Ecology of Oysters, Oyster Growth and Water Quality

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RIVER LAB Lesson Plans

Lesson 1: **Ecology of Oysters** Lesson 2: **Oyster growth and water quality**
Rationale:

The history of New York City is carved by its abundance of protected and productive waterways. Native Americans and later, the early Dutch and British settlers relied on these waterways for transportation and sustenance. Rivers, streams and lakes provided residents with fresh water. As the settlements of New York increased in population, so did the amount of pollutants, sewage and over-fishing practices. As water became more and more degraded, intense efforts to access fresh drinking water became necessary. In 1667, British settlers began to tap the ground water in lower Manhattan. In the mid-1800s, New Yorkers began diverting northern water supplies to quench the city's growing thirst. Although fresh drinking water became more accessible through improved technology, local water quality continued to decline. Oysters were a staple food and commerce of early New York City, but at the start the twentieth century, depleted oyster populations were deemed unsafe to eat due to typhoid scares and high bacteria levels in local waters. In response to public health concerns, water monitoring programs began with the Metropolitan Sewerage Commission of 1909. Sewage systems were designed to protect local bathing beaches; however, raw sewage, industrial wastes, farm runoff and other non-point source run-off continued to pollute the Hudson River and its estuary until the Pure Waters Act of 1966 and the Clean Water Act of 1972.

The twenty-first century has granted us the opportunity to reverse the unsustainable practices of the past 300 years. Recent times have shown a dramatic improvement in water quality due in large part to increased waste water treatment, stronger legislation and decreased waterfront industries and farming. The newly expanded Hudson River Park provides the public with greater access to the water. With this access comes the opportunity to for citizens to act as stewards in restoring this precious resource. Pier 40, two blocks west of City-As-School High School, is located within the Hudson River Park which extends along the waterfront from the Battery to 59th Street.

River Lab is a program that brings students to the Hudson River Estuary for science education and recreation. The program includes a water quality research component, a boathouse internship and rowing. By exposing students to the Hudson River, New York City's largest open space park, we hope to increase stewardship and awareness. Throughout the course students will be monitoring the growth of the Eastern Oysters (*Crassotrea virginica*), which will serve as bio indicators that represent the "health" of the estuary system.

The three lessons included in the action plan are taken from an eight week science course that was designed for high school juniors and seniors whom have previously taken biology. The lessons may be adapted for biology, environmental science, or social studies courses from grades 6-12.

Essential Question: How do sustainable oyster populations impact water quality in our region?

Action Plan:

Lesson 1: **Ecology of Oysters**

Pre-twentieth century New York City waterfront was spotted with oyster carts before the hot dog was a street staple. It is documented that navigation in the East and Hudson Rivers was arduous in large part due to impressive oyster reefs. Many towns, islands and streets were named in reference to the high populations of oysters or the industries that relied on them for commerce (ex. Pearl Street, Oyster Bay and Great Oyster Island - now know as Liberty Island). What may have not been know then is that oysters were as important to the estuaries' ecology as they were tasty. Oysters, unlike other native mollusks which attach to rocks and piers, strive in brackish water by forming large free-standing reef habitats. The reefs are composed of older oyster shells which fix to a hard medium at the bottom of the water. During spawning, pheromones are given off that attract larvae to attach to existing shells. The older shells die off and are hollowed out by decomposition and predators/scavengers. The newly attached "spat" remain sessile where they grow, feed and contribute to the reef structure. As oysters reproduce and grow, the reef continues to rise high into the water column. Large reefs can extend over 10 meters from the bottom of the estuary but take hundreds of years to mature. Some reefs located in intertidal regions are exposed at the top during low water (oysters are tolerant of dessication for several hours). Oysters eat by filtering water and removing phytoplankton. Oysters that are perched above the murky bottom have less sediment to filter and greater access to photophilous food near the surface. The benthic region of the estuary can be home to many parasites; many of which are not tolerant of dessication. Free- swimming oyster larvae use the interstitial nooks for protection from predators. Studies have shown that oysters bond best to oyster shells over smoother less irregular surfaces (ex. clam shells, discarded trash, etc). In addition to being beneficial to oyster populations, the oyster reefs are analogous to coral reefs in that they increase biodiversity. Reefs provide habitat, reproductive sites, and feeding opportunities to a wealth of other marine and estuarine organisms.

Other variables which influence oyster populations include temperature, dissolved oxygen levels and salinity. Like most aquatic and marine aerobic organisms, oysters are stimulated by high oxygen levels. Different studies have shown that salinity levels have a profound impact on oyster growth rates and disease resistance. To generalize, high salinity tends to stimulate growth but reduce disease resistance while low salinity has a reverse effect. Dermo, a protozoan disease of oysters, does not seem prevalent below a salinity of 12 parts per thousand (ppt).

In addition to biological services, oysters also greatly benefit overall water quality in several ways. The filtration of water for phytoplankton tends to balance algae populations. Increases in algae populations reduce turbidity (impacting light penetration to organisms at greater depths) and oxygen levels. Algae, like plants, conduct photosynthesis in the presence of light and produce oxygen as a byproduct. However, algae/plants, like all aerobic organisms, use oxygen 24 hours a day to respire. Large algal blooms can greatly deplete oxygen levels for all organisms in an aquatic/marine ecosystem. Along with the water containing algae, inert and polluting sediments are filtered by oysters. An adult oyster can filter up to 25 gallons of water a day. When oysters take in water through their gills, the foods are sent to digestive organs while non-food sediments are mixed with sticky secretions (similar to the matrix that make up shells, pearls and the affixing substrate). The wastes (psuedofeces) are egested in a form much denser than their original composition and they sink to the bottom where they are more quickly decomposed or covered by other sediments and thus removed from the water column. When not filtered by oysters, concentrated sediments in water can cause excess heat adsorption and reduce oxygen levels.

The natural process of filter feeding can cause organisms to intake harmful contaminations. Oysters are still illegal to harvest in NYC because they take in many pathogens and toxins when they filter water. In some areas of New Jersey (ex. Raritan Bay), oysters are being harvested again. Although they can be grown and removed from local waters, they must then be brought to a different area to be stored in clean water to purge pathogens (relay) and/or brought to a facility to flush pathogens by storing them in tanks containing treated water (depuration).

Activity 1: A ten gallon (or larger) clear container can be used to demonstrate the filtration properties of oysters. Filling the container with mucky river water and then allowing a dozen or more live oysters to feed will show a dramatic increase in the clarity of the water in a few hours. Experiments using different size/numbers of oysters can be conducted and timed. Other variables, such as temperature, can be tweaked so that students may design their own experiments, collect data and draw inferences.

Lesson 2: Oyster Data

In order to restore local oyster populations, oysters are being cultured by volunteer groups and monitored for mortality and growth rates. The Baykeeper is collecting data from all the "oyster gardening sites" in the Hudson-Raritan Estuary and creating a database. The data generated will be used in a regional study to locate suitable sites for oyster reef sanctuaries. Volunteers monitor the oysters for up to one year. Once data is collected, the cultures are used to create a generation of healthy seed oysters. City-As-School (CAS)/Floating the Apple at Pier 40 and The River Project at Pier 26 are the two groups studying oysters in the lower Manhattan Hudson River Estuary. Along with growth data and water chemistry, biodiversity is also being studied. The River Lab Program(CAS) is monitoring 400 oysters kept off the southern dock at Pier 40. They are suspended mid-water column in a five-tier net habitat. They were bred at a hatchery in Connecticut on the Long Island sound, then transported to The River Project to acclimate to the Hudson River, and ultimately given to City-As-School on December 9th, 2000. At that time, they were approximately 7 months old and about 27 mm in length. Students have been monitoring them for the remainder of the school year and at the end of June, the year-old oysters will be collected by the Baykeeper and used to seed a newly-constructed reef. We expect that they will average over 30mm in length.

The River Lab program also monitors pH, dissolved oxygen, salinity and temperature. We have two traps suspended near our oysters for biodiversity studies. We have collected and released a large number of invertebrates and identified over 10 species of fish.

Water Chemistry:
Students monitor water chemistry data, along with oyster growth rates, and submit data to the

Baykeeper (see attached data sheet).

pH is the measurement of hydrogen ions in solution. It is a logarithmic calculation that is translated into the pH scale which ranges from 0 to 14. Any measurement below 7 is considered high in hydrogen ions and thus acidic. Values above 7 indicate an alkaline pH which is low in hydrogen ions but high in hydroxide ions. A pH of 7 is neutral (ex. pure water). The pH value will often influence the rate of growth of living things. Most organisms that live in water have an optimal pH range for maximum growth and a narrow range of tolerance. Students will use pH kits to test estuary water. Since estuaries are often greatly influence by marine sources which have high calcium deposits, the pH tends to be higher than 7. The water at Pier 40 has tested to have a consistent pH between around 8.

Dissolved oxygen is the measurement of the number of oxygen molecules dissolved in water. The range is usually between 0 and 17 (maximum saturation) parts of oxygen gas per million parts of water molecules (ppm). Oxygen levels have rebounded in recent decades. In the mid-seventies, horrific benthic oxygen levels were recorded, averaging below 3 ppm in summer months. This level is below tolerance of many benthic organisms, especially fish. Oxygen levels now average above 5 ppm in summer months and we have recorded oxygen levels as high as 8 ppm at pier 40.

Salinity is the measurement of dissolved salts in the water. Salts high in sodium, phosphorous and calcium or typical in marine biomes. Salinity greatly influences growth and disease resistance in oysters. Salinity in waters near Upper Bay are greatly affected by tidal action. When the tides go out and there are heavy rainfalls in Upstate New York, salinity tends be at its lowest due to the influx of fresh water from runoff and the ebbing of the Hudson River. When the tides are coming in and/or during drought, there is significant rise in salinity. Salt water is more dense than fresh, thus in brackish ecosystems like an estuary, the deeper waters tends to be higher in dissolved salts. At Pier 40, we have recorded salinity levels as low as 11.5 ppt at the surface and as high as 22 ppt near the bottom.

Turbidity is often measured using a Secchi Disk to record Secchi Transparency. Secchi Transparency is an estimate of the clarity of surface waters. Secchi reading above 5 feet are exceptional but not typical of productive estuaries due to high nutrient and plankton concentrations. Secchi readings below 3 feet are indicative of degraded waters. Plankton blooms and suspended solid concentrations greatly affect Secchi readings. Oysters grow best in areas where plankton is present but suspended solids are in low concentration. Pier 40 surface waters range between a 3 and 4 feet Secchi Disk reading.

Temperature varies seasonably in the northeast. There is a proportional relationship between water temperature and oyster growth rates. Very warm temperatures can have a negative effect on oxygen levels and thus hinder growth. In December the temperature at Pier 40 averaged 4 - 6 degrees Celsius and by June, it had warmed up slowly to 16 - 18 degrees Celsius.

Other water quality factors measured by the DEP regularly include Chloropyll a and Fecal Coliform Bacteria.

We hope to incorporate these variables into future projects.

Activity 2: Students will use calipers to measure the length and width of juvenile oysters in millimeters. Current data will be compared to previous growth data and correlated with water quality factors. In addition to size, oysters will be monitored for mortality rates and parasites. When oysters die, they remain open and empty.

Lesson 3: Sustainable Oyster Reefs

As discussed previously, water quality has improved and large-scale oyster harvesting has ceased for almost 100 years! The immediate question should be: if there are oysters living in the Hudson River Estuary and they are reproducing why are historically large oyster populations not returning? There are four main variables that contribute to the lack of sustainable oyster populations.

1. Over-fishing:

Like many examples of marine organisms, over-harvesting can not only diminish current population size but also restrict future generations of organisms from having the critical mass necessary to restore sustainable populations. For over one hundred years, large quantities of oysters were removed from New York harbor and its surrounding estuaries with little regulation (comparisons should be made to other fishing models including tuna, swordfish and salmon - management techniques, policy, fishing methods and business models are available for contrast/comparison in future lessons). Traditionally, when oysters are harvested with large metal rakes or by dredging, the reef integrity is compromised. Once oysters were sold and consumed, the shells were ground for industrial or fill materials instead of being returned to the water. As a result of these practices, historic oyster reefs are no longer in abundance and reproducing oysters have few locals to thrive in a community.

2. Dredging:

To compound the problem, as ships increased in size, the dredging of channels became more and more prevalent, causing even more destruction to oyster habitats . This continues to be a problem today.

3. Pollution:

Although water quality is improving, the absence of oysters as filtration agents, compounded by many years of pollution, have limited growth/reproductive rates in current oyster populations. PCBs, dense oily pollutants used by electric companies as an insulation material, are concentrated in the bottom sediments of the Hudson River. The issue of cleaning up this material is currently being debated and will have profound impact on the future of the river. As more land is cleared to accommodate growing human populations, urban sprawl, and expanding industries, the threat of increased non-point source pollution from run-off is of great concern.

4. Disease:

The variables which influence the spread of disease of among oysters are not clear. MSX and Dermo, two protozoan parasites which crippled Chesapeake's oyster fisheries, seem to thrive now that there is an imbalance in the ecosystem. Increased spread of disease occurred in many areas of

Chesapeake Bay when oyster men deplete populations in a given area and then unsuspectingly import infected oysters to replenish the population. Local disease-resistant oysters were often harvested when they reached market size, compounding the problem.

Scientists feel that the fishing industries have greatly mismanaged oyster populations and have caused an ecological imbalance in eastern estuaries. Several studies have indicated that sustainable oyster populations can only be restored by creating permanent reef sanctuaries. Reef sanctuaries are three-dimensional structures composed of deposited oyster shells (a limiting factor in some projects) which rise at least one half the distance of the water depth off a hard bottom. Sanctuary reefs are best placed in historic oyster reef sites for several reasons, including optimal currents, salinity, and estuary floor composition. These sites are either still occupied by some remaining reef or can be identified on old navigation charts. Projects that spread oyster shells over a wide area have been much less successful. In addition to the advantages vertical reefs provide they increase fecundity. Since oysters reproduce by external fertilization, a close proximity of adults is critical to ensure high fertilization rates during spawning. Since larvae start out free-swimming, sanctuaries can serve the entire region by seeding surrounding reefs outside the sanctuary boundaries. Growing oysters to seed sanctuary reefs serves as a brood stock to replenish populations of this keystone species.

Activity 3:
By culturing oysters with the NY/NJ Baykeeper Organization you can contribute to local oyster restoration efforts. Currently oysters which are grown in downtown Manhattan are being relocated to an experimental reef sanctuary adjacent Liberty Island in Upper New York Bay.

One project I would like to incorporate into the program would be to have students design an experimental reef around the Pier 40 park. This would entail using water quality, light and tidal movement to locate a suitable site. Students would then contact local restaurants (ex. Grand Central Station's Oyster Bar) to arrange collection of discarded shells. The project would compliment studies of the NYC waste management issue in light of the 2001 closing of the Fresh Kills Landfill. Shells would be lowered to the bottom to create a reef structure. Seed oysters would then be added to the reef and with the help of The River Project and Urban Divers Inc., we could collect data to see if oysters begin spawning and settling into the structure.

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