Aquaponics: Breathing Life into Classrooms
Joseph K. Buttner, Professor; Cyntheara Tham, Student; Megan Fernandes, Student; Department of Biology, Salem State University

Aquaponics is a form of sustainable food production that can be easily, effectively and economically integrated into the classroom as a STEM or STEAM experience. Students learn about linkages among the natural sciences, social sciences, arts and humanities by cooperatively setting-up, monitoring, and managing one or more in-class aquaponics systems. Learning and relevance can extend beyond the classroom as each student brings home fresh produce and in-class experiences to share with family members.

How Does Aquaponics Work
Aquaponics marries two proven and increasingly important forms of food production: fish culture in recirculating aquaculture systems (RASs) and plant cultivation in a soilless medium (hydroponics). RASs and hydroponics have been used to produce food for human consumption for decades, particularly when and where water is limited and environmental control desirable. Aquaponics links RASs and hydroponics as the waste of fish is transformed by bacteria into nutrients for plants in the system. Water cleansed of toxic metabolites is returned to the fish. Fish are maintained in a tank where they live, eat, excrete and grow. Water is moved from the fish tank into and through one or more grow beds filled with an inert medium, such as ceramic chips. The grow bed

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2020 MME Spring Calendar

Check website and F&J for details.

APRIL 2 - 5
68th NSTA National Conference on Science Education – Boston
Convention & Exhibition Center
Boston, MA

MAY 1
2020 Marine Art Contest
Deadline for receipt of entries
Check website for additional information.

MAY 2
MME Annual Meeting and Conference
Woods Hole
Grace Simpkins, Conference Chairperson
gsimpkins@whoi.edu

MAY 13
MME Board Meeting
This meeting will be a virtual meeting held by ZOOM conference call
Contact MME President for information on joining the call

All MME Members are invited to Board Meetings.
Let the host know if you are coming.

CANCELLED

CANCELLED

Spring 2020 Flotsam & Jetsam
If you have been to the MME website in the past few weeks, you might have noticed that the site looks different. For the third time since we have had the website, it was time to make a change. You may have noticed this when we posted the winter F&J, and I had to send a second notice to find that issue. Over the past 2 months one of our board members, Jeffrey Morgan has taken on the task of updating the site. In addition, the site has a new URL. For the past two months, a click on the old URL has been redirected to the new site. The site is still being worked on so more changes will be coming.

Massachusetts Marine Educators are happy to announce that we have launched our new website which is live at https://www.massachusettsmarineeducators.org/ The new site will allow MME to have a stronger social media presence, better website and app integration for MME Events and will distribute Flotsam and Jetsam to a greater audience with unique, searchable URLs. Thank you to everyone that was involved in the process of designing and building the website. If you have not had a chance to check it out, now is the time! We hope you enjoy it.

OCEAN LITERACY PRINCIPLE 2:
The ocean and life in the ocean shape the features of Earth.

- Many earth materials and geochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.

- Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.
Greetings all,

I can feel the days getting longer and a few early signs of spring's imminent arrival. A few years ago we bought a witchhazel for our front yard. Witchhazels are smallish trees that have the wonderful property of blooming in winter! Bright yellow/orange threadlike petals emerge as early as the first week of February. The flowers are subtle, but quite elegant. This time of year also brings skunk breeding season, so the neighborhood has been somewhat pungent lately. Not so subtle!

We live within an easy walk of King's Beach in Swampscott, and this time of year you might often find a small group of birders huddled over their scopes, which are focused on the flock of gulls gathered at the surf line. They are looking for the mew gull, a fairly common resident of far northwestern North America and Europe, but very rarely seen here. Evidently King’s Beach is a hot spot on the east coast for mew gulls. I catch a glimpse through a scope; to me it looks just like a ring-billed gull without the ring, but a spot of black under the bill. I would never have seen this without help. But it is a treat nonetheless to see such a rare thing, even if it is somewhat plain to eye.

At MME, springtime means planning for the Annual Meeting and Conference at Woods Hole. Our theme this year will be ocean sustainability. We already have some excellent speakers lined up, and are also arranging tours and workshops. We are fortunate that MME board member Grace Simpkins is organizing this year’s event. Grace works at WHOI as the Woods Hole Sea Grant educator. In her role, she is able to bring in excellent keynote speakers and line up numerous field trips. If you have never attended an MME annual meeting, or haven't been to one in a while, I encourage you to do so this year! There is more information on the conference located here in F&J.

Speaking of sustainability, board member Howard Dimmick has donated a Zoom account to MME. Zoom is a virtual conferencing platform which will allow the board and its committees to host some of our meetings on-line, rather than having folks drive to the meeting locations, which for some can mean an hour or two in the car. Thank you, Howard!

In other news… our new website has launched! Board member Jeffrey Morgan has done yeoman’s work on this project, and we owe him a debt of gratitude. Check it out at https://www.massachusettsmarineeducators.org/. Also, Elaine Brewer has come on board to help build our social media presence and improve our member communications through the monthly e-news. You can sign up to receive the newsletter on the website, or check us out on Facebook and Instagram.

As always, if you have any questions, ideas, comments or concerns please feel free to contact me directly at dpinkerton@rpsk12.org, or call/text me at (781) 718-5770. I am on Instagram and Twitter @pinkerteach.

Best regards,

Don

Don Pinkerton, President
With little fanfare, The President in November declared the United States would “act boldly” on a gigantic task: mapping a chunk of ocean floor that’s larger than the combined land area of all 50 states.

Armed with this strong backing from the White House, NOAA is ready to go where no man has gone before. The agency this year plans to accelerate exploration of the entire U.S. Exclusive Economic Zone, with the goal of completing the job by 2030.

NOAA officials say they’re following in the footsteps of Lewis and Clark and the nation’s pioneering astronauts.

The undertaking is “fairly audacious,” as one top official described it. But the work is already underway, with roughly 40% of the EEZ mapped in recent years. The zone covers more than 13,000 miles of coastline and 3.4 million square nautical miles of ocean.

NOAA Deputy Administrator Timothy Gallaudet, who’s overseeing the agency’s big push, figures there’s no reason that ocean exploration can’t do for NOAA what space exploration did for NASA a half-century ago.

“Every time I’m on the [National] Mall — I usually run on the Mall every day at lunchtime — I will see a kid in a NASA shirt,” Gallaudet said. “I wanna see a kid with a NOAA shirt — and maybe with an ROV and an AUV on it.”

An ROV is a remotely operated vehicle, while an AUV is an autonomous underwater vehicle; both pieces of equipment will be used to help NOAA map the Exclusive Economic Zone.

Oceanographers liken it to having robots mow the lawn — a very big lawn. With technology changing rapidly, NOAA officials say machines could be doing the work by themselves by the mid-2020s.

“You send these robots out on a mission — what we call mowing the lawn — to just run a pattern over the seafloor, to not only get a sense of what the topography is, but also to get video of what’s on the seafloor,” said Alan Leonardi, director of NOAA’s Office of Ocean Exploration and Research.

“The easiest way to describe what we do on a daily basis is we go to places in the world’s oceans that have never been explored — nobody knows what’s there,” he said. “We’re going to these places for the first time.”

NOAA’s recent discoveries have run the gamut, from an 85-mile-long coral reef off the coast of South Carolina to a shipwreck to 25 new marine species. NOAA officials say more ocean exploration could lead to new cancer drugs, along with new sources of economic development and new ways to promote trade, fisheries, tourism and energy exploration.

“We’ve only explored 5% of the ocean’s volume — think about that,” Gallaudet said.

Gallaudet said the nation’s “blue economy” is expected to employ an estimated 40 million people by 2030, more than doubling its contribution to the overall U.S. economy.

With the program getting “a lot of attention and great support” from the White House, Gallaudet told NOAA’s Ocean Exploration Advisory Board last month that “it’s a lot of fun right now.”

“It’s an exciting time, and I think the opportunities are vast,” he said.

‘Especially lacking’

The EEZ dates back to 1983, when President Reagan designated the waters between 3 and 200 miles from the U.S. coast as territory where the nation controls the resources and economic activities.

In a November memorandum, Trump said U.S. policy would be to “act boldly to safeguard our future prosperity, health and national security through ocean mapping, exploration..."
From the Editor’s Desk

“Winter” has been a very mild one so far in the Boston area, with just a few weeks left before spring officially arrives, it seems that we have dodged a proverbial bullet this year. While the time has passed, with mid-year exams and winter break behind us, your MME board has been hard at work planning our upcoming events. In a few days our annual High School Marine Science Symposium will be upon us. This promises to be a very busy day for the students who will attend.

One of our newer board members has updated our MME website. Jeffrey Morgan has spent countless hours in updating the site. This is the first major change we have had in the past ten years, and it comes with a new on line address of massachusettsmarineeducators.org. If you have been on the website in the past several weeks you may have noticed that you were automatically transferred to the new website. During the time since the winter issue of F&J appeared changes have been made to update the site. You will note several new features as mentioned on page 3. There will be additional changes made to the website over the coming weeks as Jeffrey continues work on the new site. Make sure that you have the new address bookmarked. Thank you, Jeffrey, for your hard work.

About ten years ago we featured Aquaculture in an issue of F&J. Since that time, Dr. Joe Buttner who produced an article for that issue has continued work in the field. He “retired” from full time teaching at Salem State University but hardly from his research. This issue features work that is being carried out by Dr. Joe and a group of his students. The students also helped prepare the lead article in this issue.

You will find some classroom activities related to aquaculture written by a past MME President Bill Andrake. Bill still is teaching in the Swampscott School System. Perhaps you will get some ideas from his activities which you can use in your classroom.

On March 11, the following announcement arrived in my e-mail box:

Due to the increasing health concerns and escalating developments that have occurred over the last several days regarding the coronavirus (COVID-19) outbreak, including the state of emergency declared in Massachusetts less than 24 hours ago, by conference call the NSTA Board of Directors voted unanimously that a face-to-face meeting in Boston on April 2–5, 2020 will no longer take place. NSTA staff are thoughtfully exploring options for a future event and will provide an update once a final decision has been made.

As the largest education organization in the world dedicated to the teaching and learning of science, we adhere to the facts involved, including following precautionary measures issued by the World Health Organization (WHO) and the Centers for Disease Control (CDC). As difficult as this decision is, the health and safety of our attendees, exhibitors, presenters, volunteers, and staff remain our top priority.

Thousands of hours of pre-planning go into these meetings, and many thanks need to be sent to those on the local committee, including some MME members deserve thanks for their efforts. The Boston meetings of NSTA in the past have been some of the largest they have ever held. I cannot imagine the logistics involved in un-planning a meeting of this size by NSTA Staff and volunteers.

On the same day, your MME Board had a planned board meeting and we heard the sad news that due to the same virus outbreak Woods Hole Oceanographic Institution could not open their campus to any outside organization to use facilities there. TWO BOMBSHELLS on the same day. As a result, our annual meeting on May 2 would have to be cancelled. Additional Information will be found on a later page of this issue.

Howard Dimmick, Editor
This year Earthwatch teams up with Woods Hole Sea Grant at the Woods Hole Oceanographic Institution for another year of the Girls in Science Fellowship. This fellowship aims to promote diversity and expose young women to a variety of marine careers in STEM.

WHO IS ELIGIBLE?
• Current Sophomores and Juniors in high school
• Currently a student in Massachusetts
• Excited to work with a team of diverse students and scientists at the Woods Hole Oceanographic Institution exploring bioacoustics and marine mammal research
• Available August 8–15, 2020

QUESTIONS?
PLEASE CONTACT: Sarai Zelada: 978.450.1236 | szelada@earthwatch.org

earthwatch.org/education/student-fellowships/girls-in-science
medium provides a surface for nitrifying bacteria to colonize and prosper. Bacteria, primarily in the grow bed, transform nitrogenous wastes, essentially ammonia produced by fish into nitrates an essential nutrient for plants through the process of nitrification:

Ammonia $\rightarrow$ Nitrites $\rightarrow$ Nitrates

The medium also serves as a substrate to support and anchor plants. Plants remove and use nitrates to generate new tissue. The ecological footprint of aquaponics is minimal. The waste of one cultured species (fish) serves as the food and nutrient of another cultivated species (plant). In essence, aquaponics systems are miniature ecosystems used to grow primarily plants (80-90% harvest biomass) and secondarily fish (10-20% harvest biomass). Bacteria are the “Rodney Dangerfield-like” facilitators, they get no respect but are essential to proper operation of the system. Since most plants are intolerant of sodium ions, aquaponics is pursued in freshwater.

**How Can Aquaponics be Pursued**

Aquaponics is versatile; it can be pursued at large, modest and small scale levels. Large or commercial scale aquaponics systems grow fish and plants at high densities under carefully controlled conditions for economic gain. Their purpose and sophistication is beyond the scope of a classroom setting. Modest and small-scale aquaponics systems produce limited quantities of fish and plants, sufficient for classroom explorations, personal consumption and supplemental income. The goal of small and modest levels of operations is not solely or primarily economic gain, but rather education. Participants gain hands-on experience that builds upon and extends theoretical concepts. Students experience the interdependence of disciplines, while those aspiring to pursue aquaponics for personal or economic motives gain insight into whether or not aquaponics is appropriate for them.

Since 2010, Biology faculty and students at Salem State University (SSU) have pursued aquaponics, assisted aspiring and novice practitioners, and visited dozens of operations. Information and experience gleaned from these activities have provided insight on the assembly, monitoring and management of small to modest scale aquaponics systems suitable for classroom settings.

**How to setup an Aquaponics System**

Aquaponic production of plants and fish can be pursued successfully by multiple approaches. At SSU, we use grow beds with media to culture both nitrifying bacteria and plants. A floating raft covers fish in their tank thereby reducing the exposure of fish to light, discouraging fish from jumping, and providing a germination/nursery site for plants. Most materials needed to construct the system are locally sourced and reasonably priced (e.g., from Home Depot, Lowe’s, or Walmart). More specialized components, such as pumps, can be readily acquired from on-line sources (e.g., Amazon, Pentair/Aquatic Ecosystems). Components are selected to be user friendly to facilitate assembly, operation, disassembly and storage.

Biological components are similarly sourced. Organic seeds, primarily nitrogen-loving, rapid-growing and easy-to-maintain leafy greens are grown. Seeds are obtained from reputable sources (e.g., Johnny’s Selected Seeds, Winslow, ME). Koi (*Cyprinus carpio*), a cool water, omnivorous fish...
that grows well at room temperature, does well on a low-protein prepared ration, and requires no permit to grow in Massachusetts. Goldfish (*Carassius auratus*) are a good, alternate option. Fish are either purchased or donated by a local provider (e.g., Country Gardens, Rowley, MA), where quality fish feed can be also acquired and fish transferred when harvested.

Systems can be assembled and stocked at the start of the academic term. At the end of the academic term systems can be harvested, disassembled, and stored. Students can be involved with setup and breakdown of the system(s).

**Aquaponics System Operation**

Once constructed, a system is tested to ensure water flow and quality are suitable for fish. Once environmental conditions suitable for fish are confirmed, small fish (10-30 g each) are stocked at low density. We typically stock 5-8 fish per 70 L tank. The fish are fed lightly for 4-6 weeks so bacteria can colonize and populate the media. Concurrent with introduction of fish and colonization by bacteria, seeds are planted and germinated in plastic cups that can be transferred to the grow bed when seedlings are 20-30 mm tall. Once the system is fully functional: nitrifying bacteria have colonized, fish are feeding well (fed at 1-3% body weight per day), and plants are growing well, a standardized monitoring and management protocol can be initiated.

Successful operation of an aquaponics system requires daily, weekly, and monthly monitoring and management activities. Koi survived and grew well in aquaponics systems, quadrupling their weight and value during the 8-month academic year. Plotted values are observations made for a half dozen fish in each of two simulated, 8-month academic years. Growth was similar during both simulations.

### Monitoring and Management Activities

<table>
<thead>
<tr>
<th>Task</th>
<th>Activities</th>
<th>Time (mins.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>Check fish and system</td>
<td>3-6</td>
</tr>
<tr>
<td></td>
<td>Feed fish</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Add bicarbonate (as KHCO₃)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clean pump filter if needed</td>
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</tr>
<tr>
<td></td>
<td>Add water if needed (0-2 cm)</td>
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</tr>
<tr>
<td>Weekly</td>
<td>Monitor water quality</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Plant harvest</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Add Standard f/2 1-2 mL</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Remove sediments</td>
<td>2-4</td>
</tr>
<tr>
<td>Monthly</td>
<td>Measure fish</td>
<td>15</td>
</tr>
</tbody>
</table>

### Productivity and Environment

- **Koi production (g)**: 422.5 and 462
- **Plant production (kg)**: 3.4 and 5.3
- **Ratio plant to fish production**: 8.1 and 11.5:1
- **Koi FCR**: 2.7 and 3.6
- **TAN (mg/L as mean and SD)**: 0.11 (0.10) and 0.01 (0.02)
- **NO₂⁻ (mg/L as mean and SD)**: 0.06 (0.02) and 0.06 (0.09)
- **NO₃⁻ (mg/L as mean and SD)**: 30.4 (27.4) and 128 (90)
- **Alkalinity (mg/L as mean and SD)**: 184 (44) and 143 (21)
- **Temperature (°C, as mean and SD)**: 21.4 (3.7) and 20.7 (4.5)
- **Dissolved Oxygen (mg/L as mean and SD)**: 6.6 (0.7) and 6.4 (1.1)
- **pH**: 7.6 (0.4) and 7.6 (0.2)

Koi that average approximately 30g each are stocked into fish tank of the aquaponics system.
and monthly monitoring; however, monitoring alone is insufficient. Information collected by monitoring must be assessed and appropriate actions initiated. Some management practices occur daily such as feeding fish, addition of potassium bicarbonate (KHCO₃) and replacement of water lost through evaporation. Other management practices including plant harvest, seed planting, removal of sediments from the fish tank, adjustment of KHCO₃ added daily, and addition of essential micronutrients as F/2 algal medium occurs weekly. Fish growth is assessed monthly and used to adjust the daily feeding and KHCO₃ rate.

Operation of an aquaponics system for the academic eight month academic year adds much to the learning experience as students collect, process and interpret data. The system rewards participants by yielding substantial quantities of leafy greens and fish that are grown essentially organically, which can be consumed, shared or sold.

Next Step
Aquaponics can be pursued successfully, but it is not without problems. Good preparation can minimize surprises, but they will occur. Dealing with aphid infestations, identification of plants that grow best in a classroom setting, and determining optimal addition of micronutrients are current challenges. However, if the potential of aquaponics in your classroom, backyard or basement has whetted your appetite, you may care to attend the 2020 Massachusetts Marine Educators Annual Meeting and Conference in Woods Hole, MA on 2 May. A “how-to” presentation on setting-up and operating a small to modest scale aquaponics system will be offered.

Acknowledgements
Information assembled and shared here was made possible through support provided by many groups including colleagues at Salem State University, the Massachusetts Department of Agricultural and Resources, Full Circle Earth, and Country Gardens. Several Salem State students assisted with design, construction, operation and data collection/analyses throughout many aquaponics iterations: Franki Vetrano Olsen, Kelan Joshua, Erbo Ou, Ashlee Molla, Kenneth Moore, David Simon, Ethan Fertsch, Anastasia Perullo, Laura Presutti, Eliza Kesseler, Ali Kluge, Mikayla McCarthy, and Joe Incatasciato.

NOTE: Identification of a potential source of supplies is meant to provide guidance and is not an endorsement.

About the Author
Dr. Joe Buttner (Dr Joe) is a Certified Fisheries Scientist who has been involved in aquatic science and aquaculture for over four decades as a faculty, researcher, and extension specialist. He is currently an Adjunct Faculty and Professor Emeritus in the Department of Biology, Co-coordinator of the NorthEastern Regional Aquaculture Center, and Outreach Specialist of the Cat Cove Marine Laboratory at Salem State University in Salem, MA. His focus is on education, broadly defined to include traditional and nontraditional venues of instruction, development of aquaculture in West Africa, and small to modest scale aquaponics systems suitable for classroom and personal use. Other activities include culture of warm, cool and cold water aquatic organisms (vertebrates, invertebrates, algae) in open, semi-closed and closed systems.

OCEAN LITERACY PRINCIPLE 5: The ocean supports a great diversity of life and ecosystems.

Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate and circulation. A few regions of the ocean support the most abundant life on Earth, while most of the ocean does not support much life.
Dear Marine Educators,

It is with sincere regret that we are canceling our May 2 Woods Hole Conference due to increasing health concerns within Massachusetts about the Coronavirus Disease 2019 (COVID-19).

Those of you who have already registered for the Annual Meeting and Conference will be refunded. We will not be rescheduling the conference because we are unsure of how COVID-19 will progress in the upcoming months. We are, however, looking forward to seeing you all at the Boston Harbor Educators Conference this fall.

Because registration for the Annual Meeting and Conference includes membership dues, we do ask that you all renew your membership this spring. Renewing your membership will ensure that MME continues to do great things for marine education in Massachusetts.

Although we will not be meeting in person, we will be hosting a virtual Annual Meeting on May 2 so that we can vote in our new board for 2020–2021. Please watch your email for upcoming information about this meeting.

The Board will address changes as they develop, and we will provide you with information concerning MME events as soon as it is available.

I ask that you all take precautions to remain safe and healthy. The marine education community is resilient in times of crisis. This should not be any different.

Best,
Don Pinkerton
MME President
and characterization.” The White House said data collected from mapping will help advance U.S. commerce, domestic seafood production, recreation, environmental protection and national security.

“The nation is poised to harness cutting edge science, new technologies, and partnerships to unlock the potential of our oceans through increased ocean mapping,” Trump said in the memorandum.

Trump, who also hosted a summit on ocean exploration in November, gave NOAA six months to develop a strategy for mapping near the shoreline of Alaska and the Alaskan Arctic, where he said information is “especially lacking.”

The president also asked for recommendations on how to speed up the permitting and authorization process for ocean research and mapping, saying they frequently require multiple environmental reviews.

NOAA has a $42 million annual budget for its ocean exploration but relies on partners in both academia and the private sector to do much more. Much of the research is conducted on the NOAA ship Okeanos Explorer and the exploration vessel Nautilus, which is owned by the Ocean Exploration Trust.

In May, NOAA launched a new $94 million ocean exploration institute that will be led by the University of Rhode Island. It’s part of a five-year partnership with the Ocean Exploration Trust, the Woods Hole Oceanographic Institution, the University of New Hampshire, and the University of Southern Mississippi. The group — called the Cooperative Institute for Ocean Exploration — will work with NOAA to explore and survey roughly 3 billion acres of submerged U.S. territory.

Ocean discoveries “will soon be made by robots that operate 24 hours a day, seven days a week,” said Robert Ballard, lead investigator of the institute, who also serves as president of the Ocean Exploration Trust and director of the Center for Ocean Exploration at the University of Rhode Island’s Graduate School of Oceanography.

“U.S. territorial waters cover more ocean than those of almost any other country on Earth — imagine we’re about to lead the next Lewis and Clark expedition, only six times over,” he said. “When we’re done, we’ll know what we have.”

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Select 2019 Marine Art Contest Winners

**Scientific Illustration**
1st Place: Jessica D., gr. 8, Diamond MS, Lexington. *Red-Gilled Nudibranch*

**High School**
1st Place: Jayana McGuire, gr. 12, Bourne, HS. *Green Sea Turtle & Moon Jelly*

**Middle School**
1st Place: Hantong L., gr. 8, Luckie Art Studio, Lexington. *American Lobster*

**Elementary School**
1st Place: Dylan Y., gr. 4, Thoreau School, Concord. *Atlantic Wolffish*
In my twenty plus years of classroom aquarium keeping I have found that many of the learning standards we need to address can be made relevant and meaningful by integrating some form of aquaculture in the classroom. Whether its a simple aquarium or large aquaculture system, I have found that most students are fascinated by aquatic life and welcome the opportunity to observe and raise these creatures.

The science of the aquarium is the science of ecology. Lessons in biology, physical science, and chemistry can be incorporated into the maintenance and operation of an aquarium. The challenge to aquarium keeping is to mimic those conditions found in nature using mechanical devices, chemicals, and cooperative creatures.

To make sure the simulated environment is safe for the residents of the aquarium involves measurement, data collection, and analysis.

In addition to good science, the aquaculture projects promote lessons in responsibiltiy, teamwork, and stewardship. Most importantly, aquarium keeping is an exercise in creative and practical problem solving, as there are inevitable problems (teaching opportunities) that arise in even simple systems. It is rewarding to see students identify a problem in a system from their water quality data and then take the steps needed to solve it. As is often the case, I don’t have a solution for many of these problems, thus we need to work together to solve it and we all learn.

I certainly do not consider myself to be an expert in this area as I am always learning new methods for aquaculture and still making mistakes. However, with each mistake I find that I am better equipped to anticipate a potential problem and take the necessary precautions to prevent it. Its nice to see this ability develop in my students as we carry out our projects.

It would be nearly impossible for me to share all that I have learned in this contribution to “F and J.” However, I thought that I would summarize in this issue some of the projects that I do with my seventh graders and I would like to offer some basics I have learned on aquarium filtration to which apply to any system. I would also like to thank those who have helped me to implement aquaculture in my classroom especially Brandy Wilbur and Sarah Hammond with MIT Sea Grant’s Aquaculture Education Programs and the Adopt a Salmon Family Project with the U.S.Fish and Wildlife Service.
The seventh-graders at Swampscott Middle School have been working with M.I.T. Sea Grant’s education outreach program since 2003 in the aquaculture of Winter Flounder.

Like many of our commercially valuable saltwater finfish, Winter Flounder populations are in decline due to pollution and overfishing. The aquaculture of these fish is one way to help restore their populations.

Our students have conducting several projects involving the aquaculture of Winter Flounder, *Pleuronectes americanus* in a recirculating aquaculture system. It has been a great opportunity for our students to learn experimental design and experience the scientific process in a real and “hands-on” manner.

The Winter Flounder are raised in a chilled recirculating aquaculture system or “R.A.S.” designed by aquaculture specialists at M.I.T. seagrant. See an animation of the system here: [http://seagrant.mit.edu/education/resources/recirc.html](http://seagrant.mit.edu/education/resources/recirc.html)

The following are photos of our R.A.S.

*Young Winter Flounder (Pleuronectes americanus)*

*Winter Flounder in the culture tank of our aquaculture system*
ILLUSTRATION OF THE R.A.S.

(A) Culture or Habitat Tank
(B) Particle Bag Filter
(C) Circulation Pump
(D) Biofilter
(E) Undergravel Filter Tank
(F) Chiller

**Particle Filter.** Water from culture tank passes through filter bag removing particles down to 100 microns in size.

**Bio-filter.** Water is pumped here where bacteria growing on thousands of plastic pellets “biomedia” convert harmful ammonia from fish waste safer nitrogen compounds.

Water leaves the biofilter and returns to the culture tank after passing through the undergravel filter tank, which serves as an extra culture tank as well as another biofilter in the system.
Adopt a Salmon Family Project

Working with the U.S. Fisheries Wildlife Service, Middle School Students (Grade 7) aid in the restoration of the Atlantic Salmon to the Merrimack River through U.S. Fisheries’ “Adopt a Salmon Family” Project. This project is an interdisciplinary watershed education program highlighted by students raising young salmon from eggs received in mid-winter and releasing them into a tributary of the Merrimack in the spring. The curriculum integrates many basic science principles, promotes student ownership, and explores a range of subjects including, but not limited to:

- Watersheds and the Water Cycle
- Ecosystem and Biodiversity
- Habitat Protection
- Endangered Species
- Water Quality and Pollution
- Anadromous Fish Restoration through Aquaculture
- Cultural and Historical Links to the Environment

Link to Adopt a Salmon Family Project with US Fish and Wildlife Service:

http://www.fws.gov/northeast/cnefro/salmontimes.html

1 Our students obtain “eyed eggs” of Atlantic Salmon from the Salmon Hatchery in Nashua, NH near the end of January and placed in chilled aquaria (incubators).

2 Salmon hatch in mid-February and enter the “alevin stage” or “sac fry.” They lie at the bottom in their gravel nest obtaining nutrients from their yolk sac. Their heart beat and blood flow is very visible at this stage.

3 In April the salmon are still sac fry but are looking more like a fish. Their fins are developed, getting color, and their yolk sac is almost out of food. They are much more aware of their surroundings and will be swimming and feeding soon.

4 In May the salmon are now fully developed “salmon fry.” They are swimming and feeding on brine shrimp. They are now ready for release.
Salmon are transported to the release site in aerated coolers.

Since we started participating in this project in 2000 our students have successfully released 3,409 Atlantic Salmon into the Souhegan River.
Greenland’s Rapid Melt will mean More Flooding

The Greenland Ice Sheet, seen here in Oct. 2018, is melting at a rapidly accelerating rate because of Earth’s warming climate. As the ice melts into the ocean, it raises the sea level around the world, causing flooding and other damage to coastal communities. Credit: NASA/JPL-Caltech

The Greenland Ice Sheet is rapidly melting, having lost 3.8 trillion tons of ice between 1992 and 2018, a new study from NASA and the European Space Agency (ESA) finds. The study combined 26 independent satellite datasets to track global warming’s effect on Greenland, one of the largest ice sheets on Earth, and the ice sheet melt’s impact on rising sea levels. The findings, which forecast an approximate 3 to 5 inches (70 to 130 millimeters) of global sea level rise by 2100, are in alignment with previous worst-case projections if the average rate of Greenland’s ice loss continues.

Changes to the Greenland and Antarctic ice sheets are of considerable societal importance, as they directly impact global sea levels, which are a result of climate change. As glaciers and ice sheets melt, they add more water to the ocean. Increasing rates of global warming have accelerated Greenland’s ice mass loss from 25 billion tons per year in the 1990s to a current average of 234 billion tons per year. This means that Greenland’s ice is melting on average seven times faster today than it was at the beginning of the study period. The Greenland Ice Sheet holds enough water to raise the sea level by 24 feet (7.4 meters).

These animations show the cumulative change in Greenland Ice Sheet thickness and the melting ice sheet’s contribution to global sea level from 1992 to 2018, with projections through 2100. The projections were drawn from the 5th Assessment Report (AR5) by the United Nation’s Intergovernmental Panel on Climate Change (IPCC). IMBIE, or the Ice Sheet Mass Balance Inter-comparison Exercise, is an international collaboration between polar scientists from 50 scientific institutions supported by the European Space Agency and NASA. Credit: University of Leeds/Planetary Visions/Technical University of Denmark

The paper, published Dec. 10 in Nature, is the result of an international collaboration between 89 polar scientists from 50 scientific institutions supported by NASA and ESA. The Ice Sheet Mass Balance Inter-comparison Exercise, or IMBIE, used well-calibrated data from 13 NASA and ESA satellite missions to create the most accurate measurements of ice loss to date. The team found that half of the loss is tied to surface ice melting in warmer air. The rest of the loss is the result of factors such as warmer ocean temperatures, iceberg calving and the ice sheet shedding ice into the ocean more quickly.

“There are climate projections that are based on models of varying levels of complexity and observations, but they have large uncertainties. Our study is purely an observational one that tests those uncertainties. Therefore, we have irrefutable evidence that we seem to be on track with one of the most pessimistic sea level rise scenarios,” said Erik Ivins, second author and lead scientist at NASA’s Jet Propulsion Laboratory in Pasadena, California.

Greenland is home to the only permanent ice sheet outside Antarctica. The sheet covers three-fourths of Greenland’s land mass. But in the last 26 years, Greenland’s melting ice has
Greenland’s Rapid Melt will mean More Flooding

continued

added 0.4 inches (11 millimeters) to sea level rise. Its cumulative 3.8 trillion tons of melted ice is equivalent to adding the water from 120 million Olympic-size swimming pools to the ocean every year, for 26 years.

“As a rule of thumb, for every centimeter rise in global sea level, another 6 million people are exposed to coastal flooding around the planet,” said Andrew Shepherd, lead author and scientist from the University of Leeds in the United Kingdom. “On current trends, Greenland ice melting will cause 100 million people to be flooded each year by the end of the century, so 400 million in total due to sea level rise.”

In addition to storm surges and high tides that will increase flooding in many regions, sea level rise exacerbates events like hurricanes. Greenland’s shrinking ice sheet also speeds up global warming. The vast expanse of snow and ice helps cool down Earth by reflecting the Sun’s rays back into space. As the ice melts and retreats, the region absorbs more solar radiation, which warms the planet.

The new study will contribute to the evaluation and evolution of sea level rise models used by the Intergovernmental Panel on Climate Change in evaluating risks to current and future populations. The results of the study currently appear consistent with the panel’s worst-case projections for sea level rise in the next 80 years.

“The full set of consequences of future melt from the Greenland Ice Sheet remain uncertain, but even a small increase in sea level can have devastating effects on ports and coastal zones, cause destructive erosion, wetland flooding, and aquifer and agricultural soil contamination with salt,” said Ivins.

This is the third IMBIE study on ice loss as a result of global warming. IMBIE’s first report in 2012 measured both Greenland and Antarctica’s shrinking ice sheets, finding that the combined ice losses from Antarctica and Greenland had increased over time and that the ice sheets were losing three times as much ice as they were in the early 1990s. Antarctica and Greenland continue to lose ice today, and that rate of loss has accelerated since the first IMBIE study.

IMBIE is supported by the NASA Earth Science Division and the ESA Climate Change Initiative. To learn more about NASA missions studying climate change, visit: https://climate.nasa.gov
To learn more about NASA’s study of sea level rise, visit: https://sealevel.nasa.gov

View the latest sea level data in Earth Now: https://go.nasa.gov/341j5aV

News Media Contact
Arielle Samuelson
Jet Propulsion Laboratory
Pasadena, CA
818-354-0307
arielle.a.samuelson@jpl.nasa.gov

More 2019 Marine Art Contest Winners

High School
4th Place: Helen Tang, gr. 10, Lexington HS, Least Terns

Middle School
3rd Place: Ava W., gr. 7, Diamond MS, Lexington, Sea Raven

Elementary School
2nd Place: Christina Q., gr. 4, Peter Noyes ES, Sudbury, Atlantic Puffins
The annual High School Marine Science Symposium allows students to explore marine and environmental science research, issues, resources, and careers by attending hands-on workshops, demonstrations, and a keynote lecture delivered by STEM professionals. The Symposium has been hosted by MME for over 30 years thanks to many collaborators, including the Northeastern University Marine Science Center, cohosts since 2013.

The Science Symposium takes place each year in March during spring break at the college hosting it. Students will enjoy a morning of learning and networking, including lunch and a light breakfast.

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