish in the beaker. Calculate the total number of fish in the culture tank. You know three of the four variables.

$$\frac{\text{\# fish in beaker}}{\text{vol of water in beaker}} = \frac{\text{(x) \# of fish in whole tank}}{\text{total vol of culture tank}}$$

Record the data in the Fish Log. This will help in determining the survivorship of the species you are culturing.

4) Graph growth and survivorship results monthly as a class by using a scatter plot. Use the average calculated from each sampling day. Locate the days when mortality was high and see if there were any other events that would justify the high number of deaths. Was it a major developmental point for the larvae? Did you change their feed? Or were their other factors effecting their survival? (Water quality?, light?, feed/lack of or overfeed?, system failure?, maintenance?) Can you predict the growth rates of the larvae?

5) Keep a daily journal of events for the system and fish. This will aid in determining what went wrong and/or right during the culture process and help you learn for your next hatchery run.

Assessment Suggestions:

1) Students can predict rates of hatching and growth for the fish being cultured. After collecting data on actual hatches and growth rates, have students prepare hypotheses which could be tested against the actual data to determine what were the important factors in hatching rates and growth (ex. feeding rates, temperature, etc.).
2) Students can design mini-experiments that can be used to determine hatching and growth rates based upon various variables (i.e. light, temp., feed amounts) that they could control and let vary in parallel recirculating systems.

Unit 5: Taking Care of Your Fish

Teacher Overview:

This section gives guidelines on how one is to determine the health of the larvae. Observation of larvae is one of the most important aspects of hatchery work. Because the larvae are transparent at this stage, it is easy to identify various developmental focus points.

Student Overview:

Observation of larvae is very critical during this early life stage of fish development. The fish need to be examined under the microscope to determine if they are feeding and developing properly. There is a considerable amount of time involved in giving the larvae the proper care they need to survive and grow.

Goals:

To learn proper techniques involved in caring for marine finfish larvae

Learning Objectives:

- Identify the ability of the larvae to feed on different prey
- Observe and record the feeding events of the larvae
- Understand the importance of system maintenance and its affect on the larvae
- Recognize when the larvae are feeding and when is it appropriate to wean them to a new feed

Skills:

Observing Cooperative problem solving
Estimating Predicting

Key Concepts/Terms:

- Hatching
- Larvae
- Weaning

Questions to Answer:

- When can the larvae accept larger feeds?
- What is an acceptable weaning period?
- How can you identify when the fish are feeding?

Activity #12 How do I hatch, feed and care for my fish larvae?

Objective:

To hatch the fish eggs and to raise the larvae on the rotifers and *Artemia*.

Procedures:

Live Feed Cultures

It is essential to the survivorship of your larvae to have a plentiful and stable rotifer culture. The culture must be maintained and stable by the time your eggs arrive. Rotifer cultures should be started six weeks in advance of egg shipment. This will give you enough time to learn how to culture the animals and build a population large enough to supply live feed to your larvae. *Artemia* can be hatched out the day before you need them for feed. It is good to practice the *Artemia* hatching technique a few times before the larvae need to move onto this larger feed.

Hatching

Once the eggs hatch, reduce the aeration so that the larvae are not getting pushed into the tank walls. This will reduce the stress of the larvae hitting the walls of the tank. Too much mechanical movement in the tank can cause high mortality of the larvae. A good way to measure the aeration is to have the air high enough so that bubbles do not break within 4 inches of the sidewalls of the tank. Because the larvae are very sensitive to mechanical agitation, the flow rate of the water entering your culture tank should remain at 0.5 L/min for the first seven to 20 days.

Larvae

Before the yolk sac is completely depleted (this should take 1-3 days depending on the species), you should start adding rotifers to the culture water at a density of 3-5 rotifers/ml. This initial feeding will allow the larvae to learn how to feed before they absorb their entire yolk sac and enter the critical stage in which they must begin feeding or else they could die. The larvae should be efficiently feeding by the time the yolk sac is completely absorbed. This will ensure a better survival rate of your larvae. The larvae will need to be fed a live feed 2 - 3 times per day. The number of feedings depends on the species and temperature of the system. Most fish can get by with one full feeding per day over the weekend. Once the larvae are approximately 8 mm, you can introduce *Artemia* to the tank. Co-feeding of the rotifers and *Artemia* should occur for 5 days. Every day during the co-feeding period, you should reduce the amount of rotifers and increase the amount of *Artemia*. Once the larvae are weaned onto *Artemia*, the fish can be monitored for their consumption of *Artemia* because *Artemia* are orange in color and can be observed easily in the gut of the larvae. As the larvae grow, they can eat larger prey. Therefore, you can growout your *Artemia* for 2-3 days and enrich them before feeding to the larvae. Eventually you will wean the larvae onto a dry feed.

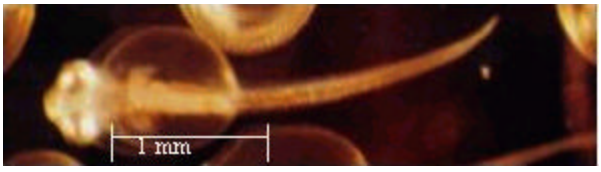


Figure 28: Yolk sac larvae.

Observing the Larvae
Fish should be examined under the microscope daily. Larvae are transparent which allows you to see the feed in their stomach. When the larvae are feeding on rotifers, their guts will be white. As you begin to wean them onto *Artemia*, you will notice orange and white in their gut. When they are fully on *Artemia*, their guts will be orange. Once you have gained a trained eye for observing the larvae, you will be able to tell if they are eating simply by looking at them through a glass beaker.

Student Maintenance Program (also see Unit 2)
You must develop a maintenance schedule to ensure the upkeep of your hatchery system.

Particle Bag Filter
The 25-micron particle filter bag must be cleaned every day. Remove the bag from the mounting holder, turn inside out and rinse clean. It is recommended to use a hose to blast off excess feed and debris. Replace bag on its holder. Cleaning this bag daily will allow you to monitor the amount of excess feed that is getting flushed from your system because all the feed that does not get eaten will get trapped in the filter bag. The filter bag can be rinsed with freshwater and the waste can be disposed of in the municipal sewage system.

Tanks
The tank should be siphoned at least once a week to maintain tank cleanliness. Use airline tubing attached to a 3-foot piece of 1/2" PVC with duct tape. Carefully siphon the debris off the bottom of the tank into a bucket. By collecting the water in a bucket, you can save any larvae you accidentally suck up. Return any live larvae to the tank by scooping them out with a small beaker. Count dead larvae that were siphoned from the bottom of the tank for your records.

Water Quality
The water quality of the system needs to be tested every other day initially and twice a week once the parameters are stable. See Unit 6 for stable water quality parameters. If water quality parameters are not in the acceptable range, you can replace the saltwater to dilute the high level harmful toxins. To replace water, siphon out 25% of water and replace with saltwater from your mixing storage tanks. **Never replace more than 50 % a day so you can insure a good nutrition source for your biofilter.** Continue this replacement every day until the water quality parameter are within the safe limits. Be sure to add BactaPure to the biofilter after you do the water replacement.

UV
The UV bulb should be changed every 6-9 months depending on manufacture recommendation.

Flow Rate
As the fish grow, they produce more waste and ammonia. Therefore, the water in the tank will need to be processed through the biofilter more frequently. The flow rate will need to be increased to 1 L/min when the larvae are fed *Artemia*. Turn up the flow rates to 2 L/min after the fish have been on *Artemia* for two (2) weeks. Once you wean the juvenile fish onto dry

formulated feed, adjust the flow rates to the point of keeping good water quality but not too high to push the fish around (max. is 3 L/min).

<u>Activity #13</u> What do I do when the fish no longer need rotifers or *Artemia*?

Objective:

To wean the fish from the rotifers and *Artemia*

Procedures:

Weaning

Changing feed types for the fish as they become larger and can physically eat larger prey is called weaning. When weaning occurs, two feeds are offered at the same time. This co-feeding period should last for at least 1-2 weeks. Your larvae will be weaned from rotifers to *Artemia* and from *Artemia* to dry feed. You want to wean the larvae onto dry feed as soon as you can because using a commercially developed pellet requires much less maintenance. **Be sure to order dry feed when the larvae begin to feed on *Artemia***. Once the larvae are completely weaned on to dry feed you can stop hatching out the *Artemia*.

Dry Feed

Initially you will need to use a fishmeal type food to convert the fish to a commercially available pellet. The pellet size will be 600 microns and less. Once the fish are on the dry food, you can offer them a larger size pellet as they grow. The following are the increments of feed necessary for changing fish feed (in microns): 400, 700, 1000, 1500, 2000, etc.

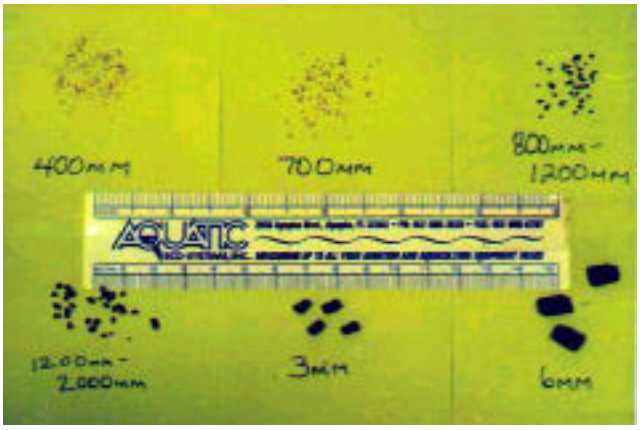


Figure 29: A variety of feed sizes that will be offered to the hatchery fish.

Figure 30: Juvenile haddock weaned onto dry pelleted feed.

Assessment Suggestions:

Use also with Activity #14, below.

1) Have students estimate when and how fish will change from one food source to another and why. For each of the major food sources, rotifers, *Artemia*, and dry food, have them estimate how large the fish need to be to shift from one food to another. Have them compare their estimates with actual data and discuss why there are differences, if there are.

Activity # 14 - Are The Fish Eating?

Objective:
To monitor the growth and feeding of the larvae. By comparing growth and survival data, correlation's and a hypothesis can be formed.

Materials:
Microscope
Slide
Log sheet

Procedures:
1) Use a beaker and scoop out a few larvae from each culture tank to be examined under a microscope.
2) In small groups or as a class, observe the development of the larvae. After hatching occurs, look for a developed mouth and a very small yolk sac. This is an indicator that the larvae can be fed rotifers.
3) Once rotifers are offered to the larvae, they must be monitored to ensure that the fish are actually feeding on the zooplankton (i.e. rotifers and *Artemia*). Larvae are very easy to monitor since their bodies are transparent until the metamorphosis. You should see white rotifers in the larvae's gut.
4) When weaning from rotifers to *Artemia*, or co-feeding, you should see white rotifers and orange *Artemia* in their gut. As you reduce the amount of rotifers you offer the larvae, more *Artemia* should be present in the gut.
5) Log all the results such as feeding, proportions of each feed, how long your co-feedings occurred, etc.
6) Challenge: Compare the larvae development and feeding data with the collected growth and survival data. Is there any correlation with survival and changing feed types? Are there any differences in growth rates when feeding different animals?

Assessment Suggestions:
1) Compare the growth and survival data. In advance of the activity, have students create hypotheses as to what will happen when feed types are changed? Have students be specific and give estimates, in numbers, of what they think will happen. Have them then address the following: Is there any correlation (numerical connection) with survival and changing feed types? Are there any differences in growth rates when feeding different prey to the larvae?

2) Create a graph of the life history of the fish from larvae to eating dry food. On the graph note down each time the feed type changes and the mortality/survival rate at that point.

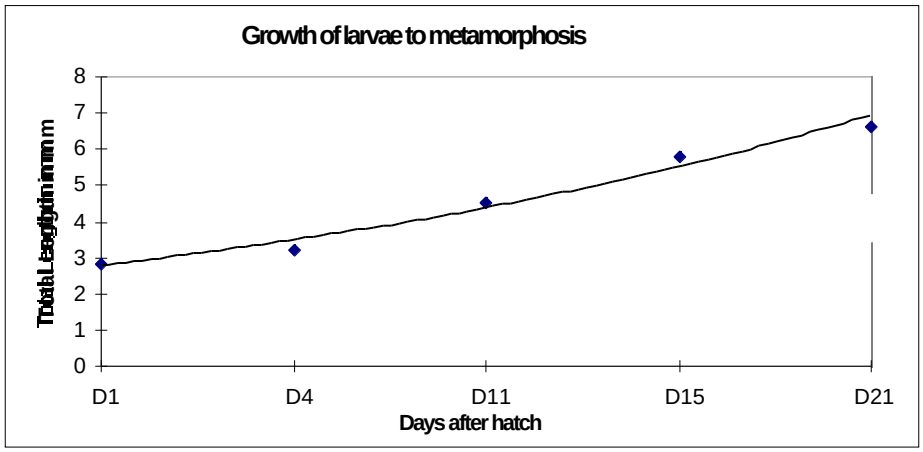


Figure 31: Example of larval growth to metamorphosis.

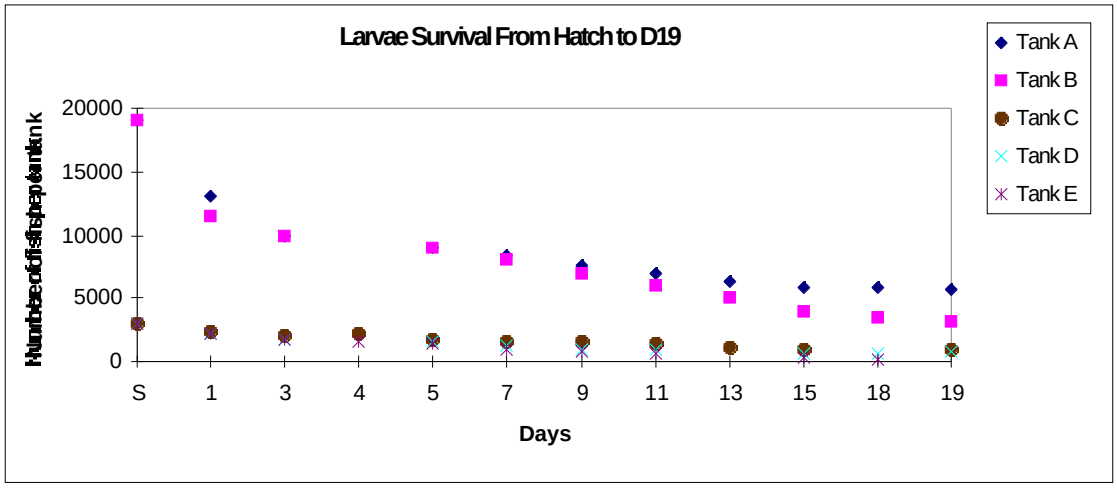


Figure 32: Example of larval survival to metamorphosis.

Unit 6: How's The Water?
Monitoring Water Quality

Teacher's Overview:
The quality of the tank's ecosystem is based on good water quality. The health and survival of the fish are dependent on the maintenance procedures previously described in the curriculum. Monitoring of fish survival, growth and behavior are means for identifying the quality of the water. To prevent possible die offs and other impacts (high bacterial loading) on survivability, the importance of monitoring the nitrogen cycle and bacterial populations to the culture system cannot be overstated. The water quality parameters and the acceptable limits are outlined below as are monitoring procedures.

Student Overview:
The tank's ecosystem is dependent on good water quality. Maintaining specific levels of chemical and physical characteristics in the water are critical to the health and survival of the fish. The nitrogen cycle and bacterial populations are very import to the culture system.

Goal:
To develop and implement a water quality monitoring program for the recirculating system and to adjust water quality to meet the needs of the fish population.

Learning Objectives:
- Understand the concept of the nitrogen cycle in an enclosed ecosystem (recirculating system)
- Read and comprehend instructions for a water quality test kit
- Measure water quality and analyzing the test results
- Learn how to rouble shoot cause and effect problems of the water quality in system
- Present water quality data by using graphing software
- Learn to use metric and English systems for measurements

Skills:
Graphing
Measuring
Predicting
Problem solving skills
Observing

Key Concepts/Terms:
- Metabolize
- Biological filter
- Polyculture
- Nitrogen cycle

Questions to Answer:

- What is the significance of the nitrogen cycle and how does it pertain to the working systems of aquaculture?
- What is the importance of water quality testing and how does water quality affect the growth of the fish?
- What are the sources of poor water quality conditions and how do we fix water quality problems?

Background:

Recirculating systems are a unique and environmentally friendly way to culture aquatic animals. This is because all environmental effects and impacts to the animals being reared are controlled. One must be aware of the importance of keeping the culture water clean to allow the fish to thrive. Many biological and chemical reactions are occurring in a recirculating system that can affect the fish.

When fish eat and **metabolize**, they produce waste as well as excrete ammonia, urine and carbon dioxide through their gills. In order for the fish to thrive, the waste needs to be removed from their water. Carbon dioxide can be removed by aeration or by plants through photosynthesis. Nitrifying bacteria breaks down nitrogenous waste. Plants can use the final form of nitrates present at the end of the **nitrogen cycle**.

In a recirculating system, the **biological filter** is the main component that allows for the culture water to be recycled, it is the home for nitrifying bacteria. Nitrifying bacteria is the good bacteria you actually WANT to grow in your system, because it uses the waste products from the fish as an energy source. ***Nitrosomonas*** first breaks down ammonia to nitrite. Then, ***nitrobacter*** breaks down the nitrite to form nitrate. Ammonia and nitrite are dangerous forms of nitrogenous wastes because they interfere with the body's normal functions and exchanges. Nitrate, which is the end product of these reactions, is the least toxic form of nitrogenous waste and has a minimal effect on the fish at moderate concentrations. Water exchange is needed (approximately 10% per day) in a well-seeded recirculating system to rid of excessive amounts of nitrate. Alternatively, a **polyculture** that includes plants or shellfish can be used to remove the nitrates.

There are a variety of biological filter media available. Each type of media is categorized by the amount of surface area it has. This is an important factor because the more surface area on the media means the more surface available for the nitrifying bacteria to grow. The type of media used is often determined by the space available for the system and the amount of fish being grown. Once a system is functioning for a few months, bacteria will begin to colonize on the biofilter media as well as inside the pipes of the system.

Bacteria require oxygen to breakdown the ammonia and nitrites. Oxygen demands of the system will rise as the fish and the bacteria grow. You do not want algae growing inside your tanks because **t**hese algae will consume the oxygen within your system. The dissolved oxygen (DO) level needs to be monitored within your system to be sure that there is enough oxygen available for your fish and nitrifying bacteria. You should maintain a minimum of 80% saturation of dissolved oxygen in your system at all times. (See Saturation Chart in the Appendix C). To prevent algae from growing in your tanks, do not let direct sunlight come in contact with any part of the system. A low dissolved oxygen level within your system can stress the fish and inhibit their survival and growth rates.

There are several measurements that need to be monitored along with dissolved oxygen (DO) to ensure a healthy environment for your fish. Here are list of the parameters that need to be tested in a salt water system:

pH: Safe levels: 6-9. Measures the intensity of the acidity of the water. A normal reading for salt water is between 7.5 - 8. pH is effected by other water quality parameters such as alkalinity and CO_2 levels. When pH is high, it can limit the ability of gills to transport ions essential to the fish, which can lead to **osmoregulatory** failure or death.

Ammonia: Safe levels: 0 - 0.1 mg/L. Ammonia is a result of fish excreting waste and metabolizing feed. It is toxic to the fish. Levels that remain high (+5ppm) for a long or short period will stress the fish and make them more susceptible to other pathogenic bacteria and viruses present in the system. Low levels of ammonia (1ppm) that persist for a long period of time can have an overall negative effect on the fish as well. Fish will become stressed from the toxic ammonia in their water, which will allow them to be more susceptible to acquiring a disease.

Nitrite: Safe levels: 0 - 1 mg/L. Nitrite is a toxic form of nitrogen. It is the result of the nitrifying bacteria *Nitrosomonas* breaking down ammonia. When it is present in high concentrations, it will stress the fish and allow them to be more susceptible to pathogenic bacteria and viruses present in the system. Also, when nitrites oxidize the iron in the blood, it enables the blood to bind oxygen and carry it to the tissues.

Nitrate: Safe levels: up to 10 mg/L. Nitrate is the end result of the conversion by the nitrifying bacteria *Nitrobacter* and is considered to be non-toxic to fish. If nitrates are continually present in an over abundant amount (+150 mg/L), osmoregulatory failure can occur in the fish.

Dissolved Oxygen (DO): Safe levels: 7 - 9 mg/L. This is the amount of oxygen available to the fish in the water. This is an important parameter. Low DO concentration levels can have adverse effects of fish health including respiratory stress, tissue hypoxia and eventually death. The saturation point of the water is dependent on the temperature.

Alkalinity: Safe levels: 90- 150 mg/L. This is the measurement of the total concentration of basic substances dissolved in the culture water. Alkalinity serves as a buffer to the culture system and does not allow wide swings in the pH to occur.

Carbon dioxide: Safe levels: 0 - 8 mg/L. CO2 in tanks is present due to fish respiration and metabolism. Adverse effects of carbon dioxide are affected by temperature and DO. CO2 toxicity will increase when DO is low. Increased water temperatures decrease CO2 toxicity by decreasing its solubility. Also, if the fish become stressed, they respire at a high pace, which produces more CO2. If the level of CO2 in the blood rises, the oxygen carrying capacity will decrease causing respiratory distress because little oxygen is being transported to the tissues.

Salinity: See life history requirements for the culture fish. Salinity should be within 2 ppt of the desired number.

Temperature: The temperature of your system should be maintained at +/- 1 degree of the temperature required for the fish that was found in the research about the chosen species. The use of a heater or a chiller may be necessary to maintain the desired temperature. Fluctuations of temperature will stress the fish and allow them to be susceptible to pathogenic bacterial and viral infections. Having temperature control over the whole culture room is important as well. A temperature change in the culture water of more than 5 degrees in a period of 2 hours can cause fish health problems as well as hinder their growth due to stress. Continuous temperature changes to the culture water should be avoided because the fluctuating temperature will continuously stress the fish.

There are several types of chemical test kits and probes that are available to monitor the water quality parameters. The various parameters will evaluate the health of your culture environment.

What do you do when the parameters are high?

When the results are higher than recommended, the best thing to do is to replace more than the typical 10 % water in your system. Depending on the magnitude of the high-test results, up to 50% of the culture water can be changed at one time to lessen the effect of the outlying parameter. Be sure to have enough storage of saltwater available for emergency water exchange situations. **They will happen.** Common problems in new systems will be high initial ammonia loads and low DO. If parameters are high, continue to test the water daily until the parameters are acceptable for more than 3 days in a row. Do not replace more than 50% of the original culture water per day. If you do this, you are eliminating the source of ammonia for the bacteria and risk a change in your systems temperature if the storage and culture tanks are not maintained at the same temperature.

Activity #15 Where Did the Water Come From?

Objective:

To practice using water quality test kits and to demonstrate the differences in water quality parameters between different aquatic environments.

Materials:

Saltwater chemistry kits for:
Ammonia
- Nitrite
- Nitrate
- pH
- Alkalinity
- DO
- CO2

Hydrometer
8 - beakers
1 box of pipettes
Logbook for data
1-2 litter bottle of different sources of water:
fresh, local pond or ocean and your recirculating system
Graphing software (ex. Excel) or graph paper

Procedures:

1) There are three stations set up in the classroom. Each station will have a different type of water. Divide the class up into three groups.
2) You will test two of the water quality parameters at each of the stations.
3) Predict where each water source came from and explain why you think that is the case.
4) Have one student from each group write down the groups' predictions on the worksheet.
5) Discuss the results as a class.

Your teacher will tell you where each sample of water came from. Discuss your predictions and why the results were the same or different from the actual samples.

Where did the water come from?

	Source #1	Source #2	Source #3
PH			
Ammonia			
Nitrite			
Nitrate			
Alkalinity			
CO_2			
Salinity			
DO			

Predictions for:

Sample site1	Why?
Sample site2	Why?
Sample site3	Why?

Activity #16 Monitoring Your System

Objective:
To continuously monitor your culture system for chemical and physical changes.

Materials:
Salt water chemistry kits for:
- Ammonia
- Nitrite
- Nitrate
- pH
- Alkalinity
- DO
- CO2

Hydrometer
8 - beakers
1 box of pipettes
Fish Log for data
Graphing software (ex. Excel) or graph paper
1- fish log book

Procedures:
1) Monitor your systems water at least twice a week and record data in your Fish Log book. Read the instructions for each test kit. If a parameter is out of the normal range, you should conduct a water change and continue to monitor the water frequently until the problem is corrected.

2) Observations of the fishes swimming and feeding behavior and water clarity should be recorded in the Fish Log daily. These observations will assist in the trouble shooting of water quality issues. Sometimes fish will display unusual behaviors such as swimming on their side toward the bottom or not feeding. These signs often indicate poor water quality.

Assessment Suggestions:
1) Have the students do a pre/post test on their knowledge of the nitrogen cycle and how it relates to a recirculating system.
2) List the various kits and what they measure on a matching quiz and have students match the kit to the parameter in a pre and post-test format. List the source of the problems that occur for each parameter (i.e. DO = dissolved oxygen, low due to too much decomposition in the water or too little aeration).
2) Present a short essay scenario to your students. Explain that a closed, recirculating system has recently shown a dramatic change in one or more of the following factors (nitrogen levels, DO, pH, salinity). Have students identify how they would test the water and then design an experimental procedure for finding the cause(s) of the problem or for fixing the problem.

Appendix A

Glossary

aerate: to add an air source to water and create bubbles that will oxygenate the water
aquaculture: the science of raising aquatic animals and plants in a confined area
Artemia : zooplankton that ranges from 200-400 microns in size
asexual: reproduction involving a single individual without male or female gametes
bacteria: any number of unicellular microorganisms or parasites having a wide range of biochemical and pathogenic properties
bi-annual: a fish that only spawns twice a year
biological filter: a compartment containing high surface area media for nitrifying bacteria to grow
bottlenecks: a difficult stage during the development process where there is a significantly high mortality
broodstock: adult fish that are held in captivity to be used as a source of eggs for the hatchery
chlorine: highly irritating liquid that is used to purify water, disinfect or bleach
chorion: outer layer of a fish egg
co-feeding: to feed two types of feed at one time
culture: to grow a plant or animal in a controlled manner
discharge: amount of water that is replaced and disposed of as waste from a facility
embryo: an organism in its early stages of development
endogenous: internal source of nutrition
enrichments: the addition of nutrients
estuaries: a body of water that connects the ocean and a mouth of a river. It has a varying salinity depending on the rate of water exchange between the ocean and the river.
exogenous: external source of nutrition
extinct: no longer exists or living
eyespots: the formation of bumps on the side of the embryo during development. These bumps will turn into functioning eyes
fingerling stage: fish that are 1-3 inches in length
gape: the size of the opening of the mouth
growout: to raise the fish from fingerling stage to a final product or size
habitats: an area or type of environment in which an organism lives
harvest: to gather
hatchery: the initial phase of hatching eggs and culturing them until they are 1-2 inches in length
hydrometer: meter that measures the specific gravity of seawater and determines the salinity
larval: newly hatched or earliest stage of an organism that will undergo metamorphosis
live feed: feed that is alive and moving
life history: the stages of life an organism goes through
marine fish: fish that live in any body of water that has salt in it
market size: fish that have reached the size that will fetch a good price in the market
metamorphosis: an abrupt transformation from one distinct life stage to another

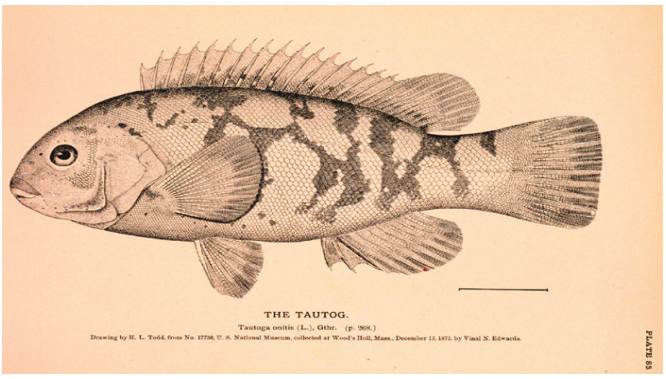
microns: a unit used for measurement; one millionth of a meter
model: a small object that was built to scale, that represents a larger object
monitoring: to keep track of or test
multiple spawner: a fish that spawns several times a year
nitrifying bacteria: to oxidize into nitrite or nitrate
nitrobacter: bacteria that breaks down nitrite to nitrate
nitrogen cycle: the cycling of nitrogen throughout the atmosphere, water and earth
nitrosomonas: bacteria that breaks down ammonia into nitrite
osmoregulatory: the maintanence of an optimal and constant osmotic pressure in the body of a living organisim
phototactic: the movement of an organism in response to light
pigmentation: coloration of tissue by pigment in the skin
pollution: contamination of soil, water or atmosphere by the discharge of harmful substances
polyculture: to culture more multiple organisms at a time in the same system
population: the number of organisms in a given area
prey: an organism hunted or caught for food
recover: to restore to a normal state
recirculating system: a system that has components that allow water to be recycled
rotifers: a multi-cellular aquatic organism; ranges from 80-120 microns in size
salinity: the amount of salt that is present in water
salt marsh: coastal community periodically drained and flooded by tidal waters
single spawners: a fish that only spawns once a year
spawning: to produce eggs of an aquatic species
species: a category of taxonomic classification
teleost: a subgroup of the hierarchical classification of the major groups of fishes that contain all the modern body fish
weaning: to withhold original food source and substitute it for another nutritional source
yolk sac larvae: larvae that is free swimming and has a yolk sac for a nutritional source
zooplankton: microscopic aquatic animals

Appendix B

Fish Descriptions

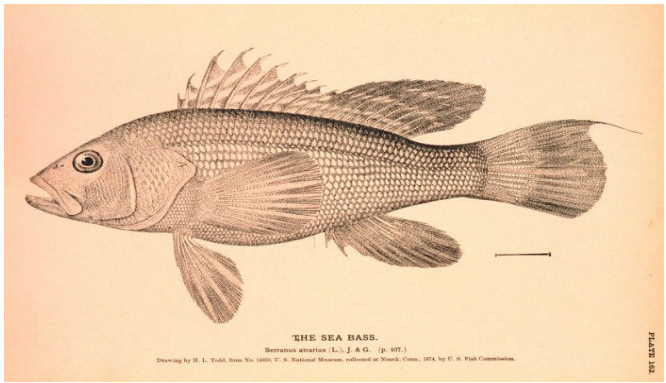
Common Name **Scientific name**

Tautog ***Tautoga onitis***



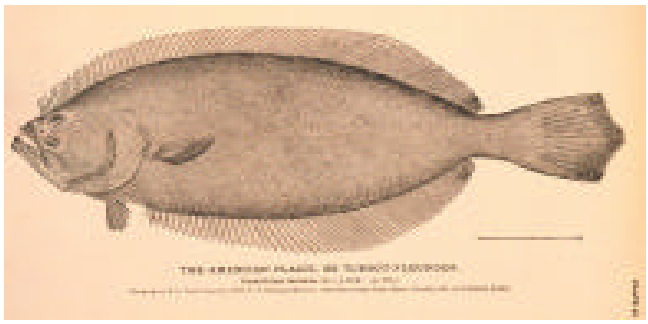
Popular food fish in the Northeast. Its range is from Nova Scotia to South Carolina. The fish are structurally oriented and can be found in rocky areas and around pilings, piers, wrecks, etc. Feeds on shellfish. Males are dark olive to grey with little blotching; white chin. Females and young are blotched with darker grey and black on a paler olive to brownish background.

Black Sea Bass ***Centropristis striata***



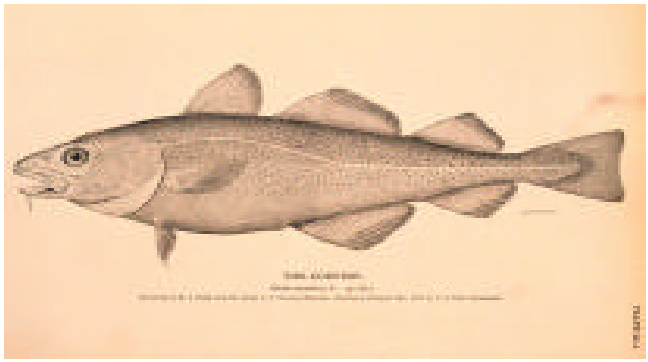
Ranges from North Carolina to NE Florida; Gulf of Mexico and the Florida Keys. These fish prefer hard bottom habitats. Their head and dark areas of the body are blueish in color.

Summer Flounder *Paralichthys dentatus*



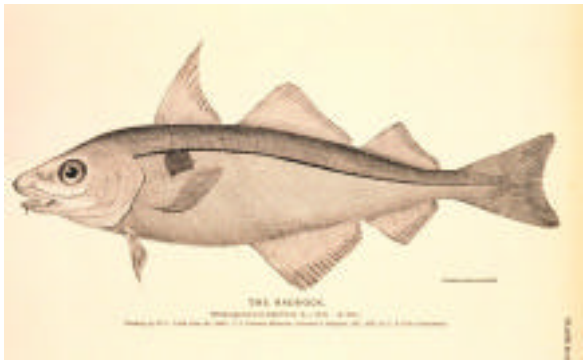
Important food and sport fish. Ranges from Maine to northern Florida. Left eyed flounder.

Cod *Gadus morhua*



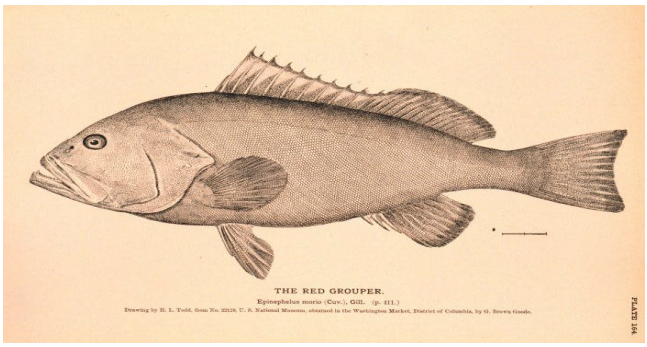
One of the world's most popular commercial fish. They range from S. Greenland to Cape Hatters and the East Atlantic. Brownish body color with a white belly. Well-developed barbel protruding from the chin.

Haddock *Melanogrammus aeglefinus*



Important commercial fish now greatly depleted by overfishing. Ranges from N. Newfoundland to Cape Hatters and East Atlantic. Dark grey body with purple reflections. They have a black blotch on their side and a black lateral line. Small barbel protruding from the chin.

Grouper



There are several species of grouper that are popular commercial fish. Grouper are found in warm-temperate and tropical coastal waters. Most species occur on rough bottoms, around pilings, rocks, coral reefs, and shipwrecks. Sex reversal occurs in all species. When the fish is small, it is female and then transforms into a male later in life.

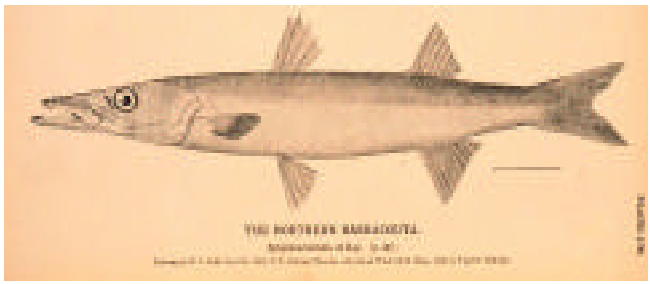
Snapper

Important food and game fish. This species is wide ranging, mainly of tropical shore waters. Reef species are often tan and yellow in color whereas species that inhabit deep, rocky slopes are usually red.

Red Drum *Sciaenops ocellatus*

Important game fish. This fish ranges from Massachusetts to N. Mexico including S. Florida. Bronzed colored fish, darker above. No chin barbels.

Great Barracuda ***Sphyraena barracuda***

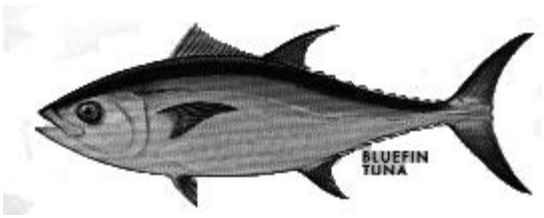


Gray with a greenish cast above, whitish below. Ranges up to 6 feet and 100 pounds. Important game fish and are widely eaten although they are know to cause the disease ciguatera. Has been known to be dangerous to swimmers and divers although attacks are rare.

White Shark ***Carcharodon carcharias***

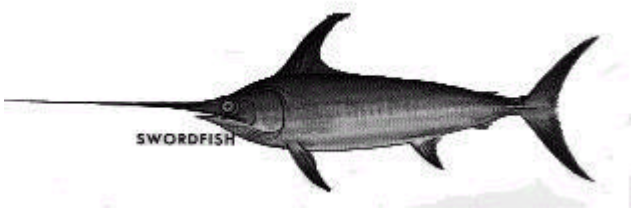
Heavy-bodied. Slaty blue or lead gray, becoming dirty white below. Blunt snout, large head. Teeth unmistakably large and triangular with serrated edges. Can reach 26ft. Worldwide distribution in temperate and tropics waters. Aggressive, dangerous and may attach man.

Bluefin tuna *Thunnus thynus*



Pectoral fin short, tip does not reach point below beginning of 2nd dorsal fin. 2nd dorsal and anal fins dusky with some yellow. Finlets bright yellow with dark edges. Head relatively long and pointed. Eyes relatively small. Can reach 14 ft. and 1500 pounds. Found worldwide in tropical and temperature waters. Important game and food fish with great economic importance

Swordfish *Xiphias gladius*



Upper jaw sword like-prolonged and flattened. Pelvic fins absent. No teeth in first jaw. A famous game and food fish. Found around the world in tropical and temperate oceanic waters. Can reach 15 feet and 1300 pounds

Southern Sting Ray ***Dasyatis americana***

Disk almost in perfect rhombus with pointed corners. Mid-dorsal row of low spines, a few spines in short rows near shoulder. Whip-like tail with barbed spine. Up to 6 feet across disk. Tropical waters.

Appendix C

Oxygen Saturation Chart

For 35 ppt salinity

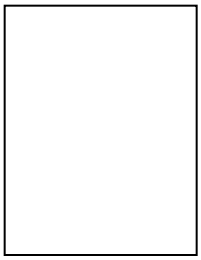
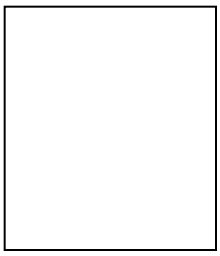
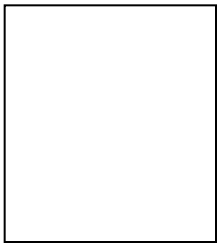
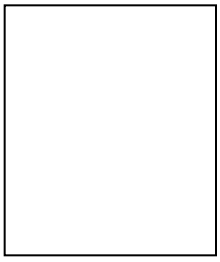
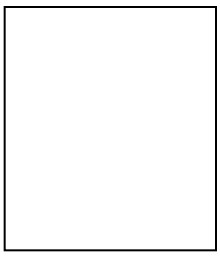
Celsius	Farenheight	DO(ppm)
10	50	9.0
15	59	8.1
20	68	7.4
22	72	7.1
24	75	6.9
26	79	6.6
28	83	6.4
30	86	6.2
35	95	5.8

Appendix D

Worksheets/Quiz Sheets for Each Unit

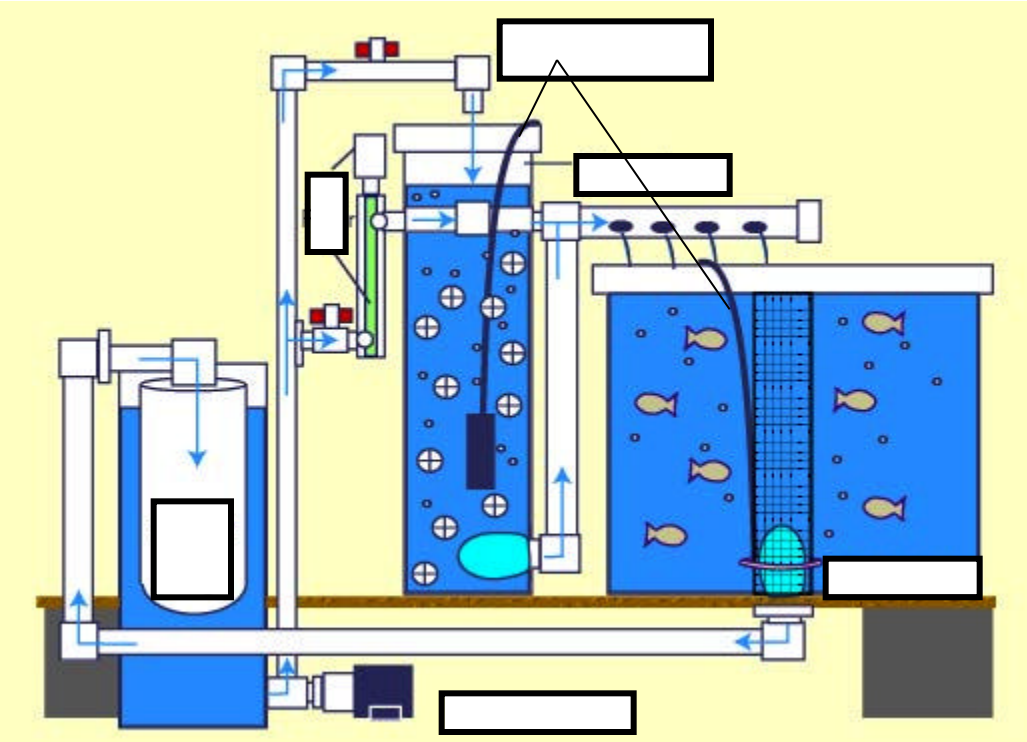
Worksheet/Quiz
Unit 1

Draw each part of a recirculating system. Number each part in the proper order to create a functional system. In the space provided at the right of the picture, explain what each part does.

Number	Drawing	Part	Function
_____		Pump	_____
_____		Mech. Filter	_____
_____		Tank	_____
_____		UV	_____
_____		Bio. Filter	_____

Worksheet/Quiz
Unit 1

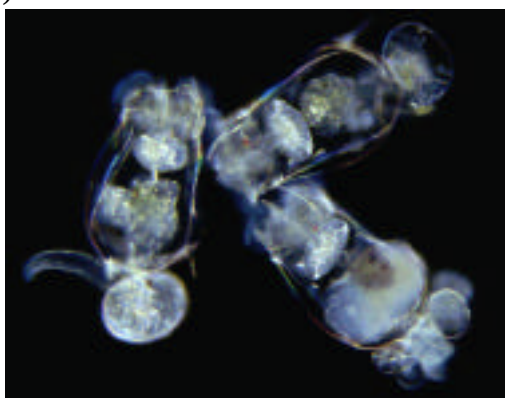
Label the parts of the recirculating system:



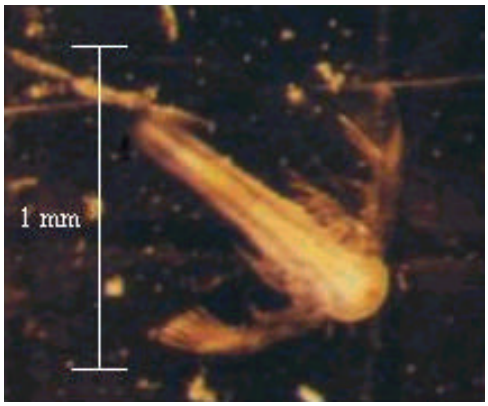
Worksheet/Quiz
Unit 4: Activity #9

Label each prey item:

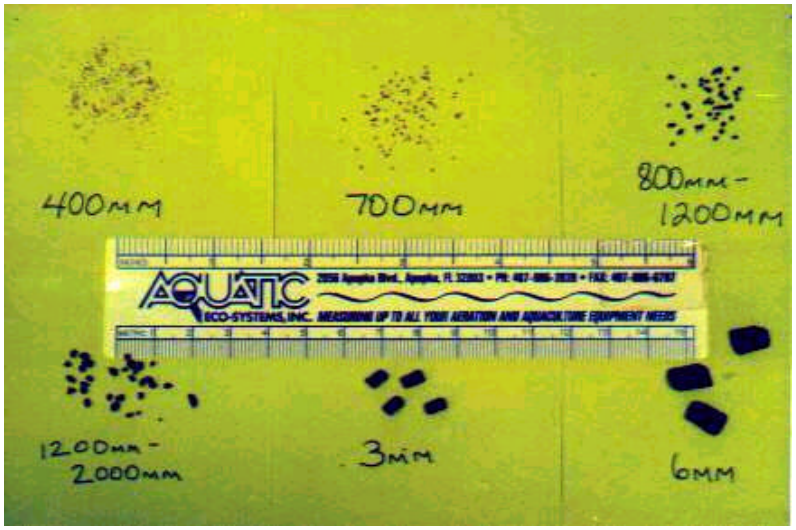
1)



2)



3)



How many days are the fish feeding on each of these types of feed?

1)_____ 2)_____ 3)_____

What size are the fish when they can feed on these different feeds?

1)_____ 2)_____ 3)_____

Worksheet/Quiz
Unit 5: Activity #12

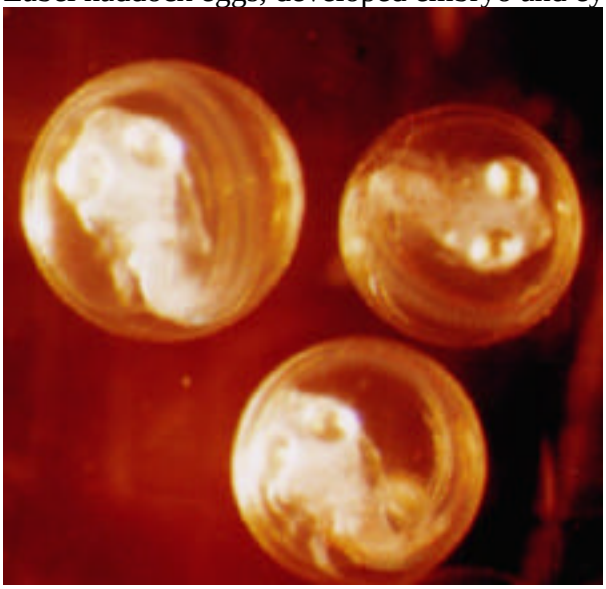
Draw the different stages of egg and larval development
Ex.: Chorion, embryo, eyespots, and pigmentation

Embryo:	Eyes spots in developing egg:	Yolk sac larvae:
Larvae with finfold:	Metamorphosis:	Juvenile:

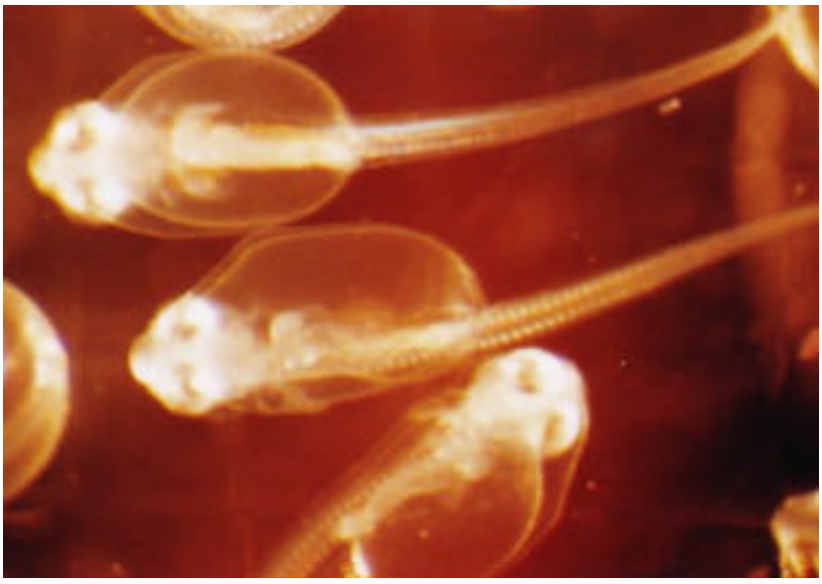
Worksheet/Quiz
Unit 5

Developmental stages of a marine finfish:

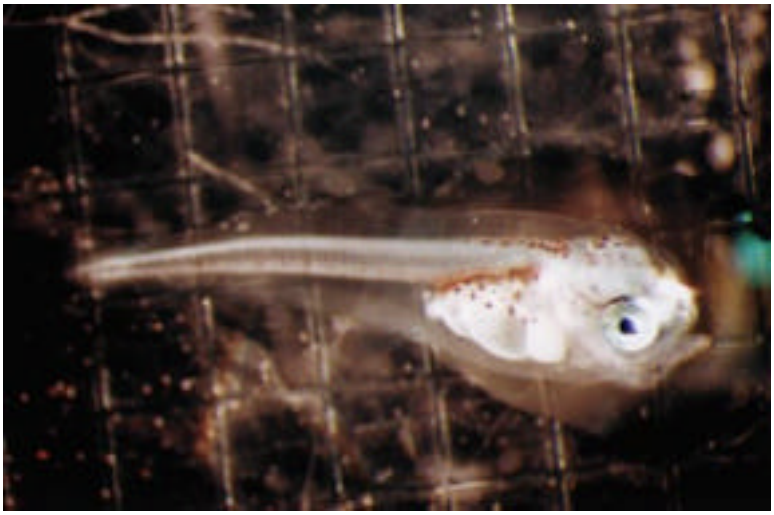
Label haddock eggs, developed embryo and eye spots:



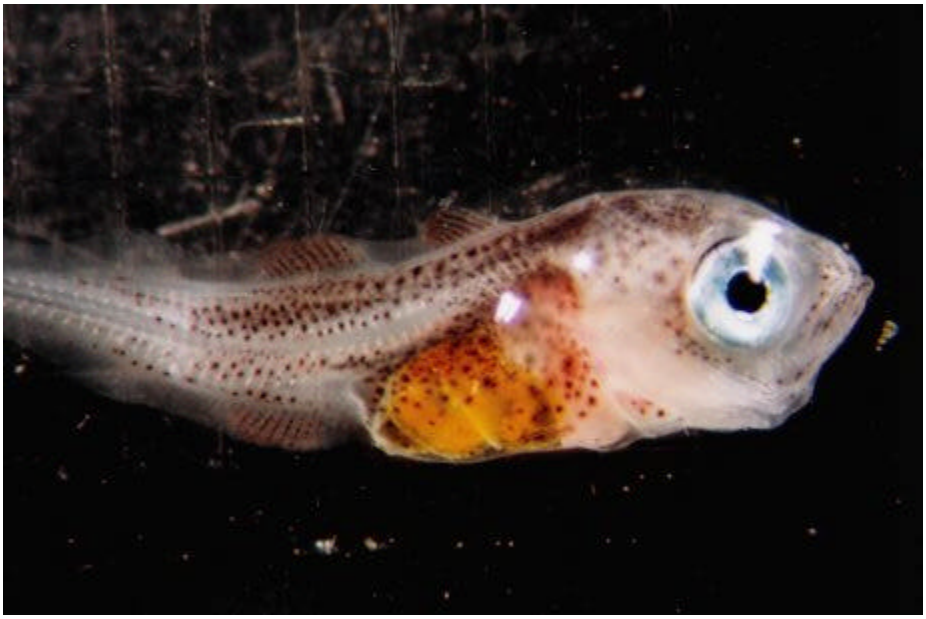
Label yolk sac on haddock larvae:



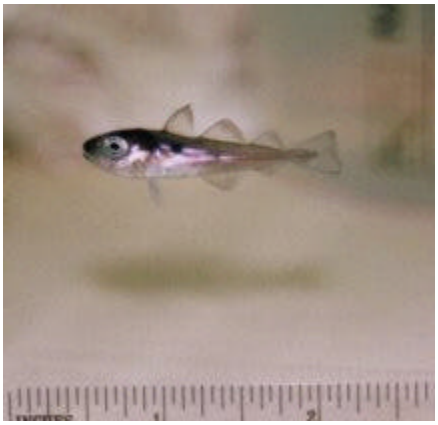
Label finfold, pigmentation spots and white stomach full of rotifers on larval haddock:



Label fin development, pigmentation and orange stomach full of *Artemia* on metamorphosing haddock:



Label juvenile haddock eyes, fins and distinctive markings:



Label adult haddock eyes, fins and distinctive markings:

Worksheet/Quiz
Unit 6

Match the following water quality parameters to their appropriate test:

pH	the amount of oxygen that is available to the fish
ammonia	the amount of acid in the water
alkalinity	the amount of NH3 in the water
nitrite	the amount of carbon dioxide that is given off from the fish
nitrate	the ability for the water to buffer any pH swings
dissolved oxygen	the amount of NO-2
carbon dioxide	the amount of NO-3

Appendix E

References

The following books, web sites and journal are resources that are available to give more detail on the various aquaculture topics discussed in this curriculum.

Introduction/ General Aquaculture Material:
-Aquaculture "How To" Series by the National Council for Agriculture Education
-New England Board of Higher Education RASCALS and Recirculating and Freshwater Aquaculture (publication out soon)
- National Council for Agricultural Education: http://ag.ansc.purdue.edu/aquanic/publicat/govagen/ncae/council.htm
- Aquaculture Network Information Center (AquaNIC): http://www.aquanic.org/
- NOAA Fisheries**: http://www.noaa.gov/**
- OceanLink: An Interactive Information Page for the Marine Sciences: http://oceanlink.island.net/
- National Sea Grant Office: http://www.nsgo.seagrant.org/

Recirculating Systems:
Info on recirculating systems: http://www.mda.state.mn.us/DOCS/MKTG/Aquacult/Recirc.htm
- Water Recirculation Project by the Northwest Fisheries Science Center: http://www3.nwfsc.noaa.gov/recirc/trial.html#update

Live Feed:
Plankton Culture Manual by Frank Hoff and Terry W. Snell
- Rotifer information: http://www.microscopy-uk.org.uk/mag/articles/winrotif.html
Artemia information: http://allserv.rug.ac.be/~jdhont/index.htm
http://www.ncsu.edu/sciencejunction/terminal/lessons/brine.html

Larvae/Fish Information:
-International Aquaculture – Species: http://www.321website.com/members/home/data/aquaculture/species.htm
- EFH Source Documents: Life History and Habitat Characteristics: http://www.nefsc.nmfs.gov/nefsc/habitat/efh/

Water Quality and Nitrogen Cycle:
- Water on the Web: http://wow.nrri.umn.edu/wow/
- LaMotte Water Test Kits : http://www.lamotte.com/
- Water quality and the Nitrogen cycle: http://www.fishgeeks.com/faqs/water.htm
- Nitrogen Cycle: http://fluid.state.ky.us/ww/ramp/rmnox.htm
- Water Quality Information Center: http://www.nal.usda.gov/wqic/

References/Journals:
-Electronic Journals: http://www-marine.stanford.edu/HMSweb/ejournals.html
-Aquaculture Dictionary: http://www.aquatext.com/
-Hydrology, marine science, freshwater science and aquaculture journals:
http://www.sciencekomm.at/journals/hydro.html
- Aquaculture
-Journal of World Aquaculture
-Fisheries
-Canadian Journal of Fisheries and Aquatic Sciences
-Bulletin of Marine Science
-Journal of Fish Biology
-Carl Uncover: a web base search engine for articles, journals, etc.: http://uncweb.carl.org:/
- Aquaculture Online Magazine: http://www.aquaculturemag.com/

Professional Societies:
-Welcome to The World Aquaculture Society: http://www.was.org/home.htm
- Massachusetts Aquaculture Association
- American Fisheries Society: http://www.fisheries.org/index.html
- Aquaculture Engineering Society: http://www.aesweb.org/
- National Marine Educators: http://www.marine-ed.org/

State Contacts:
Massachusetts Depart. Of Food and Agriculture: Scott Sores, State Coordinator
Northeast Regional Aquaculture Center- http://www.umassd.edu/specialprograms/nrac/

Supplies
- Aquatic Eco Systems: http://aquatic-eco.com/
- LaMotte Water Quality Test kits: http://www.lamotte.com/
- That Fish Place: http://www.thatpetplace.com/
- US Plastics: http://www.unitedstatesplastics.com/

Fish Health:
Fish Vets: http://users.jaguNET.com/~fishvet/

Appendix F

Materials and Supplies Source

Component Vendor Contact Information

Aquacenter, Inc. 166 Seven Oaks Rd. Leland, MS 38756	Tel: 800-748-8921	Fax: 601-378-2862
Aquatic Eco-Systems, Inc. (AES) 1767 Benbow Court Apopka, FL 32703-7730	Tel: 877-FISH-STUFF	Fax: 407-886-6787
U. S. Plastics Corp. 1390 Neubrecht Rd. Lima, OH 45801	Tel: 800-537-9724	Fax: 419-228-5034
Water Management Technologies P.O. Box 66125 Baton Rouge, LA 90249	Tel: 504-627-3930	Fax: 504-627-6918
That Fish Place (TFP) 237 Centerville Rd Lancaster, PA 17603	Tel: 888-THAT PET	Fax: 717-295-7210
Aquaculture Supply 33418 Old Saint Joe Rd. Dade City, FL 33525	Tel: 352-567-8540	Fax 352-567-3742

Appendix G

Marine Aquaculture: Raising Salt Water Fish in Your Classroom
Meeting the Massachusetts Curriculum Standards for Science and Technology/Engineering and Mathematics

Framework Learning Standard | **Marine Aquaculture Activity** | **Suggested Assessment**

Strand Inquiry: Grades 6-8

1. Design an investigation or problem, specifying variables to be changed, controlled and measured.	Activity 2: Where can you hatch a fish? Activity 5: How many rotifers do I need?	Pre-test using pictures of each element of the hatchery system randomly placed. Place each element in order and label what each does. Post-test with a list of all parts of the hatchery system and have them draw them in the right order. Pre-test using student estimates of numbers of rotifers based on specifics of rotifer size and fish size. Post-test by having students calculate actual versus estimate (when given appropriate formula) numbers.
2. Use more complex tools, technologies and appropriate measurement units to make observations, collect and organize qualitative and quantitative data.	Activity 2: Where can you hatch a fish? Activity 5: How many rotifers do I need? Activity 15: Where did the water come from?	Same as Inquiry 1 above
3. Present and explain data and findings using multiple representations including tables, mathematical and physical models, demonstrations and graphs.	Activity 2: How many rotifers do I need? Activity 6: Rotifer Production Activity 7: Maintenance and harvesting rotifers Activity 8: *Artemia* Production	Post-test includes students presenting data from monitoring system. Presentations should be in graph, model and verbal forms.

4. Communicate scientific procedures, results and explanations using appropriate	Activity 16: Monitoring your system	Post-test includes student presenting data from monitoring system. Presentations should be in graph, model and verbal forms.

Strand Life Science: Grades 6-8

5. Organisms of different types interact with one another in various ways besides providing food.	Activity 1: What species of marine fish can we culture in our classroom? Activity 2: Where can you hatch a fish?	Pre-test with a list of fish species, both fresh and marine. Students categorize each by its habitat and list reasons why some are better for marine aquaculture. Post-test with the accepted list and students match fish species with culture requirements
6. Ecosystems can change over time in response to physical conditions or interactions among organisms. Changes may be the result of predictable succession or the result of catastrophes.	Activity 9: How do I hatch, feed and care for my fish larvae? Activity 10: What do I do when the fish no longer need rotifer and *Artemia*?	Pre-test with open-ended questions for students: What happens to the feeding behaviors of our fish as the fish grow from egg, to larvae to adult? What changes in feeding patterns does that mean for us? What happens to fish in the marine environment that parallels these changes in the classroom?
7. Dead plants and animals are broken down by other living organisms	Activity 12: What are the stages in the development of a fish? Activity 16: Monitoring your system	Post-test includes student's presenting data from monitoring system. Presentations should be in graph, model and verbal forms.

Strand Earth Sciences: Grades 6-8

5. Heat is transferred through the earth system by three mechanisms: radiation, conduction and convection	Activity 2: Where can I hatch a fish?	Pre-test with students drawing a chart of energy path from the air to water and within water in an aquarium. Post-test with student's demonstrating with thermometers and graphs how temperature flowed in the system, into and from the system.

Strand Technology/Engineering: Grades 6-8

1. Develop an understanding of technology as a system that includes a goal, input, process, output and feedback, and uses resources such as people, materials, tools, energy, information, finances, and time (the universal system model). Technology involves decisions related to advantages and disadvantages of process and products.	Activity 2: Where can I hatch a fish? Activity 3: How do we condition the tank to prepare for the fish eggs?	Same as Inquiry #1 above.
3. Using the manufacturing process, explore and analyze the actions used to change primary processed materials into finished products.	Activity 3: How do we condition the tank to prepare for the fish eggs? Activity 4: What do you do when the eggs arrive? Activity 7: Maintenance and harvesting of rotifers Activity 11: Are the fish eating?	Same as Inquiry #1 above. Pre-test with students estimating needs of hatchlings based on research performed above. Predictions are then tested. A model is created for number of hatchlings and number of rotifers. Post-test includes application of that model to varied situations of numbers.

4. Explore and analyze the bioengineering systems used to develop and engineer devices for agricultural applications, monitoring and testing devices and physiological replacement of human organs and limbs. 6. Design a product using engineering and scientific principles 7. Produce (using tools and machines), use, evaluate and improve the product that was designed. 8. Document the design process through written and graphic means, including three-view drawings. 9. Make and engineer a presentation on the finished product (including an explanation of the scientific principles involved) using print visual and electronic media.	Activity 2: Where can I hatch a fish? Activity 3: How do we condition the tank to prepared for the fish eggs? Activity 4: What do you do when the eggs arrive? Activity 7: Maintenance and harvesting of rotifers Activity 11: Are the fish eating?	Same as Inquiry #1 above.

Mathematics Learning Standards: Grades 5-6

<u>Data Analysis, Statistics and Provability</u> 1. Describe data sets using the concepts of median, mean, mode, maximum and minimum and range. <u>Numbers and Operations</u> 2. Apply ratios and proportions to the solution of problems 4. Solve problems involving addition, subtraction, multiplication and division with whole numbers, fractions and decimals including percents.	Activities 5, 6, 7, 8, 10 and 14	Students will collect data from observations of numbers of fish, rotifers and *Artemia*, and hatching and surviving. Calculations for each parameter with the appropriate measures for their samples will be done.

Mathematics Leaning Standards: Grades 7-8

1. Choose and apply appropriate measures of central tendency (mean, median, mode) to represent a set of data	Activities 5, 6, 7, 8, 10 and 14	Students will collect data from observations of numbers of fish, rotifers and *Artemia* hatching and surviving and calculating each of the appropriate measurements for their samples.
3. Differentiate between continuous and discrete data and ways to represent them.	Activities 5, 6, 7, 8, 10 and 14	Pre-test with students attempting to determine if hatching rates and growth rates are continuous or discreet data. Post-test with reassessment of the distinction.
4. Make inferences about a characteristic of a population from a well-constructed sample; e.g., capture-recapture	Activities 2, 6, 7, 8	Students estimate populations based on numbers in a single sample. Multiple samples are taken and estimate of total populations is determined. Discuss causes of discrepancy and error in sampling and estimations.