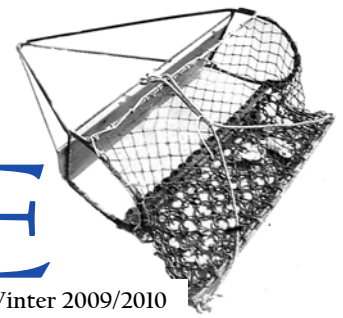


# THE DREDGE

Volume 4(1): Winter 2009/2010



Connecticut Sea Grant, University of Connecticut

Publication No. CTSG-10-02

## Oysters as Ecosystem Service Providers: The Case of Nitrogen Sequestration in the Long Island Sound



Oystermen harvest nitrogen from the Long Island Sound. Photo by Rich Press.

### Introduction

Estuaries are among the most productive, and the most threatened, ecosystems on Earth. The main threat to many estuaries is eutrophication, which is an overloading of organic material into the ecosystem. Eutrophication in the Long Island Sound (LIS) is caused by the release of nitrogen-rich wastewater from sewage treatment plants. This nitrogen feeds phytoplankton, which ultimately bloom resulting in hypoxia, or low dissolved oxygen, during the summer. Hypoxic waters cannot support the variety of marine life necessary for a healthy, intact ecosystem.

Connecticut has been a leader in developing innovative strategies to manage eutrophication in the coastal zone. For instance, the State has a water quality trading program, called the Connecti-

cut Nitrogen Credit Exchange, which allows waste water treatment plants (WWTP's) from around the State to share the costs and benefits of removing nitrogen from wastewater. This program differs from so-called "carbon trading" programs designed to limit greenhouse gas emissions, but the underlying idea is similar: each WWTP in the State is assigned a limit to the amount of nitrogen it can release. Plants that invest in pollution controls that bring them below their emissions limit can sell the balance in emission "credits". Plants that do not meet their limits can then buy those credits to offset their over-emissions.

The result is (or should be) that overall nitrogen emissions are reduced, the costs of emissions reductions are shared, and pollution control upgrades occur at the most cost-effective sites. Currently, only WWTP's participate in the exchange, and what they buy and sell is the right to emit nitrogen. In 2008, an emissions credit for a pound of nitrogen sold for \$4.50.

While treatment plants are removing nitrogen from wastewater before it enters the LIS, there is a population of shellfish in the Sound that remove the nitrogen once it is there. They remove the nitrogen by consuming phytoplankton, and in doing so they improve water quality and limit the environmental consequences of eutrophication. This paper is the attempt to put a

*(continued on page 2)*

dollar value on the ecosystem service that the shellfish, in this particular instance oysters, provide to LIS by estimating the amount of nitrogen they remove from the water and then pricing that removal on the Nitrogen Credit Exchange.

This exercise inevitably leads to the idea that the ecosystem itself might generate nitrogen offsets that could be sold on the exchange. For instance, wastewater treatment plants might purchase ecosystem-generated offsets to balance some portion of their emissions. If the resulting revenue were used to increase oyster production above what it would otherwise be, then this market mechanism could be a useful tool for managing water quality while maintaining a healthy ecosystem. Swedish scientist Odd Lindahl<sup>1</sup> has argued convincingly that shellfish-based ecosystem services should be integrated into emissions trading markets. This paper analyzes how well this idea applies in Connecticut.

### **The Role of Nitrogen in Water Quality**

In many ecosystems, nitrogen is a limiting nutrient and its availability plays an important role in regulating population structure and ecosystem function. Humans overcame this limiting factor in 1913 with the invention of the Haber-Bosch process of nitrogen fixation. This process is used to produce the agricultural fertilizers necessary to feed the world's population. There is a downside, however: industrial nitrogen fixation has nearly doubled the magnitude of the global nitrogen cycle.

Much of this industrial nitrogen eventually ends up in lakes and coastal estuaries where it initiates a process of eutrophication. That is, it overloads the ecosystem with organic material. Since nitrogen is a fertilizer, it stimulates excessive growth, or a "bloom" of phytoplankton. As this bloom dies, it is decomposed by oxygen-

consuming bacteria. During warm months stratification in the water column can prevent the bottom layer of water from being refreshed, and it becomes depleted of oxygen. In severe cases, this condition, called hypoxia, can cause a coastal "dead zone."

Hypoxic conditions occur every summer in the western LIS. The government agencies that manage water quality in the Sound - the U.S. Environmental Protection Agency, the Connecticut Department of Environmental Protection, and the New York State Department of Environmental Conservation - have developed a computer model that, among other things, relates nitrogen loading to changes in dissolved oxygen.

Using this model, they have determined the maximum amount of nitrogen that the Sound can safely absorb.

In the LIS, anthropogenic or human-derived nitrogen loading is dominated by point sources such as WWTP outflows and combined sewer overflows. The states of New York and Connecticut together

plan to abate point-source nitrogen loading into the LIS by 60% from 1990 baseline levels by the year 2014. If achieved, this goal should bring the nitrogen levels in the Sound into compliance, or nearly into compliance, with state water quality standards for dissolved oxygen. Connecticut is using the Nitrogen Credit Exchange as a tool to meet its abatement target. The State of New York does not have a water quality trading program, and is using more traditional regulatory control to meet its target. The remainder of this report focuses on abatement efforts in Connecticut.

To meet its abatement target, the State has assigned a wasteload allocation to each of its 79 WWTP's. The allocation is an upper limit or "ceiling" on the amount of nitrogen that each

*(continued on page 4)*

*In the LIS, anthropogenic nitrogen loading is dominated by point sources such as Waste Water Treatment Plant outflows and combined sewer overflows.*

## FDA Reverses Decision on Oyster Ban

During the fall of 2009, the U.S. Food and Drug Administration (FDA) announced plans to ban harvesting of raw, unprocessed oysters during the summer months, beginning in the 2011 season. The proposal was intended to prevent the severe illness, and sometimes death, resulting from human consumption of oysters containing the bacteria *Vibrio vulnificus*.

Each year, an average of 15 people die from eating untreated oysters harvested from the Gulf Coast, and as a public health agency the FDA determined that it was in the best interest of the public to prevent this from happening by enacting a major policy change.

However, the announcement sparked an outcry among oyster harvesters and state officials along the Gulf Coast and around the country, who protested that the ban would have potentially devastating effects on local economies invested in deriving a large percentage of annual income from summer oyster harvesting.

While there are post-harvesting procedures that can eliminate the virus, oyster aficionados argued that these procedures interfere with the culinary quality of the oyster, and pointed out that the technology and equipment necessary would be unaffordable for smaller harvesting operations. The ban would also put several thousand people out of a job.

The FDA has determined that these are legitimate concerns and that “there is a need to further examine both the process and timing for large and small oyster harvesters to gain access to processing facilities or equivalent controls in order to address this important public health goal.”

The decision has been made to conduct an independent study assessing the feasibility of enacting post-harvesting procedures that can be implemented with assurance of protecting both public safety and regional economies. Discussion and collaboration between the FDA and the In-

terstate Shellfish Sanitation Conference will continue while this study is being conducted, and the FDA plans to offer technical support to local farmers in order to enable them to use post-harvesting procedures without suffering financial consequences.

The FDA will also work with the National Oceanic and Atmospheric Administration and the U.S. Department of Agriculture in an effort to combine protection from human exposure to the virus with protection of the oyster industry.

*Submitted by Greta Rosenberger, Marine Science Intern, Connecticut Sea Grant and Department of Marine Sciences, University of Connecticut*

### CALENDAR

#### Spring

Coastal Perspectives Lecture Series  
Alternate Tuesdays at 7:30pm UCONN, Groton  
<http://www.marinesciences.uconn.edu/public.html>

#### March

1-5 National Shellfisheries Association  
Aquaculture 2010 Meeting  
San Diego, CA  
<http://www.shellfish.org>

14-16 International Boston Seafood Show  
<http://www.bostonseafood.com>

#### April

27-29 Basic Seafood HACCP Course  
Narragansett, RI  
Contact Lori Pivarnik: [pivarnik@uri.edu](mailto:pivarnik@uri.edu)

#### May

5 Segment 2 HACCP Course  
(follow-up to Internet Class)  
Narragansett, RI  
Contact Lori Pivarnik: [pivarnik@uri.edu](mailto:pivarnik@uri.edu)

**“Oysters...”** (continued from page 2)

plant can emit. The wasteload allocations will decrease each year until 2014, by which time the State should meet its overall abatement target.

One way that WWTP's can reduce their nitrogen emissions is to install a bioreactor, a system of tanks containing bacteria able to convert reactive nitrogen into harmless gas. Not all WWTP's have to install bioreactors, however. The Nitrogen Credit Exchange allows individual WWTP's to buy and sell emissions credits so that the costs and benefits of abatement can be distributed most efficiently. Crucially, not all pounds of nitrogen abatement are considered equal; rather, abatement is weighted for proximity to the LIS. For instance, every pound of abatement at the Stamford WWTP, which releases directly into the Sound, sells for full value. However, abatement at the Putnam WWTP, in the northeast corner of the State, is discounted to reflect the fact that most of the nitrogen released upstate dissipates in the watershed and never makes it to the Sound. Therefore, the residents of Putnam can most effectively meet their obliga-

tion by purchasing offsets generated in Stamford. This weighting mechanism has the effect of directing abatement dollars to where they will have the greatest impact.

The Nitrogen Credit Exchange differs from a “cap-and-trade” system in several ways. First, the price of an emissions credit is not set on an open market; rather, the Nitrogen Credit Advisory Board sets the dollar value of a pound of nitrogen abatement once each year. In 2008, the price was set at \$4.50. Each year the price of a credit goes up as the emissions ceilings go down.

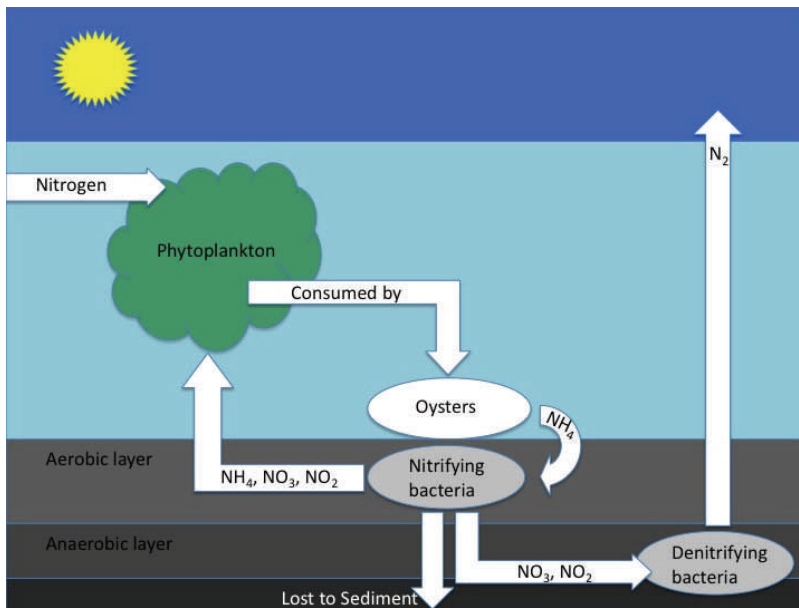
Because the price is not determined by the equilibration of supply and demand, the exchange often fails to clear. For instance, since 2005, there has been a shortage of credits for sale. That is, too few credits have been generated to offset the excess emissions of plants that have failed to meet their allocation. Instead, the State simply charges over-emitters the fixed rate to release nitrogen which, in effect, is a tax. This means that, overall, the State has not met its abatement targets and that, in fact, there is no cap on emissions. It also means that the price of a credit is set too low. However, raising the price sufficiently to clear the market, of course, might prove politically difficult. Despite these limitations, participants consider the exchange to be an effective means of moving dollars to the WWTP's where upgrades will be most cost effective.

While WWTP's are removing nitrogen from wastewater before it is released into the Sound, there is a population of oysters and other shellfish that remove the nitrogen from the Sound once it is there.

### The Role of Oysters in Water Quality

As filter feeders, bivalve shellfish remove suspended material, including nitrogen-fed phytoplankton, from the water column and deposit that material

(continued on page 5)



**Figure 1:** The role of oysters in nutrient cycling. Adapted from Newell et al., 2005. Some nitrogen is recycled back into the water, where it feeds back into phytoplankton production, and some is removed permanently via sedimentation or denitrification. The ratio of recycling to removal is location specific; it depends on wave and wind action, depth, sediment type, and a host of other local variables.

on the seabed in the form of feces and pseudofeces, which are what becomes of the particles that they ingest but reject

without sending to the stomach. By transforming suspended matter into less buoyant packages, shellfish accelerate water-clearing and sedimentation. In addition to depositing material on the seafloor, they also incorporate some portion of the ingested nutrients, including nitrogen, into their own tissue and shell.

Oysters are prodigious filter feeders. Most bivalves stop feeding when “full” and whatever pseudofeces they produce are composed of indigestible matter such as silt. Oysters (and mussels) on the other hand filter water almost continuously, even when their gut is full. When filtering with a full gut oysters divert all ingested matter, including nutritious particles, into pseudofeces production. In other words, oysters transfer suspended material to the seafloor almost continuously. Scientists have estimated that, before they were fished down, the oyster population of the Chesapeake filtered the entire volume of the Bay every nine days during summertime<sup>2</sup>.

In the context of eutrophication then, oysters are doing much more than simply removing nitrogen from the water. They exert grazing pressure on the phytoplankton population, keeping it in check. However, to integrate this complex ecosystem service into the Nitrogen Credit Exchange, which is the proposition considered in this exercise, requires a much simpler conceptualization, because a buyer of credits must know exactly what they are getting for their money. There is no established metric for phytoplankton control. For this reason, the unit of analysis is simplified to match the currency of the exchange: pounds of nitrogen removed from the water. The drawback of this approach is that it

surely underestimates the value of the ecosystem service rendered. On the other hand, the resulting valuation, because it is conservative, is more credible.

### How much nitrogen do oysters remove?

Unfortunately, the answer to this question is not clear. Figure 1 shows the various trajectories that nitrogen can take once it leaves the oyster. Some nitrogen is recycled back into the water and some is removed permanently via sedimentation or denitrification. The ratio of recycling to removal is entirely location-specific; it depends on wave and wind action, depth, sediment type, and a host of other local variables. Furthermore, there is very little published research on this issue, and none as it pertains to the LIS. For this reason, any assessment of nitrogen removal via biodeposits in LIS would be speculative at this time.

Therefore this analysis takes a second conservative step and considers only that portion of consumed nitrogen that is incorporated into the tissue and shell of the oysters. The assumptions are that the nitrogen originated in the water, and it is removed when the oyster is harvested. This second conservative accounting method will cause this analysis to further undervalue the ecosystem service rendered, but again will yield a more credible result.

### Running the numbers

The value of the ecosystem service that the oysters provide by filtering the water in the LIS is now assessed as part of the analysis. This is different than calculating the number of offsets that the oysters might generate for sale on the exchange. Offsets would have to be additional, that is, production above that which is already occurring anyway.

*(continued on page 6)*

*Scientists have estimated that, before they were fished down, the oyster population of the Chesapeake filtered the entire volume of the Bay every 9 days during summertime*

Ratio	Source
250 Oysters/bushel	Personal communication with Inke Sunila
1g DTW* / market-size oyster**	Newell et. al., 2005, p.113
150g shell / market-size oyster	Newell et. al., 2005, p.113
0.07g N / g DTW	Newell et. al., 2005, p. 113
0.003g N / g Shell	Newell et. al., 2005, p. 113

**Table 1:** Conversion factors used in nitrogen accounting.

\*DTW stands for Dry Tissue Weight.

\*\*Average market-size oyster is a 3-inch oyster.

Calculation for Total Nitrogen Harvested
<p><b>Given a harvest of 893,964 bushels in 1992:</b></p> <p><i>Nitrogen in harvested tissue:</i></p> $893,964 \text{ bushels} * 250 \text{ oyster/bushel} * 1\text{gDTW/oyster} * 0.07\text{gN/gDTW} * \text{kg}/1000\text{g} = 16,000 \text{ kg N}$ <p><i>Nitrogen in harvested shell:</i></p> $893,964 \text{ bushels} * 250 \text{ oyster/bushel} * 150\text{g shell/oyster} * 0.003\text{gN/g shell} * \text{kg}/1000\text{g} = 100,000 \text{ kg N}$ <p><i>Total N (nitrogen) harvested in 1992 = 116,000 kg</i></p> <p>Translated into the currency of the CT Nitrogen Credit Exchange, that equates to 255,000 pounds, or 127.5 tons of nitrogen removal.</p>

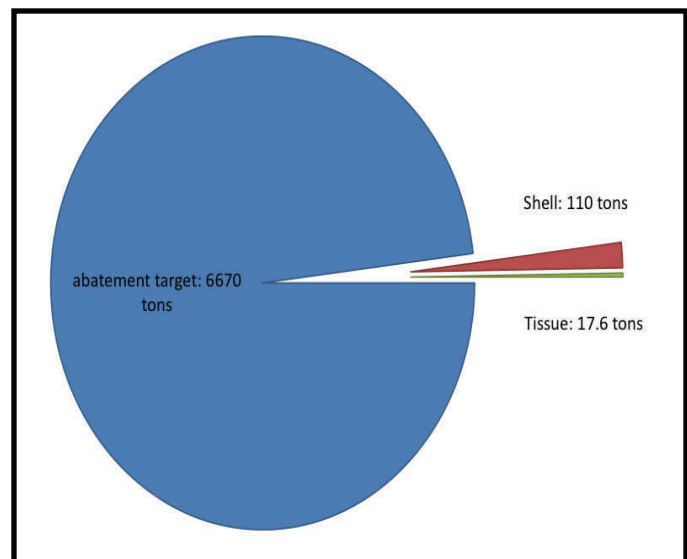
**Table 2:** Calculation for total nitrogen harvested.

The year 1992 was a banner year for Connecticut oyster production: 893,964 bushels went to market. Since this analysis has been so conservative until this point, let's go out on a limb and use the 1992 harvest for the calculations. Table 1 shows the conversion factors used to translate the catch data into pounds of nitrogen removed at harvest. Table 2 shows the calculation for nitrogen harvest.

At \$4.50 per pound, 255,000 pounds of nitrogen removal would be worth \$1,147,500. Since the price of a pound of nitrogen increases each year as the State nears its abatement target, the value of this ecosystem service will grow along with it, all else being equal.

Figure 2 shows that the 255,000 pounds of nitrogen in the 1992 oyster harvest is equal to

*(continued on page 7)*



**Figure 2:** Nitrogen harvested with the 1992 oyster catch relative the policy objective of 6670 tons of annual nitrogen abatement from baseline levels by 2014. The 127.6 tons of

1.9% of the policy objective of 6670 tons of abatement. That is, within the policy context, and given a good year's harvest, oysters remove a small but not insignificant amount of nitrogen from the waters of the LIS.

### **The Role of Ecosystem Service Markets in Water Quality**

In order for oyster-generated offsets be sold on the Nitrogen Credit Exchange, those offsets must be "additional." That is, they would have to result from production that would not happen in the absence of a sale. After all, why pay for a service that is currently being provided for free? Before oyster offsets could be sold on the exchange, economic models would have to be developed that can distinguish additional production from baseline production. This could be an interesting area of future research.

However, in the analysis above, it appears that oysters, even at 1992 production levels, remove a relatively small amount of nitrogen from the water. Could any additional as opposed to baseline effect have a meaningful economic value? It might. This analysis greatly underestimates the impact of oyster production on water quality because it considers only that nitrogen which ends up in oysters' tissue and shell, while ignoring the nitrogen removed from the water via deposition to the seafloor. The true impacts, while currently difficult to measure, may be considerably greater. A handful of scientists, including Gary Wikfors at the NOAA National Marine Fisheries Service laboratory in Milford, are considering how to measure the nitrogen that oysters deposit on the seafloor. If they succeed in developing a model that can accurately account for biodeposition, then a more significant ecosystem service value might be reliably obtained.

In the meantime, this situation amounts to an interesting case study in the difficulty of establishing markets for ecosystem services. Markets require transparency and resolution, while ecosystems are complex and indeterminate. In order to bridge that gap the model was simplified by

counting only incorporated nitrogen, but in doing so the analysis failed to capture the true value of the ecosystem service provided. Further research, into the ecological question of biodeposition, and into the economic question of additionality, is needed before oyster-generated offsets could be sold on the Connecticut Nitrogen Credit Exchange.

Still, it is clear that oyster aquaculture has a positive effect on water quality. The measurable value of the ecosystem service that oysters provide, as shown in this analysis, is small but significant, and the true value of that service is likely much greater. Even in the absence of an ecosystem service market, aquaculture should be considered one important part of an integrated approach to managing water quality in the Long Island Sound.

*Article submitted by Rich Press, Yale School of Forestry. For additional information on this analysis, please contact: [richard.press@yale.edu](mailto:richard.press@yale.edu)*

#### Works Cited:

<sup>1</sup>Lindahl, O., Hart, R., Hernroth, B., Kollberg, S., Loo, L.-O., Olog, L., Rehnstam-Holm, A.-S., Svensson, J., Svensson, S. and U. Syversen. (2005). Improving marine water quality by mussel farming: a profitable solution for Swedish society. *Ambio*. 34:131-138.

<sup>2</sup>Newell, R.I.E., Fisher, T.R., Holyoke, R.R. and J.C. Cornwell. (2005). Influence of Eastern oysters on nitrogen and phosphorus regeneration in Chesapeake Bay, USA. Pp. 93-120 *In* ØR. Dame and S. Olenin (Eds), *The Comparative Roles of Suspension Feeders in Ecosystems*. NATO Series IV—Earth and Environmental Sciences. Vol 47, Springer, Netherlands.

<sup>3</sup>Fulford, R. S, D. L Breitburg, R. I.E Newell, W. M Kemp, and M. Luckenbach. (2007). Effects of oyster population restoration strategies on phytoplankton biomass in Chesapeake Bay: a flexible modeling approach. *Marine Ecology Progress Series*. 336: 43-61.



University of Connecticut  
Connecticut Sea Grant  
1080 Shennecossett Road  
Groton, Connecticut 06340-6048  
<http://web2.uconn.edu/seagrant>



## Would You Like to Contribute to *THE DREDGE*?

Please submit comments, news, articles, and/or classified items, to:

*The Dredge* Newsletter  
c/o Tessa Getchis, Editor  
Connecticut Sea Grant  
1080 Shennecossett Road  
Groton, CT 06340-6048

Prefer an e-newsletter? Contact us:  
(860) 405-9104  
[tessa.getchis@uconn.edu](mailto:tessa.getchis@uconn.edu)