Marine Pollution Bulletin 116 (2017) 175–181

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

# Nitrogen extraction potential of wild and cultured bivalves harvested from nearshore waters of Cape Cod, USA

Joshua Reitsma [a,*], Diane C. Murphy [a], Abigail F. Archer [a], Richard H. York [b]

[a] Cape Cod Cooperative Extension & Woods Hole Sea Grant, PO Box 367, Barnstable, MA 02630, United States
[b] Mashpee Department of Natural Resources, 16 Great Neck Road North, Mashpee, MA 02649, United States

ARTICLE INFO

*Article history:*
Received 15 July 2016
Received in revised form 9 December 2016
Accepted 28 December 2016
Available online 6 January 2017

*Keywords:*
Oyster
Quahog
Nitrogen
Tissue
Shell
Bioextraction

ABSTRACT

As nitrogen entering coastal waters continues to be an issue, much attention has been generated to identify potential options that may help alleviate this stressor to estuaries, including the propagation of bivalves to remove excess nitrogen. Oysters (*Crassostrea virginica*) and quahogs (*Mercenaria mercenaria*) from numerous Cape Cod, MA, (USA) sources were analyzed for nitrogen content stored in tissues that would represent a net removal of nitrogen from a water body if harvested. Results showed local oysters average 0.69% nitrogen by total dry weight (mean 0.28 g N/animal) and quahogs average 0.67% nitrogen by total dry weight (mean 0.22 g N/animal); however, these values did vary by season and to a lesser extent by location or grow-out method. The differences in nitrogen content were largely related to the mass of shell or soft tissue. Nitrogen isotope data indicate shellfish from certain water bodies in the region are incorporating significant amounts of nitrogen from anthropogenic sources.



## 1. Introduction

Coastal water bodies and estuaries are essential habitat for many species and are also important to the economic health of coastal communities. While nitrogen (N) is a vital nutrient to the marine environment, in excess it causes eutrophication or an increase in the rate of supply of organic matter to a system (Nixon, 1995). Nitrogen can enter coastal waters from various point and non-point sources, although increased human activity has accelerated the rates of N enrichment (Carmichael et al., 2004a). This increase in nitrogen enrichment and subsequent eutrophication has a negative impact on coastal waters and can be a root cause of habitat degradation (Bowen et al., 2007; Howarth, 2008).

The approach to combat this growing problem in coastal Massachusetts is to reduce nitrogen to threshold levels identified as important in maintaining ecosystem health in coastal waters. Strategies being considered for reduction of nitrogen include centralized or improved wastewater treatment, stormwater treatment, increased tidal flushing, enhanced attenuation via wetlands, in addition to other techniques (Dudley, 2003). The use of shellfish production and harvest has also recently garnered interest as an option in plans to reach nitrogen management thresholds (Bricker et al., 2014; Carmichael et al., 2012; Grizzle et al., 2016; Higgins et al., 2011; Rose et al., 2014).

The removal of nitrogen via bivalves can occur through harvest of tissue and shell, long-term burial in the sediment, or conversion of N in biodeposits to di-nitrogen gas through stimulated microbial activity (reviewed in Kellogg et al., 2014 and references therein). While the latter pathways of burial and denitrification have been demonstrated in relation to oyster reefs (Kellogg et al., 2013), significant variability exists as to rates and quantifiable numbers (Kellogg et al., 2014). Current data have shown that oyster aquaculture has some ability to stimulate denitrification (Higgins et al., 2013; Testa et al., 2015; Humphries et al., 2016), though results are limited regarding the impact of clam farming (Nizzoli et al., 2006; Murphy et al., 2015). The variability of site and bivalve density may also have significant impacts (Burkholder and Shumway, 2011).

The "nutrient bioextraction" potential of filter feeding bivalves may be most directly quantifiable through the quantity of N contained in harvested shellfish. Reported values have indicated that percent N in the soft tissue of Eastern oysters (*Crassostrea virginica*) may range from 7–9.3% (Newell, 2004; Higgins et al., 2011; Carmichael et al., 2012; Sisson et al., 2011; Grizzle et al., 2016), whereas the shell range is 0.2–0.3% (Higgins et al., 2011; Sisson et al., 2011; Newell, 2004; Grizzle et al., 2016). It has been suggested that oysters vary significantly in morphology, and may also vary in nitrogen content by space and season such that values for N removal through oysters will likely be location specific (Kellogg et al., 2014; Grizzle et al., 2016). The data for quahogs (*Mercenaria mercenaria*) are more limited, but nitrogen content in soft tissue ranges from 4.2–6% (Table 1, Rice, 2001, Sisson et al., 2011) and shell nitrogen was reported at 0.15% in wild quahogs from

* Corresponding author.
*E-mail address:* jreitsma@barnstablecounty.org (J. Reitsma).

http://dx.doi.org/10.1016/j.marpolbul.2016.12.072

**Table 1**
Samples collected by site, and the larger region of influence.

| Site | Waterbody | Region | Quahogs | | Oysters | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Wild | Cultured | Wild | On-bottom | Off-bottom | Off-triploid |
| DB | Duxbury Bay | Cape Cod Bay | | | | X | X | |
| BH | Barnstable Harbor | Cape Cod Bay | X | X | | X | X | |
| WH | Wellfleet Harbor | Cape Cod Bay | | X | X | X | X | X |
| TC | Town Cove | Atlantic Ocean | | X | | | | |
| PB | Pleasant Bay | Atlantic Ocean | | | | | X | |
| OP | Oyster Pond | Nantucket Sound | X | | | | X | |
| SR | Swan River | Nantucket Sound | | | X | | | |
| CB | Cotuit Bay | Nantucket Sound | X | X | | | | |
| PP | Popponesset Bay | Nantucket Sound | X | X | X | X | X | |
| SB | South Buzzards Bay | Buzzards Bay | | | | | X | |
| BO | Bourne Harbors | Buzzards Bay | X | X | X | X | X | |
| NB | North Buzzards Bay | Buzzards Bay | | | | X | X | |

Virginia (Sisson et al., 2011). The goal of this study was to examine oysters and quahogs from Cape Cod, MA as a nitrogen bioextraction tool through harvest of both species from a variety of sources and during differing seasons.

## 2. Methods

Oysters (*Crassostrea virginica*) and quahogs (*Mercenaria mercenaria*) were collected for nitrogen content analysis from various water bodies in the Cape Cod, MA, (USA) region to represent the predominant shellfish commercially harvested and a range in local geography (Table 1 and Fig. 1). To assess potential differences related to season, a first set of samples were collected in June 2012, and then a second collection later in October 2012. Wherever possible, both oysters and quahogs were taken from the same water body for comparison. Considering potential differences in the life history or type of grow-out used, oysters were separated into 3 main categories: wild, cultured on-bottom, and cultured off-bottom. A smaller fourth group of cultured off-bottom triploid oysters was included at one site only. Quahogs were separated into two categories: wild and cultured. For the purposes of this study, an animal was considered cultured if held in shellfish culture gear at any portion of the life cycle, whereas wild shellfish represented native or naturally propagated populations.

Shellfish were selected for inclusion in the field samples at typical local harvest sizes, which is 3–3.5 in. (76–89 mm) in shell height (measured as the longest axis) for oysters, and 1–1.5 in. in shell hinge width (as measured between the convex apex of the right shell and the convex apex of the left shell) for quahogs. Four animals were collected for each category or group sampled. Shellfish samples were individually labeled and held refrigerated until measurements for shell height, length, and width to the nearest 0.01 mm using digital calipers, and whole wet weight to the nearest 0.01 g were recorded. After initial processing, samples were frozen and delivered to the Boston University Stable Isotope Laboratory for separation of the shell and soft tissues, drying, and measurement of dry tissue weights. Percent nitrogen and carbon analysis was provided on dried ground shell and soft tissues (gut intact) using standard Eurovector CN analyzer methods for the laboratory.

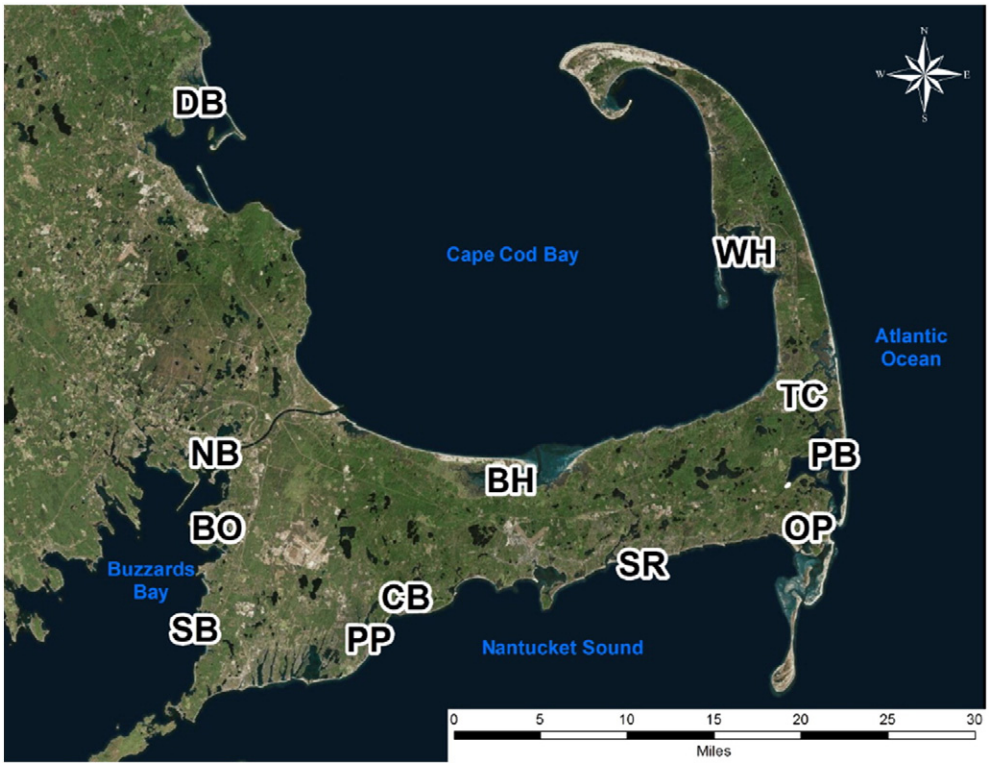


**Fig. 1.** Map showing sample locations (abbreviated), and proximity to regional water bodies.