Gulf Of Maine Institute

Update on GOMI Journal: *Learning to Steward the Gulf*

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Contents

LETTER FROM THE EDITOR

By John Terry

This issue celebrates GOMI's Learning to Steward the Gulf (L2SG) six-year participation in NOAA's Gulf of Maine ocean drifters study. We have included five articles, along with John Halloran's Naturalist's Notes, that provide different perspectives and experiences of students, teachers, and scientists variously involved in the GOMI/NOAA partnership. We hope you will share their enthusiasm and sense of reward in being part of the on-going NOAA study. Jim Manning, our "go to person" on the Gulf drifter project, has dedicated much of his professional life to studying and modeling the currents of the Gulf. With equal dedication, Jim has engaged many students and their teachers, elementary through high school, in the study of the Gulf's currents. The data from their projects have called attention to the important role currents play in ensuring the biodiversity of the Gulf along with their unheralded contribution to the economy of humans living within the Gulf's watershed.

GOMI first connected with Jim at a teacher workshop he was conducting in a Massachusetts North Shore community. For GOMI the timing was serendipitous. We had over a decade of experience providing planning, technical and financial support to local community-based stewardship projects (CBS)*. Our mantra was and is, "act locally and think bioregionally." Our local CBS projects, ranging from Cape Cod, MA to the southwest tip of Nova Scotia, were diverse and vibrant. To buttress the "think bioregionally" theme we evaluated and emphasized the connection of the local to the bioregional at our weeklong summer residential workshops. We sensed, however, the need to deepen students understanding of this connection required a Gulf-wide project(s) that had meaning to all our teams. We sought a bioregional, community-based effort that had scientific merit and importance to the region. Meeting with Jim, and hearing about his drifter project and his readiness, indeed eagerness, to engage students in his work was our eureka moment. We were on-board! Shortly thereafter, GOMI BOD implemented a strategic shift in emphasis from the earlier youth-to-community team model, described above, to a teacher-professional development model that included elementary through high school teachers. The shift was made in a desire to bring CBS experience to more students and classrooms. The initiative was named, Learning to Steward the Gulf (L2SG) and as the articles attest, it has been successful.

Jim Manning, in his article, *GOMI Contributing to Our Local Ocean Observing System: Drifters*, provides historical and scientific background to this unique Gulf-wide CBS effort and expert testimony to the contributions being made by students. Included in Jim's article, are links to the NOAA student drifter database. John Halloran, in his *Notes from the Naturalist*, tells the tale of how two schools, one upstream, New Hampshire's Bethlehem Elementary, and other downstream, Nock Middle School, Newburyport, Massachusetts, and how they discovered, though the drifters, their eco-interdependence. You may read more about Bethlehem Elementary in Bryan Smith's article, *Bethlehem Go with the Flow Watershed Unit*and the Nock Middle School from teachers Kristen Vincente, Mary Kate Allen and Brad Balkus in their article, *Ocean Drifters: Bringing Technology Engineering into the Science Classroom*. In addition, there is the thrilling turtle rescue saga told by Olivia Bourque, *Mass Audubon Wellfleet Bay Wildlife Sanctuary*. These are but a few examples of the many ways in which GOMI and NOAA have collaborated to bring youthful wonder and enthusiasm to the stewardship of their bioregional place.

Also, you will want to read the articles from two GOMI alums, Dominic Noce, currently a freshman at the University of Montana majoring in wildlife biology, and Kelly Conway, a senior at Columbia University studying earth and environmental engineering. Dominic's article is a follow-up to his earlier coyote article and Kelly's is a shortened version of her senior paper on storm water management in the Merrimac River watershed. Both demonstrate early exposure influence on career commitments. All our students do not choose to major in environmental or ecological studies. Most, however, gain a deep appreciation of and commitment to citizen stewardship. The importance of the latter cannot be underestimated.

Combined, these articles illustrate the power, beauty, and application of the CBS approach and why it should be included as a part of K-12 education. It makes sound educational sense and offers insurance for meeting environmental challenges like climate change. Meeting environmental challenges requires generations of scientifically informed citizen stewards committed to maintaining a healthy planet. CBS is an effective, not the only, way of doing both. The approach requires administrative commitment, teacher support, such as professional development opportunities and rewards for performance along with minimal modification of school curricula and scheduling. The physical place, that is the community bio-space, is accessible to any school any anywhere. It is just outside the door.

In closing, I emphasize three points regarding CBS that this issue illustrates:

1. The approach is an effective learning method to teach environmental sciences to elementary through high school students.
2. Learning young through one's home community may lead to a lifetime commitment to stewardship locally and regionally.
3. Early exposure to science and the environment is an effective means encouraging youth to choose carriers in related fields.

We will speak more to these three points in future issues. Your thoughts are welcome and may be submitted to the editors at jterry@gulfofmaineinstitute.org.

* Community-based stewardship (CBS) emphasizes:

1. Learning to stewardship through immersion in community-rooted, structured, experiences that emphasize unique biota, history, culture, economy, literature, and art of a specific place.
2. Civic engagement, the act(s) of doing something concrete and beneficial to improve, understand, remedy, protect and promote a healthy ecosystem.

3. Connecting local community efforts to the larger bioregion through acting locally while thinking bioregionally.

John P. Terry, founded the Gulf of Maine Institute in 1999. John was Editor-in-Chief, CYD (Community Youth Development) Journal from Aug. 1994 to Nov. 2002. John has broad teaching and administrative experience at the university level including the Massachusetts Institute of Technology, 1969-1984, University of Massachusetts, Lowell, 1985-1992, and Union College, Schenectady, NY, 1964-1969. John received national recognition in 2006 when selected as Civic Ventures,' Lead with Experience Program 2006 Purpose Prize Fellows. He is also a 2008 recipient of the Gulf of Maine Council on the Marine Environment Visionary Award.

DRIFTING TOWARDS COMMUNITY-BASED STEWARDSHIP

By John Halloran

In my role as GOMI Science Director, I work with students and teachers across the Gulf of Maine to help them design, build, launch, and track student-built ocean drifters. Schools are increasingly concerned about connecting with their communities as part of their curriculum, and they want to identify community issues in which students may participate. Student engagement in a drifter project allows them to become active citizens. They can see opportunities to play a role in helping contribute to solutions for local problems.

While most students can list some local areas of concern, they often have difficulty connecting their ideas to a larger regional view. With students scattered across three states and two provinces, we ask them to focus and work in their local area while being mindful of other GOMI projects. Our mantra to all is to "act locally but think bio-regionally."

Two programs reporting elsewhere in this journal are useful to illustrate this expanded awareness of "place." Bryan Smith and Brooke Campbell in Bethlehem New Hampshire call their 4th and 5th grade watershed studies "cross-disciplinary project-based learning." Their watershed is local and subject to the real world experiences of how the community engages with it. They study how erosion impacts their waters with site observations and classroom activities with a home-built "watershed." They observe how careless dumping and polluted runoff from impermeable surfaces reduces water quality. They work with New Hampshire Fish and Game to learn about the living creatures of the river and impacts on their requirements for life. They raise trout hatchlings for release into their waters, knowing the community must help insure their success by joining in to increase river health. They have produced very informative watershed education videos and shared them with the community. And it just so happens that the little stream in the southwest corner of their town flows into Franconia Notch and the larger Pemigewasset (Pemi) Watershed.

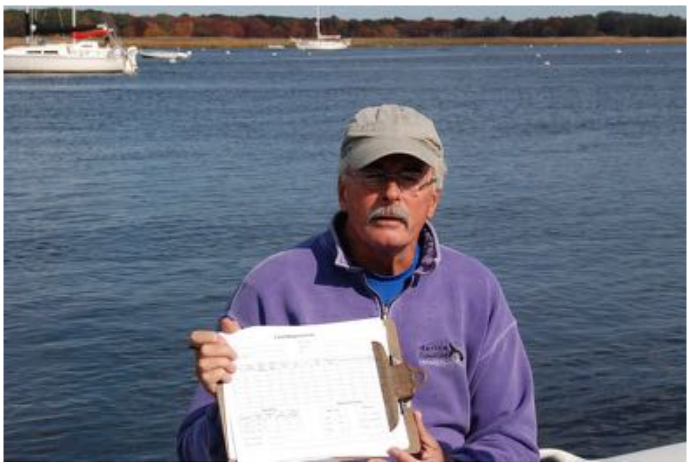
In joining with the GOMI Learning to Steward the Gulf (L2SG) project, the students were able to expand their awareness of place to a larger area subjected to the same stressors, and perhaps more. Far removed from the ocean, many of the students had never visited it, much less realized that their watershed was connected to it. A NOAA ocean drifter presentation in their classroom helped them learn that the Pemi wasn't the end point for their stream: their water also flows through the Merrimack River Watershed and on to the Gulf of Maine. And, in a more hands-on approach, the students were able to build their own drifter.

In this example, a community-based stewardship project of several square miles was connected to a larger watershed of over 5000 square miles. The Bethlehem students sat at the top of the watershed, but they were soon to learn from a group that sat at the bottom with a much different perspective. When they actually went to the sea to launch their drifter, they expanded their horizon further to the Atlantic Ocean.

Meanwhile, at the mouth of the Merrimack River, students in Newburyport, Massachusetts learn about all the varied ecosystems of their community. They explore and experience them by foot, bicycle, dory and kayak. They participate in a Mass Audubon research study of the salt marsh with over 18 years of data collected. Through all this, their sense of "place" can be as limited as that of the Bethlehem kids. They generally didn't know any more about the mountains than the other students did about the ocean. As 8th graders, they are asked to think more deeply about the ocean environment. They now know that what happens upstream also happens downstream, for example, the seemingly endless supply of plastic discs released by a New Hampshire sewage treatment plant a few years ago, or the chocolate brown color of the river staining the ocean for miles after floodwaters cause combined sewer overflows (CSOs). They wonder about the lack of fishing boats, and how we track "red tide" or cold-stunned sea turtles.

In their drifter design unit, they are asked to creatively think about ways to collect data. Although many are fanciful, others are more practical, and they are pleased to find out that some are already in place. After they build and launch their own drifter, they are provided with links to their own and other drifter tracks by Jim Manning at NOAA. These tracks can be followed by computer at school or, more readily, on their own phone. In class, they analyze data, try to identify patterns, and imagine their drifter as an upside down sailboat marking a location in the Gulf and beyond for that date and time. These data are then used by ocean modelers to validate simulations of the currents in the Gulf of Maine. Each reported position gives us more information and helps us answer questions, such as: what happens to an object drifting in the water; where does it travel; where does it end up; and how long does it take it to get there? Students engage these questions and learn more about this place, the Gulf of Maine, each time they log on to their tracks.

Hence, we see that two schools at opposite ends of a large watershed are studying a larger more complex place, the Gulf of Maine. Both schools have contributed valuable data to the knowledge of how currents move in the Gulf of Maine. Both have seen their drifters explore Massachusetts Bay, the continental shelf, the offshore seamounts, and the deep ocean basin. Their drifters have traveled up and down the Gulf of Maine, visiting all the political jurisdictions of the Gulf and the length and breadth of the Bay of Fundy. Several drifters have been recovered and their parts recycled. Students have worked with new and unusual materials in their designs, such as mushroom material on drogues and biodegradable protective cases on surface drifters. They have understood how the technology is used, have seen student-built classroom projects collect data all the way across the Atlantic, and have learned a lot more about a place called the Gulf of Maine - the place we all call home.



John Halloran is the Director of Science for GOMI and a member of the GOMI Guide Team. John's interests focus on the ocean environment where he pursues educational adventure travel, research, and recreation by sail, paddle, and scuba. John is the founder and director of Adventure Learning, Newburyport, MA, which has been involved with educational outreach in area schools and recreational programs for teens and adults since 1980. A long-time educator, John was at the forefront of the experiential education movement in the U.S. For 36 years, he taught natural science in the Newburyport Public Schools. John has special interest and expertise in teacher training and standards for learning in math and science. His role has included direct teaching, teacher training, program development, grant writing, and developing partnerships with professionals in the field.

GO WITH THE FLOW: BETHLEHAM ELEMENTARY SCHOOL'S WATERSHED UNIT

By Bryan Smith

Cross-disciplinary project-based learning opportunities grounded in the real-world experiences of the North Country challenge students to direct their own learning with relevant and local problems. An excellent example is our multi-year "watershed studies" in the 4th and 5th grades. As part of the unit of study, students are challenged to create ARC GIS maps that predict water flow within the watershed, work with Trout Unlimited to collect, categorize, and analyze trash collected along the Connecticut River, host a public watershed informational evening, and raise Brook Trout in the classroom to release into the Ammonoosuc River. Students also experiment with stream tables to investigate erosion control and then plan and test culvert designs to minimize erosion.

As a culminating event, the students design and create a GPS "drifter" to be released in the Gulf of Maine in June. The students design and construct the drifter out of materials provided by the Gulf of Maine Institute. Students not only get to build their drifter, but also they get to experience the open ocean on *The Ninth Wave*, a sailing catamaran out of Newburyport, MA.

Figures 1 & 2: Students tested and retested various ideas in a water tank

This drifter is utilized by the Gulf of Maine Institute to track the ocean current changes in the gulf created by temperature changes. These data are used as a part of a larger investigation into the impact on sea turtles and other marine life.

Figure 3: *Aboard the Ninth Waive*

Students, Donald Hilliard and Owen Snow, created the following script for an interview they are making using green screen technology.

Donald: Hi there. We're reporters from News 03574 and are here to tell you about a drifter that was launched by the 4th grade at Bethlehem Elementary School last year. A drifter is an object that travels through ocean currents and has a GPS tracking device on it.

Owen: The students launched the drifter because The Gulf of Maine Institute was concerned that the temperatures in The Gulf of Maine were rising. Ocean creatures rely on temperature to know when to migrate such as sea turtles.

Figure 4: *Bethlehem Elementary Students with the completed drifter.*

Donald: The class drove down from Bethlehem, NH to Newburyport, MA. where they boarded a catamaran sailboat called the Ninth Wave. They sailed 21 miles out into the Gulf of Maine where they released the drifter.

Figure 5: *The drifter had to be rebuilt upon arrival in Newburyport.*

Owen: After the drifter was released it started to go southeast for about 100 miles. Then it went about 200 more miles right to the edge of the continental shelf.

Donald: Well I guess it did not want to fall off of the continental shelf. So, it went northeast for about another 100 miles. Then it took a left turn to go west for another 100 miles.

Owen: The drifter swirled around for about twenty miles going northeast. Next, it swirled around a little more going northwest.

Donald: Then, the drifter went northeast for another 100 miles. After that, it drifted northwest for fifty miles.

Owen: About 40 miles off of the coast of Nova Scotia the drifter went around in circles for about 75 miles not making a lot of forward progress.

Donald: Next, the drifter continued flowing northwest for about 50-75 miles.

Owen: About 40 miles off the coast of Sandford, Nova Scotia, the drifter zig-zagged for about 150 miles.

Donald: The drifter spun around for about 250 miles in one spot until it stopped swirling and made a 700-1000 mile loop.

Owen: It washed up on the beach near Church Point, Nova Scotia and broke apart.

Editors note: The following is an anonymous Bethlehem Elementary School fourth grader's unedited account of the drifters journey from creation to rescue.

Gomi's Adventure

I'm Alive and my name is Gomi was the first thing I thought when my GPS turned on in the classroom. I think my creators were the fourth graders that were stretching canvas sails on my legs and arms. I heard the students talking about taking me to the ocean. Road Trip!! Before I knew it I was in the back of a van bouncing down the road. Yippy! I thought.

Oh, it was a bumpy ride. Eww!? What did Donald have for lunch? Tacos? That was green bean casserole. I was thinking I needed a bath when the fourth graders took me out of the van and loaded me on a huge sailboat.

The ride was rough and I was going up and down and up and down. I saw Donald's green bean casserole for a second time. After a long and bumpy ride I couldn't believe it the fourth graders threw me overboard into the deep cold ocean.

I think I swallowed some seaweed and seawater. They did something right because while my body was under the waves my head was in the air!. I wanted to yell, "Wait don't leave me, I want to go home!" I floated for a long time around and around in the current. I thought I was going the right direction, but noticed the ocean drop off below me. I think I even saw a giant shark! He looked hungry for lunch. AAAAAHHH!. I turned around for the opposite direction.

After a long journey I ended up near a rocky shore and an island. The current kept me from landing anywhere. There were pretty whales all around me. Blowing water into the sky. After spending countless days with the Whales the current took me around the side of the rocky island. I was really feeling tired. My sails had been destroyed by over 6000 kilometers at sea. I was barely functioning and forgot what it was like to be on land.

Several months after entering the sea on a cold windy day in November I saw land again. Yey!! This time I was able to make it to a beach. The waves broke my head off and I thought it was the end. Finally, a person, not a fourth grader, found me. I was saved. This is Gomi signing out until next time.

Dr. Dan Earle GOMI board member and Nova Scotia resident to the rescue.

Bryan has been teaching for 17 years in a variety of roles. Bryan started with the Trout in the Classroom program ten years ago as a way to engage students with emotional and behavioral disorders. Students learned how fragile life can be and the importance of habitat and environmental stewardship.

Today he teaches fourth grade in Bethlehem, NH. Water Science has become a year-long program connected to all areas of the curriculum, starting with hosting a "source to sea" cleanup where we explore and clean the local watershed. Students eventually design and construct a drifter to release into the Gulf of Maine through the help of GOMI.

OCEAN DRIFTERS: BRINGING TECHNOLOGY ENGINEERING INTO THE SCIENCE CLASSROOM

By Kristen Vincente, Mary Kate Allan, Brad Balkus

October 31, 2017 - If you walked into an eighth grade science classroom at the Rupert A. Nock Middle School this Halloween day, you may have been surprised to see twenty to twenty-five students fully engaged in a hands-on building project and discussing prototype design. You may have wandered around the room looking to find that one renegade student plotting out their trick-or -treat route or informing their peers about who gives out the full-size candy bars on their street. However, this off-topic student would have been hard to find during the ocean drifter unit.

As you walked around the room, you found that some students were measuring and hopefully re-measuring wooden dowels and canvas pieces, other students were adjusting their budget and counting their bright yellow money, some students were leaving the room to travel to the pre-engineering room for materials and advice, and finally other students who were simply grappling with marine glue.

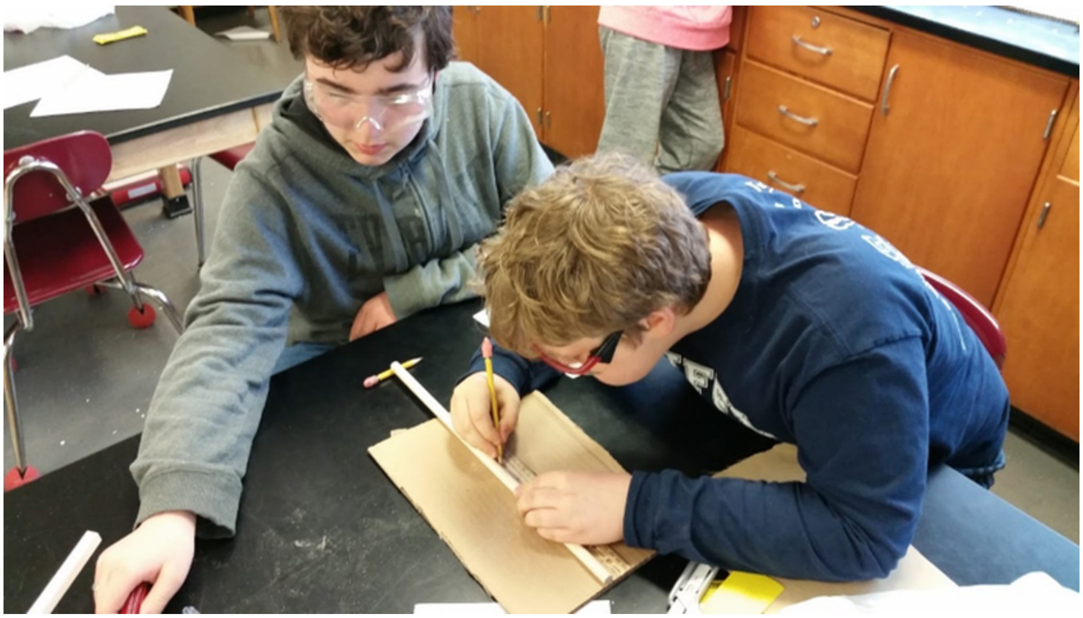
Since the 2014 - 2015 school year, we have taught a curriculum unit around ocean drifters as a collaborative process between the eighth grade science teachers and the middle school's pre-engineering teacher. The three of us participated in a STEM certification course together at Parametric Technology Corporation that did not require us to incorporate community-based education, but rather, asked us to create real-world problems for our students to solve. We were incredibly pleased to create a unit that combined both community-based education and a real-world problem that directly affects our coastal community. In fact, upon further exploration, the two seemed to flow together seamlessly.

The ocean drifter unit is spread out over a two- to three-week period. In order to introduce the unit, guests from the Gulf of Maine Institute as well as previous students who have designed and built ocean drifters present some introductory information to the eighth grade students. These presentations set the tone for the work that students will complete and let them see the real world implications of this project. On a basic level, these presentations also review major issues currently found in the Gulf of Maine and the importance of data collection in our oceans.

After these presentations, students are asked to work in a small group on concept development. Before students are given any type of design parameters, they are asked to think of creative ways to collect data in order to find out more about the issues found in the Gulf of Maine. This stage emphasizes imaginative thinking as students are encouraged to ignore any logistical concerns they may have.

Once students share their "out of the box" ideas, they are assigned partners and given the guidelines for their ocean drifter prototypes. Students are informed that the pair who builds the strongest prototype from each class, as determined by the provided scoring guide, will have the opportunity to build an actual ocean drifter that will be launched in the Gulf of Maine. Students become highly motivated by both the competitive nature of this task and its real world application.

During the next two class periods, students spend the majority of their time designing their ocean drifter prototypes, developing a detailed budget, and shopping at the makeshift drifter prototype store set up in the classroom. Each pair of students is given $100 in bills that resemble monopoly money and every item students may want to purchase to build their prototypes is given a dollar value. For example, an 8 x 11 piece of canvas is $25, while a styrofoam ball is only $10.

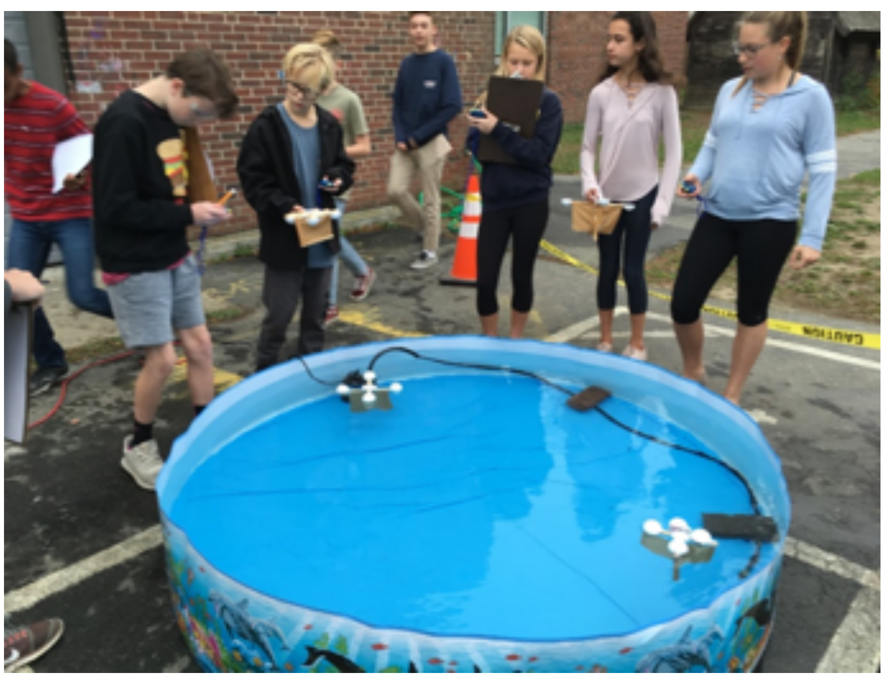


Designing and building the drifter models

At this point in the unit, things get messy in the best possible way. Students begin the building, testing, and redesigning process. Students have access to a variety of building materials, including drills, dremels, saws, and marine glue. Students also have access to a large fish tank in the classroom so that they can test the buoyancy of their ocean drifter throughout the building process. The most fascinating part about this process and the place where arguably the most learning takes place occurs when almost all students realize that they need to redesign one or many components of their ocean drifter in order to be successful. This need to redesign forces students to look for new ways to solve a problem, which is the ultimate critical thinking skill. This redesigning process can often be a point of frustration for students, but is ultimately, their greatest source of pride when addressed.

Designing and building the drifter models

Once students have had ample time to redesign and make the appropriate changes to their drifter prototype, each class spends time outside testing the prototype in a makeshift ocean environment. Large kiddie pools are filled with water and a pool pump is inserted into the pool to create a current. Seaweed and other ocean debris is added to the kiddie pool. Each pair of students places their drifter in the pool, calculates the average speed of their drifter, proves the buoyancy of their drifter, and then attempts to have their drifter avoid the obstacles in the pool. Students take an immense amount of pride in watching their drifter successfully avoid obstacles.



Testing models for buoyancy

The strongest drifter prototypes from each science class are later selected by the teachers using the scoring guides. This process provides sixteen eighth grade students with the opportunity to build real ocean drifters under the guidance of their pre-engineering teacher. This second building opportunity allows students to collaborate with one another and bring the strongest elements of their prototype design to the real design of an ocean drifter.

A few weeks after building, two real ocean drifters are deployed in the Gulf of Maine with canvas flags proudly displaying, “RAN Middle School”. In year’s past, students have even been able to board a large boat during the school day and place the drifter that they built in the ocean water.

Getting ready to launch from the Ninth Waive

Getting ready to launch from the Ninth Waive

It may seem like our students' work with ocean drifters would come to a natural conclusion once the drifters are placed in the ocean. However, this unloading of the ocean drifters actually triggers a whole other area of focus. Students are now able to track the ocean drifters via the Internet. We spend class time analyzing the data, identifying patterns amongst the drifters, and discussing why the drifters may be moving in those patterns. This aspect of the unit emphasizes the real-world connection and further highlights a strong mathematics connection.

While there are numerous benefits to this drifters unit, three things stand out as the most significant from the educator's point of view. First, student engagement during this unit is at an unprecedented high. Off-topic conversations and cuing up for bathroom passes is virtually non-existent. Students do not want to be off-topic because they genuinely want to be successful and are interested. Perhaps most notably, all learners are engaged during this time, even the learners who typically withdraw from group work or struggle on assignments. This hands-on nature of this assignment combined with the real-world challenge draws in all learners and levels the playing field in a way that most other assignments do not.

Secondly, this unit allows students to see themselves as active members of the community. At an age when so many things appear to be out of their control, it is important for teenagers to understand that there are aspects of this world that they can dramatically influence now. Students are encouraged to think deeply about their local ocean community and to see themselves not merely as victims of circumstance, but as active citizens who are capable of better understanding their environment and subsequently promoting change.

Finally, as educators, this unit enables us to find a meaningful way to incorporate technology and engineering standards into our science curriculum. Incorporating technology education standards into the science curriculum is an increasing concern based not only on the structure of the Massachusetts Next Generation Science Standards, which greatly increases the depth and breadth of technology engineering in the middle school classroom, but also as an accurate reflection of the world in which we live. The amount of technological understanding that our students will need is not going to decrease in this society. Thus, it is imperative that our sience curriculum prepares students to understand how technology can be used to better understand and to potentially solve real-world problems. We strongly believe that our ocean drifter unit does exactly that.

Kristen Vicente
Kristen Vicente is an eighth grade science teacher at the Rupert A. Nock Middle School. She has taught middle school science for the past eleven years. She holds a master's degree in government with a concentration in Educational Policy Making and is passionate about making learning accessible to all students. A major focus of her curriculum development has involved project-based learning.

Mary Kate Allan
Mary Kate Allan is a twenty-one-year veteran science teacher who has been teaching at the Rupert A. Nock Middle School for the past seventeen years. Science has been her passion since she herself was in middle school. She most enjoys watching her students create and problem solve. While not at school she spends time with her two children and their many various activities.

Brad Balkus
A twenty-year veteran of the Newburyport Public Schools, Brad has experience as a science and Engineering/Technology teacher. Hands-on problem solving is at the core of his teaching

philosophy as he integrates CAD, 3D printing, and a fabrication lab into middle school curriculum projects.

MASS AUDUBON WELLFLEET BAY WILDLIFE SANCTUARY DRIFTER PROJECT: MOTIVATED BY SEA TURTLE STRANDINGS

By Olivia Bourque

Every fall, the sea turtles that enter the Gulf of Maine to feed in nutrient-rich waters during the summer, begin to migrate south to warmer waters. Tragically, some of those sea turtles become trapped by Cape Cod's hook-shaped geography. As winter approaches and Cape Cod Bay's water temperature gradually drops below 55ºF, the remaining sea turtles become too cold to swim and their important bodily functions slow down. We refer to this hypothermic state as "cold-stunned." All of the cold-stunned turtles eventually get pushed or blown ashore, but they do not all survive the journey; those that do survive are in need of immediate intervention. That is why Mass Audubon's Wellfleet Bay Wildlife Sanctuary (WBWS) established a Sea Turtle Rescue Team on the Outer Cape.

A small team of WBWS research staff works together with help from over 175 trained volunteers to retrieve the cold-stunned sea turtles that strand on bayside beaches throughout the winter. Live turtles are rushed to the New England Aquarium's rehabilitation facility in Quincy, MA, for necessary medical attention. In recent years, between 400 and 1200 turtles have stranded in a 3-month time span, with 60-70% found alive. But the colder the water gets and the longer a turtle is cold-stunned before washing ashore, the worse its chances of survival becomes.

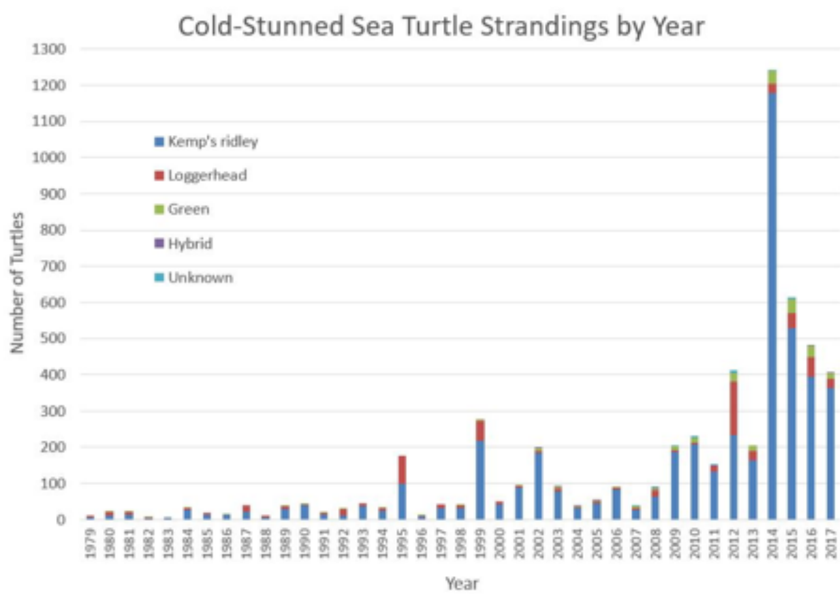


Figure 1. Number of cold-stunned sea turtle strandings by species (bar color) and year from 1979 – 2017.

We believe that a combination of the bay's tides, winds, and currents determine when and where cold-stunned sea turtles strand. Strandings typically occur around high tide after a strong wind event, and we can roughly predict where turtles will end up based on which direction those strong winds are blowing. However, not as much is known about local offshore currents within Cape Cod Bay, which also impact the passive movement of cold-stunned sea turtles. The Cape Cod Bay drifter project was implemented to aid in our understanding of the processes behind this troubling annual event.

The Cape Cod Bay drifter project is an ongoing effort that continues to grow with help from a number of collaborative organizations and partners, namely the National Oceanic Atmospheric Administration (NOAA), the Gulf of Maine Lobster Foundation, Mass Audubon, and a handful of local schools. Mass Audubon's WBWS research staff became interested in the drifter project because of the drifters' ability to provide valuable information about the bay's currents and their potential influence on where cold-stunned sea turtles wash ashore. NOAA oceanographer James Manning and his team of researchers set out to gather and analyze the data collected. For years, they have developed, tested, and altered drifter prototypes according to what works best for this study.

Figure 2. A drifter ready to be deployed in Cape Cod Bay.

One of the first ocean drifter designs was cleverly shaped like a turtle and built to float. The current models look much different and for good reason. Modern drifters are better designed to replicate the passive movement of cold-stunned sea turtles drifting within the Bay. Surface drifters are built mainly out of lightweight aluminum and canvas with sails that extend approximately 5 feet underwater, catching shallow subsurface currents and waves. NOAA also developed a drogued drifter that is designed to catch deeper water currents using a tether that extends 10 meters deep. Since we do not know exactly where in the water column cold-stunned sea turtles spend most of their time, this range in drifter sizes and designs is intended to be all-inclusive. Ideally, every surface drifter would be deployed simultaneously with a drogued drifter to illustrate how their movements within Cape Cod Bay differ. Both types are equipped with a GPS tracking unit that transmits a satellite signal every hour.

In August 2016, James Manning organized a Kickoff Meeting at St John Paul II High School in Hyannis, MA. NOAA staff, WBWS research and education staff, graduate students, and teachers from multiple Cape Cod high schools (Cape Cod Tech, Sturgis, Saint John Paul II) met to go over project details. The new drogued drifter prototype was also introduced. At this meeting, it became clear that both the Cape Cod Bay drifter project and Mass Audubon's role in it were expanding. In prior years, drifters were incorporated into a few local schools' curriculums through Mass Audubon sea turtle programs. But it wasn't until 2016 that the drifter project was also incorporated into Mass Audubon's Sea Turtle Rescue Program.

Figure 3. Students and volunteers build new drifters.

In the early fall of 2016, WBWS staff began to refurbish, assemble, and deploy surface drifters within the Bay. (Note: In both 2016 and 2017, WBWS only deployed surface drifters because we had leftover supplies from previous years and the number of drogued drifters was limited.) Then, at our annual Cold-Stunned Sea Turtle Volunteer Training, Mass Audubon volunteers were recruited to help retrieve stranded drifters on Cape Cod Bay beaches. James Manning, Bob Prescott, and I monitored the drifters' satellite tracks within the bay and formulated a recovery plan when it looked like a drifter was about to wash ashore.

Cape Cod Bay drifter deployments typically take place between October and December, during the very beginning of the cold-stunned sea turtle stranding season. We charter boats that often leave from Dennis, MA and head towards the middle of the bay. Deployment locations within the bay are largely dependent on the boat's speed and how much time we have available. Ideally, multiple drifters are released in various locations far away from the coast. The farther out the better as that increases the chances of the drifter spending more time in the bay before stranding, allowing for more data to be collected. In general, we follow deployment guidelines provided by James Manning (Fig. 4).

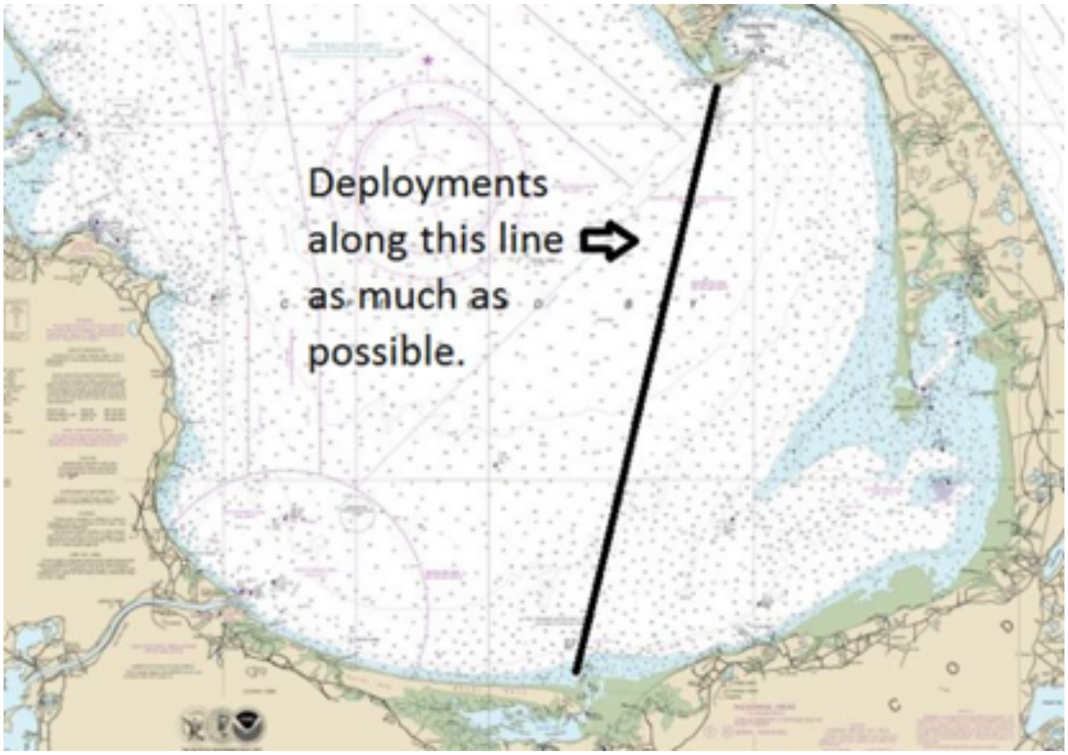


Figure 4. Nautical chart of Cape Cod Bay, showing preferred location for drifter deployment as determined by James Manning..

In 2016, Nauset High School, Monomoy High School, Cape Cod Academy, Middlesex Community College, and the WBWS Sea Turtle Field School all participated in WBWS-led surface drifter deployments. There were also several staff deployments that coincided with efforts to catch floating cold-stunned sea turtles in the bay. In 2017, both Nauset and Monomoy high school groups and the WBWS field school deployed drifters with us. Unfortunately, no additional deployments were conducted in 2017.

Figure 5. Nauset High School students deploying a drifter.

One of our goals throughout this whole process has been to connect young Cape Cod residents to their surrounding environment and provide engaging opportunities for experiential learning. Prior to the drifter deployments, participating classes received in-class lessons about the massive cold-stunning event affecting sea turtles each winter and how the drifters play an important role in our study of this phenomenon. Then, the students got to assemble and decorate their own drifters before launching them into the Bay. They could even monitor their drifters' movements online and conduct minor data analyses. This link shows all tracks from WBWS-led drifter releases in 2017: https://www.nefsc.noaa.gov/drifter/drift_audubon_2017_1.html.

At a glance, it appears that the surface drifters we deploy are at least partially affected by the same environmental variables causing sea turtles to strand at certain times and locations. For example, there were two different occasions in 2016 where a surface drifter washed up on a beach no more than 10ft away from a stranded sea turtle. It is also interesting to see unusual drifter tracks such as the red one in Figure 6, which appears to have oscillated a number of times due to the ebb and flow of the tides in Wellfleet Bay in November 2017. This same drifter also took the longest to strand (26 days), reminding us that the luckiest turtles are those who get pushed ashore quickly and rescued in a timely manner.

Figure 6. Map showing tracks (colored lines) and stranding locations (red dots) for 6 drifters in Cape Cod Bay.

These drifter data are important for updating local surface current models. Coupled with the sea turtle stranding data we collect every year, they have the potential to teach us a lot about the bay's oceanography and its impact on cold-stunned sea turtles. Right now, one of the graduate students working closely with James Manning is in the process of publishing a manuscript that looks at sea turtle stranding locations, water temperature, wind speed and direction, and drifter tracks. He uses numerical models to determine the origin of those sea turtles within the bay days earlier. Although these findings are not yet widely available, I believe they will eventually allow us to better predict sea turtle strandings in the future.

The Cape Cod Bay drifter project has developed into a multifaceted tool used for conservation, education, and research. If we can begin to connect points and see patterns in the data, then we will better understand the mechanical elements of offshore waters within the bay and have greater success at improving our protection of the impacted species. This type of science-based inquiry is also beneficial for local students who are just beginning to study environmental science and become stewards of the bay. The methods employed for this sea turtle study could even be loosely applied to other drifting organisms or objects (i.e. trash) in Cape Cod Bay and beyond. If given the chance to continue developing a few more years, I foresee this drifter project further improving prediction processes for sea turtle strandings and inspiring similar projects in other coastal areas.

Olivia Bourque received a B.S. in Environmental and Conservation Biology in 2015 and a M.S. in Environmental Science and Policy in 2016. For the past two years, Olivia worked at Mass Audubon's Wellfleet Bay Wildlife Sanctuary (WBWS) on Cape Cod, MA. During her first summer in Wellfleet, she assisted with stranded sea turtle necropsies and the Diamondback Terrapin Conservation and Nest Protection Program. She took over as Diamondback Terrapin Program Coordinator in 2017, continuing nest protection efforts and launching a pilot tagging effort. Both falls and winters, Olivia coordinated the Cape Cod Drifter Project while working full-time as part of the WBWS Sea Turtle Rescue Team. When Olivia isn't looking for turtles on cold and windy beaches, she enjoys travelling, hiking and snorkeling. Olivia is passionate about wildlife and habitat conservation, and she plans to continue pursuing field research opportunities in coastal and marine environments.

ENHANCING COASTAL RESILIENCY VIA NATURAL CAPITAL

By John Halloran

On the Massachusetts North Shore, six communities are connected to and protected by the over twenty-thousand acres of salt marsh, tidal rivers, barrier beaches and mudflats of the Great Marsh. The communities of Salisbury, Newburyport, Newbury, Rowley, Ipswich and Essex are looking for ways to make this area more resilient to severe weather events accompanied by rising sea levels while protecting existing natural and built resources. The recently released Great Marsh Coastal Adaptation Plan (GMCAP) focuses on how the existing natural capital of the Great Marsh already offers protection to these communities and suggests ways each community can enhance this resource to meet their particular needs. Most evident is the way the marsh acts like a sponge absorbing storm water, thereby protecting the infrastructure of the nearby communities. This natural infrastructure, often described as natural capital, is in contrast to some proposed solutions calling for elaborate sea walls in nearby Boston.

Photo courtesy Aber, Aber, and Valentine
Aerial View of the Great Marsh

The GMCAP assesses threats and suggests specific mitigation plans for each of the six towns. Funded by a Hurricane Sandy grant and produced by the National Wildlife Federation (NWF) and the Ipswich River Watershed Association (IRWA), it includes needed human infrastructure changes and nature based strategies, (1) as follows:

Recommendations for stabilizing the Great Marsh:
- Remove unneeded dams to restore river flow.
- Elevate roadways and move or retrofit buildings to prevent flooding.
- Restore dunes and barrier beaches through techniques such as revegetation.
- Restore connectivity of river and coastal systems to efficiently redistribute water.
- Naturally stabilize the shoreline to help absorb wave energy. (2)

Kristen Grubb, one of the authors from IRWA, emphasizes that it is not necessarily a major storm that is the greatest threat. She states that repeated storms over the course of a winter can do as much damage as a single major storm. Salisbury Beach, for example, sees repeated storm surges over their infrastructure along the beach. Riverbank erosion in Ipswich threatens the stability of the Ipswich Town Hall. (3) Plum Island, especially at its northern end, suffers from erosion and shifting sands on the barrier beach. Both Newburyport and Newbury have lost several homes to storms in recent winters.

Newburyport has held meetings to update residents about its adaptation planning which is supported by a state grant. Mayor Holaday of Newburyport emphasized that this will require continued public support and adequate funding. (4) Other towns are holding forums on coastal resiliency and the steps needed to protect infrastructure from worsening nature-based impacts.

Through GOMI, Newburyport students have introduced "climate cafés" (profiled in an earlier issue of this journal) into this region. Partnering with the regional environmental group Eight Towns and the Great Marsh, they are planning to introduce this strategy to other communities of students. With Ipswich already on board, they hope to introduce this model of civil discourse to the other towns as part of their educational outreach.

A valuable source of research is available to the communities from the Long Term Ecological Research (LTER) study of the Plum Island Ecosystem. Their base, at Marshview Farm in Newbury, hosts dozens of scientists annually monitoring studies of erosion in the marsh, impacts on habitats, and health of species which play key roles in maintaining the integrity of this protective resource. Led by Dr. Anne Giblin of the Marine Biological Laboratory (MBL) in Woods Hole MA, the LTER scientists are not just doing science, but have a vested interest in putting their knowledge into action. Their experience with changes in the Great Marsh can be important in helping the towns see the complexities involved as they address the challenges ahead.

Another source of outreach and education available is the Mass Audubon Salt Marsh Science Project. This program introduces students of the Great Marsh communities to the natural value provided by the Great Marsh to the built environment. Several smaller projects have involved local middle and high school students learning more about natural capital while participating in projects such as beach grass and eelgrass restoration and habitat remediation.

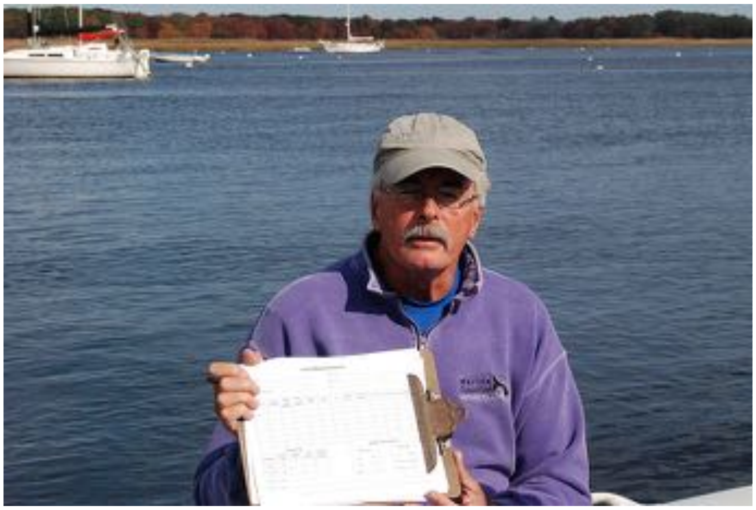
Caroline Link, Newburyport High School planting eelgrass as part of the restoration project

Author John Halloran and Mass Audubon Scientist Liz Duff preparing for a pepperweed pull on the Great Marsh

The Coastal Adaptation Plan will bring communities together to share information about what they are dealing with in their town and what they can learn from the experiences of neighboring communities. This increasing attention being paid in coastal towns is often driven by or supported by student environmental groups. There will be more leadership opportunities for GOMI's L2SG students and teachers to participate, as planning and remediation efforts continue to evolve.

Sources:

1. National Wildlife Federation, Great Marsh Coastal Adaptation Plan, Dec. 2017
2. Ibid
3. Rattigan, David, "A Buffer Against the Raging Tide", Boston Globe, Jan 28, 2018
4. Ibid



John Halloran is the Director of Science for GOMI and a member of the GOMI Guide Team. John's interests focus on the ocean environment where he pursues educational adventure travel, research, and recreation by sail, paddle, and scuba. John is the founder and director of Adventure Learning, Newburyport, MA, which has been involved with educational outreach in area schools and recreational programs for teens and adults since 1980. A long-time educator, John was at the forefront of the experiential education movement in the U.S. For 36 years, he taught natural science in the Newburyport Public Schools. John has special interest and expertise in teacher training and standards for learning in math and science. His role has included direct teaching, teacher training, program development, grant writing, and developing partnerships with professionals in the field.

US FISH AND WILDLIFE SERVICE PARKER RIVER WILDLIFE REFUGE: LEARNING AND PASSING ON

By Dominic Noce

My passion is to become a wildlife biologist to help reverse the catastrophic population decline of large predators through rewilding projects. I recognize the critical role that large predators play in maintaining healthy ecosystems and aim to educate the public on their importance and work with governments to reestablish their former ranges.

In 2013, as a freshman at Newburyport High School, I joined the Gulf of Maine Institute (GOMI), which fosters youth-led initiatives in the United States and Canada to protect the Gulf of Maine watershed. As a member of the Newburyport GOMI Team, I helped initiate positive environmental change through involvement in local team and collaborative partner projects, community education, and government. Starting my sophomore year, I began my search for a predator-based GOMI project on which to volunteer. I did not immediately succeed and encountered many dead ends and detours. In February 2016, I met with Parker River National Wildlife Refuge Manager Bill Peterson and we agreed to use scent stations and camera traps to monitor areas of the refuge for coyote activity since these methods do not require a permit. The project evolved into a first semester Wildlife Biology Internship for school credit my senior year. I arranged the internship myself through my contacts at the Refuge; it was not previously available at Newburyport High School.

I began the internship in September 2016, using my camera trap footage to analyze common times the coyotes visited the stations and to identify and observe species that thrive in coyote territory. I captured my first coyote on camera in December, a male. He was an impressive size with many wolf-like markings on his coat. Contrary to his appearance, he was extremely shy and wary around the cameras. He was only captured on camera twice during daylight hours.

Female coyote captured by camera

I captured a female in mid-February 2017 and confirmed that the two were mates two days later. The female is both more comfortable around the cameras and willing to eat the bait than her mate. The male began eating the bait in June after watching his mate safely consume it.

A bit more camera shy Male mate

Since first observing the pair together, I had been excitedly hoping they would have pups in the spring. Once April arrived, I saw the female frequently and the male only once a month. I assumed that pups were unlikely since I believed that a nursing female would be absent from the cameras. However, I was pleasantly surprised in June with camera footage of two pups.

Coyote cubs

Other animals I captured on the cameras include deer, rabbits, raccoons, fishers, mice, woodcock, and various songbirds. Deer were absent from the stations from December to April, likely to avoid the winter storms that weaken them, making them vulnerable to coyote predation. No foxes were captured, likely because the coyotes chased them out of their territory. Fishers and raccoons remained because they can climb to escape. Coyotes benefit from the fisher population since they prey on porcupines, a significant mortality risk for coyotes.

In late April, GOMI Team member Noah Keller and I presented the research findings at the Bresnahan Elementary School's annual STEM Exposition. We educated second and third graders about the project using camera trap footage, animal skins, and footprint casts. In July, I presented my project entitled "The Eastern Coyote: A True Survivor" to the Newburyport community at the Parker River National Wildlife Refuge. I enjoyed the opportunity to educate the public about the coyote's history, behavior, and important role in maintaining the health of our local ecosystem.

It has been an amazing experience studying these animals. Coyotes are one of the most persecuted and misunderstood predators and my research helped document their social and charismatic nature. They keep deer and rodent populations in check, preventing the spread of diseases and increasing crop yields. Coyotes are particularly important to the Newburyport area because they are vital to maintaining bird diversity by decreasing populations of mesopredators such as foxes, raccoons, and cats. The Parker River National Wildlife Refuge provides key habitat for migrating and nesting shorebirds that attract birders to the area. The Plum Island coyote pack indirectly supports income from bird ecotourism.

Bob cat on the prowl

This project has provided valuable experience integral to the wildlife biology profession and helped prepare me to assist in similar projects while in college. Camera traps provide vital data by surveying wildlife populations and are much more cost effective than radio telemetry. Fortunately, GOMI is committed to the project. I have trained GOMI members Kendall Woods and Bailey Fogel to use the camera traps to continue documenting the pack's activity.

Dominic Noce is a first year student at the University of Montana, and has chosen to major in wildlife biology. As a high school student Dom was an active member of the Gulf of Maine Institute's Newburyport, MA team. During his senior year, Dom tapped into GOMI's partnership with the Parker River Wildlife Refuge in Newburyport, MA, and submitted an internship project to study the refuge's coyote population to Bill Peterson, Refuge Manager. Bill agreed to engage Dom in a study of the Refuge's coyote population. The study of large predators is Dom's passion, so this internship was a windfall for him. The article is a direct result of his involvement in that study.

GOMI wishes to thank Refuge Manager Bill Peterson for providing Dom the opportunity and the support to conduct the study and for the Refuge's long-term and varied support in conducting many related stewardship events.

GOMI CONTRIBUTING TO OUR LOCAL OCEAN OBSERVING SYSTEM: DRIFTERS

By Jim Manning

What happens to a particle of water suspended in a river such as the Merrimack as it enters the sea? Where does it end up? How long does it take for this particle to exit the continental shelf and make its way across the Atlantic? These are the questions being answered by the GOMI drifter project. Beginning in 2012, several satellite-tracked drifters were built and deployed each year by local schools in the North Shore of Boston and monitored for months at sea as they reported their positions every few hours.

Figure 1. Students from Beverly High School with Surface drifters they built and decorated.

The drifter tracks are displayed, served, and archived on a NOAA computer where oceanographers as well as the general public can access the data. The primary purpose of the deployments is to provide data in validating local ocean circulation models. We can think of these drifters as the “weather balloons” of the sea. They are following the currents in the same way that balloons follow the winds and the information is used to test numerical simulations of the ocean current. Most of the drifters built by GOMI projects are designed to mark the upper meter of the ocean but some are tethered to subsurface drogues (or sea anchors) to follow the currents deeper in the water column.

Figure 2. Students preparing a drogue for a drifter that will follow subsurface currents

As seen in the photo of Beverly High School students, the standard surface drifter is constructed in the classroom with commonly available materials (aluminum square pipe mast, aluminum rod spars, canvas cloth sails, lobster buoy flotation, and a set of hose clamps) that are cut, drilled, glued, secured, and decorated by the students. The cell-phone-sized satellite transmitter which gets lashed on top is supplied by the Gulf of Maine Lobster Foundation in Kennebunk, ME working closely with NOAA’s Northeast Fisheries Science Center in Woods Hole, MA. Well over 100 schools around the region have been involved since the project started in 2003 resulting in over 1000 multi-month tracks with bi-hourly fixes.

While we strive to maintain oceanographic standards in terms of the shape and size of drifters, we experiment with the materials used to build the various drifter designs. With help from Brad Balkus at the Nock Middle School, for example, a biodegradable plastic housing was developed using their 3-d printer. In a recent development this past year, GOMI has also been involved with designing and testing a eco-friendly drogued drifter including a surface float made of natural mushroom material. Emily Flaherty’s group at the Salem Sound Coast Watch facility conducted the experiment with a series of deployments. As with any tethered drogue in shallow waters, there were some issues with premature groundings and damage to the float (see photo) but they were nevertheless the first to demonstrate the possibility of using this eco-friendly material. The students were also involved with constructing the drogue.

Figure 3. Eco-friendly drogue that used natural mushroom material for flotation


Figure 4. Deploying a drifter from the deck of the Ninth Wave, a sailing catamaran, Cape Anne, MA.

In addition to the North Shore deployments, GOMI has been involved with studies in Cape Cod Bay and the Bay of Fundy. In collaboration with the Wellfleet Bay Wildlife Sanctuary in Wellfleet, MA, dozens of drifters have been deployed each fall to simulate the flow and strandings of cold-stunned turtles that have occurred there in increasing numbers the last few years on Cape Cod beaches. A manuscript is underway to describe the physical oceanographic processes that contribute to hypothermic turtles coming ashore during cold windy conditions. Multiple clusters of GOMI-drifters deployed in the bay over the last few years document the variability of the surface currents and the complexity of the process.

GOMI has also made several deployments each year in the northern reaches of the Bay of Fundy with scientists at Acadia University in Nova Scotia. Here the drifter tracks document not only the enormous tidal flow in this region but the retentiveness of the system. Dozens of drifters have each traveled thousands of kilometers moving at multiple knots back and forth with the tide with little or no net movement (See Fig. 5 and 6) In other words, the tidal process tends to dominate the flow in this area so that sub-tidal wind and coastal current effects are minimal. The GOMI deployments made in the Bay of Fundy are also contributing to the study of harmful algal blooms (HABs) that occur there each summer. Another manuscript is underway to model the process of toxic algae collecting in this area and occasionally leaking into the great Gulf of Maine.

In engaging young students in this process, we hope to recruit some local "physical oceanographers" to sustain these observations into the next decade or two. With subtle changes in the water masses entering the Gulf of Maine over climatic time scales, can we document a change in the flow fields off our coast?

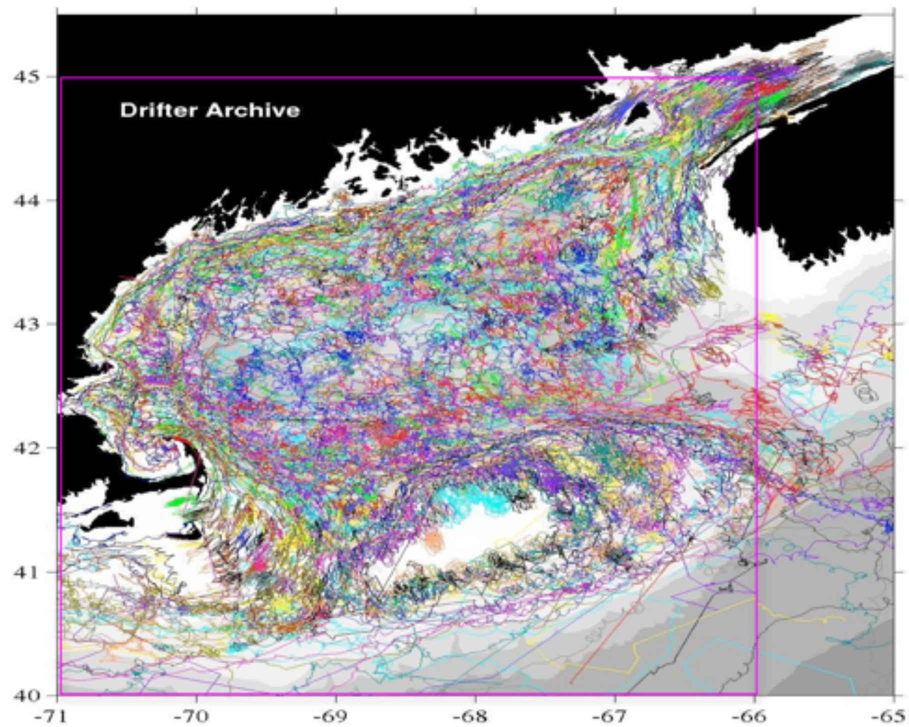


Figure 5. Tracks of over 1000 drifters deployed from the Bay of Fundy over the past few decades.

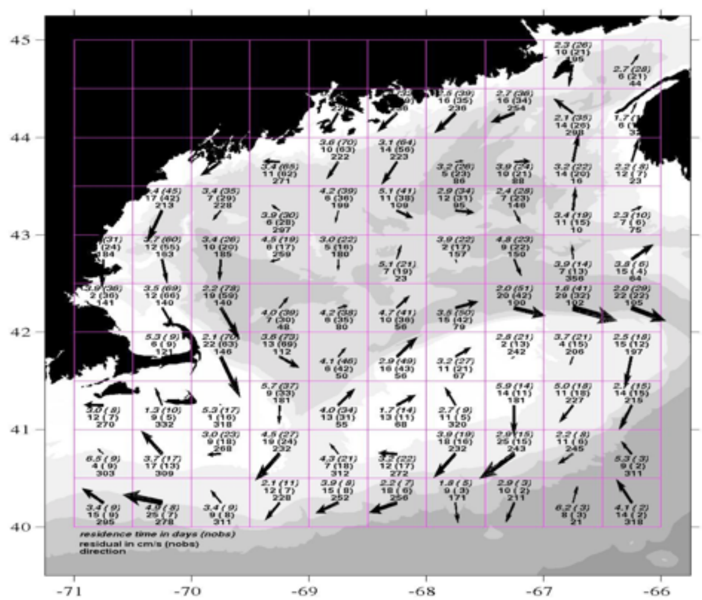


Figure 6. Flow statistics generated from compiled database of drifter deployments, showing, in each quadrant: top number: residence time, in days, of the drifter within the quadrant and the number of observations made (knobs); middle number: residual (velocity) in cm/s and nobs; bottom number: flow direction, in compass degrees. These data are also depicted by the size and direction of the arrows in each square.

Jim Manning has been at NOAA's Northeast Fisheries Science Center for 30+ years. After a bachelor's degree in mathematics (UMO) and master's degree in oceanography (URI), his career has been largely devoted to designing, building, and deploying low-cost ocean observing systems with the help of commercial fishermen. Over the last few decades, individuals in this growing network have been deploying sensors on both fixed and mobile fishing gear as well as on drifting platforms off the coast of New England. The data they generate are provided to local ocean modelers to help validate numerical simulations of the ocean.

STORMWATER MANAGEMENT AND CSO REDUCTION PROJECTS IN THE MERRIMACK RIVER WATERSHED

By Kelly Conway

Salmon, shad and Alewives were formerly abundant here . . . until the dam, . . . and the factories at Lowell, put an end to their migrations hitherward. . . . Perchance, after a few thousands of years, if the fishes will be patient, and pass their summers elsewhere . . . nature will have levelled. . . the Lowell factories, and the Grass-ground River [will] run clear again. – Henry David Thoreau, A Week on the Concord and Merrimack Rivers, 1849.

The Merrimack River has a history of poor water quality. Since the Industrial Revolution brought textile factories and mills to Lowell, MA, the water quality was degraded by industrial and human waste discharged to the water as population growth in these mill cities boomed. The environmental legislation of the 1970s and 1980s greatly improved the water quality of the Merrimack River, but the river still often fails to meet water quality standards. Today, combined sewer overflows (CSOs) make up the main problem afflicting the Merrimack River Watershed, leading to increased levels of solid waste, nutrients, and pathogens in the water following rain events. As climate change continues to progress, the frequency and intensity of abnormal precipitation events will continue to increase. It is therefore very important that we begin work on preparing for increased volumes of storm water entering the water systems in the coming decades in order to protect against future severe CSO events.

Combined sewer overflows occur when excessive rainfall or storm events overwhelm the combined sewer system (CSS), a sewer system in which municipal sewage and storm water runoff are both collected in the same pipe, and causes the system to discharge untreated water containing bacteria and other nutrients and contaminants directly into the river.
In the Merrimack River Watershed, CSOs mainly stem from the cities of Lowell, Haverhill, and the Greater Lawrence Sanitary District in Massachusetts, and Nashua and Manchester in New Hampshire. The table below contains data on CSOs published in the Merrimack River Watershed Assessment study in January 2004 for the US Army Corps of Engineers by the Merrimack River Basin Community Coalition.

Community	Maximum Number of Discharge Events per Year	Average Annual Discharge Volume (million gallons)
Manchester, NH	49	220
Nashua, NH	25	26
Lowell, MA	37	352
Greater Lawrence Sanitary District, MA	14	112
Haverhill, MA	41	71

Table 1: Data on CSO events within the Merrimack River Watershed, including the Merrimack main stem and its tributaries, from the 2004 report. . Source: Merrimack River Basin Community Coalition.

Location	Number of Outfalls to Merrimack River	Annual CSO Volume (MG) to Merrimack River
Manchester, NH	18	194.5
Nashua, NH	4	13
Lowell, MA	7	94.5
Lawrence, MA	4	103.5
Haverhill, MA	14	65.63
Total	**47**	**471.13**

Table 2: Number of outfalls on and CSO volume discharge to the Merrimack mainstream per town of study in Merrimack River Watershed. Source: Merrimack River Basin Community Coalition and CDM, "Merrimack River Watershed Assessment Study.

There are several methods of CSO prevention that I will explore in this paper. One way in which communities are tackling the issue of combined sewage overflow is by separating the sewer system into individual streams for wastewater treatment and for storm water discharge into bodies of water. Another method is to increase capacity for storage and treatment in existing sewer systems. A third method of combating CSOs is through the implementation of green infrastructure, such as bioswales, rain gardens, and permeable pavements, which infiltrate and filter storm water runoff to mimic natural forest habitats.

Analysis of 2013 Water Quality Data

In order to determine what is at stake when polluted runoff and CSOs enter the river, I will discuss the average water quality data that my team with the Gulf of Maine Institute (GOMI) found from monitoring a portion of the Merrimack River throughout the summer of 2013. The dates for monitoring were not selected due to their proximity to a rainfall event, so this average was intended to be representative of the average quality of the river in the summer. I also use this data to determine what may be the underlying concerns associated with water quality in average conditions, not just in the extreme rainfall events, in the hopes of bringing the river ultimate protection from contaminants and pollution.

Figure 1 below shows an aerial view of the Merrimack River as it goes through two points in Newburyport where the river's water quality was monitored and measured by the Gulf of Maine Institute.

Figure 1: Google Earth aerial image of the Merrimack River including the Haverhill Sewage Treatment Plant, the Artichoke River mouth, the Yankee Marina monitoring station, and the Amesbury Wastewater Treatment Plant.

Some water quality data for these points is tabulated below for the summer of 2013 at the two points shown on the map, the mouth of the Artichoke River in the Merrimack River and the point on the Merrimack right off of the Yankee Marina docks. It is important to note that the Artichoke River sampling location is upstream of the Amesbury wastewater treatment plant, while the Yankee Marina sampling point is downstream of the plant. However, it is important to note that the sampling location at the mouth of the Artichoke is surrounded by much more undeveloped forestland than at the Yankee Marina, which is surrounded by residential or commercial lands characterized by mostly impervious surfaces. Impervious surfaces lead to increased polluted runoff, while forestland retains and filters runoff, discharging cleaner water into the river. The data we collected for Table # below shows that the water by the Yankee Marina docks had significantly higher phosphate levels, slightly higher nitrate levels, significantly higher specific conductivity, and considerably higher turbidity than the water at the mouth of the Artichoke River. Phosphates often enter water by runoff contaminated by human or animal waste, agricultural fertilizer, and erosion of phosphate- rich landscapes and bedrock. High levels of phosphates are also often associated with CSO events, as sewer systems cannot handle the volume of water and thus directly discharge water with human and animal waste (phosphate-rich) into the river. The EPA provides a limit of 1 mg/L for phosphates in drinking water, and both of these locations demonstrated a summer average above the limit.

High nitrate levels also often come from human/animal waste and fertilizers as well as from CSO events. The difference in nitrate levels at the two points was not nearly as significant as that of the phosphate levels, but it is still important to recognize for analysis. Both sites had nitrate levels far below the EPA drinking water limit of 10 mg/L. The specific conductivity is also much higher at the Yankee Marina. Specific conductivity tells us about the concentration of ions in the water. In this case, it is likely that the specific conductivity at the Yankee Marina is raised by its proximity to the mouth to the Atlantic Ocean (at the far right in the aerial photo); saltwater raises the salinity and salt concentration in the water, which raises the specific conductivity. However, the high specific conductivity could also be indicative of ions in solution, including chloride, nitrate, or phosphate ions, or of the presence of runoff from clay soils with minerals that ionize in water (Fondriest Environmental). Additionally, when we took this data, we noted that the YSI equipment we used was not functioning correctly at times during the sampling, so it is important to be cautious in using this data in my analysis. Lastly, the high turbidity at the Yankee Marina suggests the presence of clay and soil particles and total suspended solids (TSS) in the water. While turbidity is not usually a health concern, it can become a health concern if the suspended solids cause metal ions to agglomerate in the water (USGS).

2013 Station Averages				
	PO_4 (mg/L)	NO_3 (mg/L)	Turbidity (FTUs)	Conductivity (∝S/cm)
Artichoke	1.66	1.34	5.2	116.86
Yankee Marina	1.92	1.375	11.5	5522.12

Table 3: average data for two monitoring stations along the Merrimack River in Newburyport, MA, for the summer of 2013.

Included in this study performed by the GOMI team was a bacterial analysis of three beaches along the Merrimack River in Newburyport, one of which (called Back River) is in the middle of the river and surrounded by salt marshes, and the other two (Salisbury Beach and Joppa Flats) which are downstream of the main industrial and commercial area of town, and specifically downstream of the Newburyport sewage treatment plant. Our study found that the Back River beach consistently had levels of Enterococcus bacteria well below the Massachusetts state limit of 104 cfu/100 mL, while the other two beaches only had bacteria levels below this limit 40% of the time. Our study also notes that generally speaking, the high levels of bacteria at these two beaches tended to happen after rain events, although this is only anecdotal as no real data was collected on the rain events. This data therefore suggests that the bacterial levels at Salisbury Beach and Joppa Flats are higher than that of Back River due to their position downstream of the treatment plant as well as their relative lack of salt marsh to filter the contaminants.

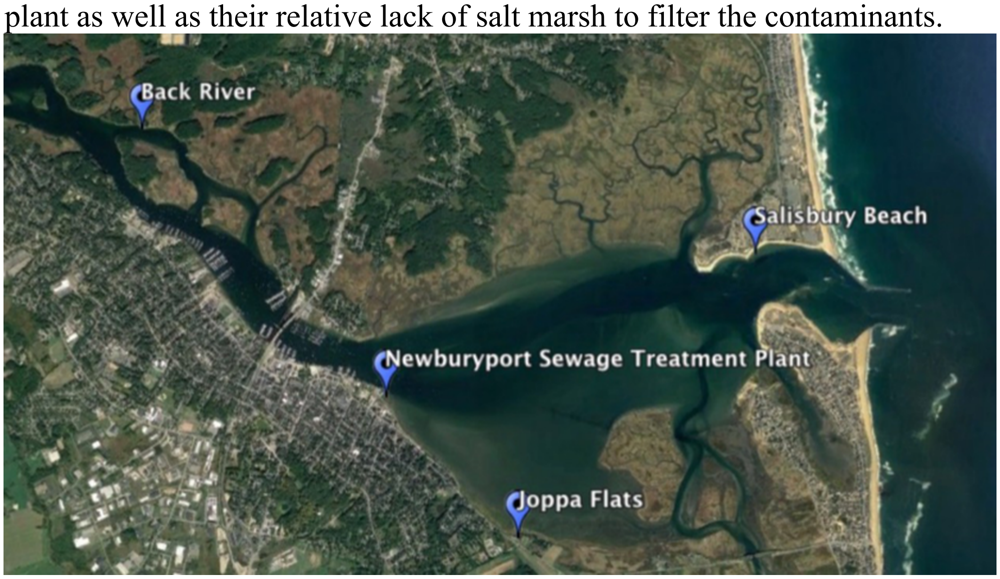


Figure 2: Map of Newburyport and Salisbury, MA, depicting the three beaches and the Newburyport sewage treatment plant.

After analyzing these results, I suggest that in addition to CSOs, other major contributors to pollution and poor water quality in the river are runoff from impervious surfaces and discharges from sewage treatment plants in everyday function. Because this data was not collected near the date or location of a CSO event, the data suggests that typical operation of the treatment plants and typical conditions can cause significantly worse water quality even without a CSO event.

Assessment of Abatement Strategies for the Merrimack River Watershed

CSO reduction projects using one or more of the three abatement strategies have taken place all over the nation as aging infrastructure fails during heavy rainfall and storm events. However, many of the projects that have been successful cover much smaller areas. The scope of the project of the Merrimack River Watershed is significantly larger than any CSO reduction project I came across in my research. After doing research on other CSO abatement projects that used separation (Alexandria, VA, Cambridge, MA, and Nashua, NH), increased storage and treatment (Alexandria, VA), and/or green infrastructure (Seattle, WA) and performing calculations specific to the Merrimack River watershed, my primary recommendation is to combine the three methods, with an emphasis on spending on storage capacity Green infrastructure should be widely implemented, but should not be relied on as the primary stormwater management practice, and should not compose much of the total project budget. Sewer separation should take place on a case-by-case basis as aging infrastructure demonstrates need. I predict this combination plan to result in over 90% reduction of CSO volume discharge per year.

CSO Reduction Strategy	Capital Cost ($M)	CSO Reduction
Complete Sewer Separation	1600	100%
Green Infrastructure	105	60%
Storage Expansion	863.8	87%

Table 4. Cost Estimate and CSO Reduction Comparison for the 3 strategies studied in this report.

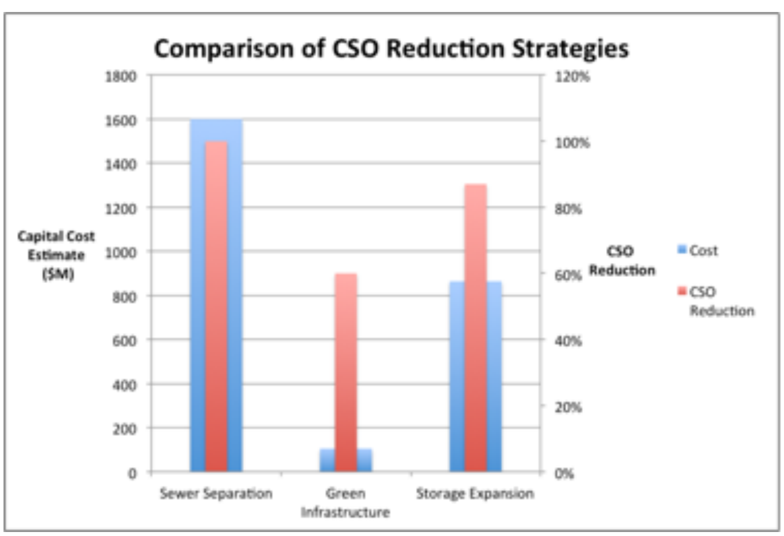


Fig. 3 Graph of cost estimate and CSO reduction comparison for the 3 strategies studied.

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Kelly is an undergraduate senior at Columbia University studying earth and environmental engineering. During her time at Newburyport High School, she was the Newburyport GOMI team lead for the monitoring of marine invasive species and an active participant in water quality testing projects, pepperweed pulls, and community and youth outreach events. She was the primary author of the 2012 GOMI Marine Invasive Species report and a major contributor to the 2012 GOMI Water Quality report. During her senior year of high school, Kelly was selected to be a Henry David Thoreau Scholar for her demonstration of environmental dedication and leadership. Her experience with environmental conservation and stewardship as a member of GOMI led her to pursue environmental engineering studies in college, specifically in the field of the water-energy nexus: the intersection of water resources, energy resources, and sustainability principles.

At Columbia, Kelly joined a laboratory group conducting research on technologies for the water-energy-environment nexus. Her research has focused on developing desalination technologies, including the study of novel nanofiltration membranes for reverse osmosis desalination. Kelly also spent a summer in Newburyport working as an intern in GZA GeoEnvironmental, Inc.'s office on a variety of environmental engineering projects around the North Shore. In November 2016, she was inducted to the New York Alpha chapter of Tau Beta Pi, a national engineering honor society. She plans to pursue further graduate study in the field of water treatment processes following her graduation from Columbia in May 2018. In her free time, Kelly enjoys distance running, hiking, playing with her intramural basketball team, and exploring new restaurants and attractions in New York City.

Kelly's article is a edited down version of a longer term paper she did for her Solid Hazardous Waste Management class. Her study was conducted on the Merrimack River Watershed, Massachusetts.