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Total Organic Carbon in Sediments around Aquaculture Farms in Coastal Rhode Island

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Synopsis: Total organic carbon (TOC) in the sediments in and around oyster farms in Rhode Island's coastal lagoons and in Narragansett Bay was studied between June and August, 2019. Sediments were sampled by hand or by grab sampling and TOC was determined by ignition loss of dried sediment samples. Results showed that overall mean values of the percent TOC inside the farms was 2.97% near the oyster farming gear, 3.06% adjacent to the farm sites, and 3.0% at a distance of about 100m from the farms, but the differences among them were insignificant based upon overlapping standard errors. The data from all individual 12 oyster farm sites show that there is no buildup of carbon-rich biodeposits attributable to the farms themselves. Data showing high sediment carbon during the late spring at Narragansett Bay sites suggests that sediment carbon may be building up during the winter and dissipating during the summer, which is consistent with previous studies. The magnitude of the background winter-summer carbon fluctuation in sediments on a temporal basis is much greater than the spatial differences in sediment carbon within and near all 12 oyster farms and their adjacent control sites.

Introduction

Based upon bivalve molluscan feeding studies, it is known that the filter feeding process acts to remove phytoplankton from the water column and produce biodeposits that end up accumulating in bottom sediments where respirative decomposition processes oxidize excess organic carbon and associated nutrients are mineralized and recycled (Norkko et al., 2001; Pietros and Rice, 2003; Kotta et al., 2005). In areas of coastal upwelling that promotes abundant coastal phytoplankton blooms, there have been documented cases of over intensification of shellfish production to the point that organic sediments build up on the bottom creating hypoxic zones that change the benthic biota by favoring anaerobic respiratory sediment processes (e.g. Tenore et al., 1982; Stenton-Dozey et al., 1999; Otero et al., 2006). However, these areas where bottom souring by intensive aquaculture activity are generally confined to mussel and other bivalve farms in coastal estuaries adjacent to areas of high nutrient upwelling from deep oceanic waters (Blanton et al., 1987).

On occasion there has been concern that there may be an over intensification of bivalve aquaculture in Rhode Island, although coastal nutrient upwelling locally is only a small fraction of that in the mussel farming regions of northwestern Spain or the Southwest African coast. The first and only study of total organic carbon in sediments (TOC) in and around Rhode Island oyster farms to date was an unpublished study by Raso (2001) in which he compared sediments at several oyster farms in Rhode Island coastal salt pond lagoons and in Narragansett Bay with adjacent sediments 100 meters outside of the farm boundaries. He found that in all farm sites tested, there was no statistically significant difference in the level of TOC inside or outside of the farms.

In 2001 during the time of the Raso study there were only 18 shellfish farms in Rhode Island with a total of 51.5 acres leased, with 543,978 oysters produced (Alves, 2001). The most recent aquaculture report (Beutel, 2018) shows that oyster production in Rhode Island has increased over 15-fold to 8,515,950 oysters produced on 76 farms on a total of 319.3 leased acres in Rhode Island public trust waters. Given the considerable intensification of shellfish aquaculture in the state over the last 18 years, it is of interest to see if there has been any resulting change in TOC buildup in oyster farm sediments in comparison to Raso's (2001) baseline study.

Methods

With the assistance of the state aquaculture coordinator at the Rhode Island Coastal Resources Management Council, twelve aquaculture farms were selected and farm operators agreed to have sediment samples taken from their shellfish farm sites. Each of the twelve aquaculture shellfish lease sites in Rhode Island are unique in terms of water depth, temperature, salinity, bottom structure, currents, and the concentrations of food particulates (Table 1).

Because of the differences in bottom depth, sampling procedure was determined by the water depth. Nine samples were taken at each lease, three no further than 100m outside the lease area, three around the lease perimeter, and three from within the lease site underneath the shellfish production gear. Sampling was done a total of five times at each site every other week from June 8 to August 24, 2019. Sites that were deeper than 1 meter were accessed by motorboat and samples were taken with a Ponar grab sampler. When the first samples were taken GPS coordinates were taken and stored into the navigation system of the boat. At sites with less than 1 meter water depth samples were taken by wading in the water to the site and gathered they samples with a gardening shovel. With sites with rocky or shelly substrate samples took more than one Ponar grab attempt. Those attempts with an incomplete sediment sample were repeated until there was enough sediment to provide for a complete lab analysis. All samples were stored in a ½ liter plastic bag and sealed. Each group of samples were labeled and stored in a -10°C freezer until further testing.

Lab testing for TOC consisted of drying about 100-120g of sediment was placed into an aluminum dish. The samples were then placed in a drying oven at 100°C for 24 hours. After the samples were dried, the samples were then weighed with a microbalance to the nearest 0.1mg. The samples were then placed in a pottery kiln for 4 hours at 450°C. After the samples had cooled and reweighed to determine ash weight, TOC was calculated using the following formula from Gross (1972).

%TOC = [(Dry Weight-Ash Weight/Dry Weight)*100%]/2

Table 1. Sediment Sampling Sites.

Site code	***Location***	***RI-CRMC Assent Number***	***Longitude, Latitude***	***Water Depth (feet)***
1-SP	Winnapaug Pond	1993-05-091	41.328468, -71.789961	2-5
2-SP	Ninigret Pond	2015-01-051	41.358912, -71.650336	2-5
3-SP	Point Judith Pond	2015-07-083	41.411113, -71.506017	3-6
1-NB	Dutch Harbor	2014-11-056	41.508472, -71.384468	21-26
2-NB		2015-11-032	41.509733, -71.388888	21-26
3-NB	West Passage	2009-01-035	41.534820, -71.415753	8-13
4-NB		1997-05-059	41.558144, -71.427407	9-15
5-NB		2006-04-099	41.575569, -71.437098	10-14
6-NB		2014-05-072	41.553938, -71.415882	15-21
7-NB		2006-11-042	41.616801, -71.405079	3-5
8-NB	East Passage	2006-06-033	41.596814, -71.281000	20-24
9-NB		2001-07-018	41.604741, -71.278125	20-24

Results

The overall average sediment carbon for all sampling dates at all oyster farm sites is presented in Table 2. Overall mean values of the percent TOC inside the farms was 2.97% near the oyster farming gear, 3.06% adjacent to the farm sites, and 3.00% at a distance of about 100m from the farms. These values are not significantly different based upon overlapping standard errors. Within each individual farm site, there are no significant differences in TOC levels inside the farm, near the farm or 100 m away from the farm sites, demonstrating little or no buildup of carbon-rich biodeposits at any of the farms.

Table 2. Mean percentage of Total Organic Carbon (TOC) and their Standard Errors of the Mean (SEM) in sediments at or near Rhode Island oyster farm sites

General Location	*Site code*	*Mean %TOC Inside*	*SEM (n=25)*	*Mean %TOC Around*	*SEM (n=25)*	*Mean %TOC Outside*	*SEM (n=25)*
Winnapaug Pond	1-SP	0.78	0.31	0.68	0.31	0.69	0.31
Ninigret Pond	2-SP	0.82	0.37	0.62	0.28	0.82	0.37
Point Judith Pond	3-SP	1.78	0.57	1.43	0.64	1.27	0.57
Dutch Harbor	1-NB	4.68	1.98	4.90	2.20	4.41	1.98
Dutch Harbor	2-NB	5.38	2.69	6.77	3.03	5.99	2.69
Greene Point	3-NB	2.23	1.00	2.43	1.09	2.23	1.00
Goose Point	4-NB	3.14	1.89	3.81	1.71	4.22	1.89
Wickford	5-NB	2.10	0.78	1.66	0.74	1.75	0.78
Fox Island	6-NB	1.60	0.96	1.58	0.71	2.14	0.96
Allen Harbor	7-NB	1.36	0.55	1.33	0.59	1.23	0.55
Coggeshall Point	8-NB	5.68	2.48	5.01	2.25	5.53	2.48
Coggeshall Point	9-NB	6.10	2.55	6.56	2.94	5.69	2.74
Overall Mean Values		**2.97**	**0.38**	**3.06**	**0.31**	**3.00**	**0.31**

In general, baseline sediment carbon levels are lower at the coastal salt pond farm sites in comparison to most sites within Narragansett Bay. Figures 1 and 2 present representative data of TOC levels in coastal ponds, showing mean TOC levels at Ninigret and Point Judith Ponds that have predominantly sandy sediment types. At both of these sites, sediment carbon shows patchiness during the late spring & early summer (June) sampling periods, but later during the summer (July and August) the sediment carbon becomes more uniform among the sampling sites inside, adjacent to and outside the farm sites.

The dynamics of sediment carbon at a representative Narragansett Bay farm site is presented in Figure 3. At this site, sediment carbon levels are high, upwards of 10% in the late spring and early summer but decrease to around 2% as the summer progresses. The magnitude of sediment carbon percentages temporally from June to August is much greater than the farm, near the farm or 100 m away from the farm sites, demonstrating little or no buildup of carbon-rich biodeposits at any of the farms.

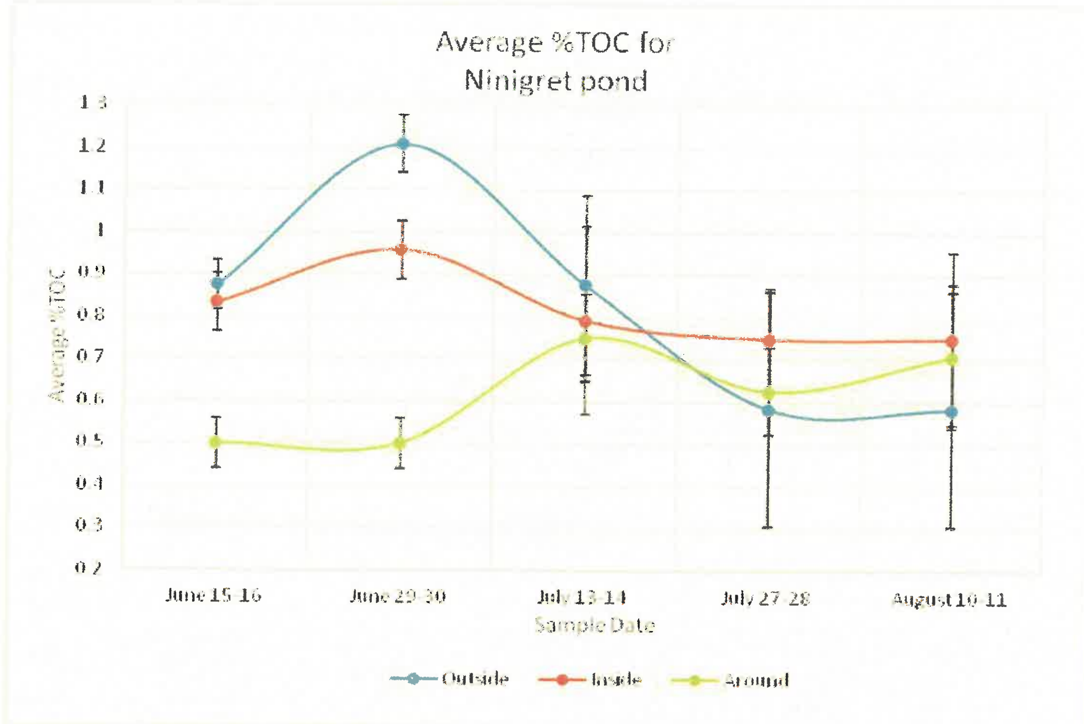

Figure 1: *The mean and SEM %TOC from June to August for site 2-SP in Ninigret Pond.*

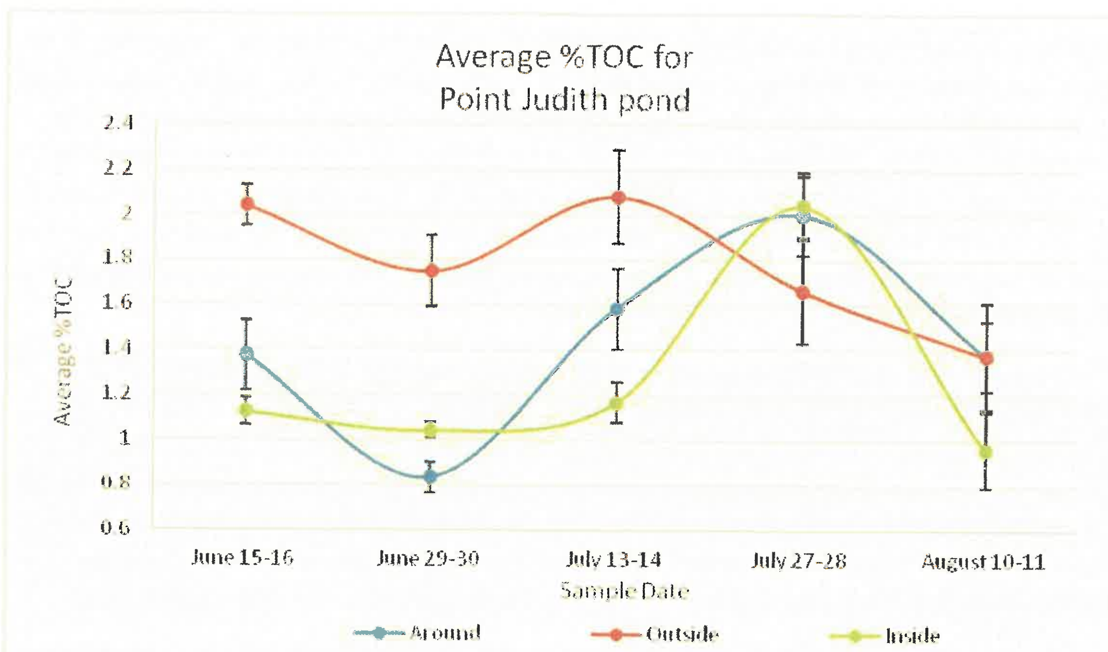

Figure 2: *The mean and SEM %TOC from June to August for site 3-SP in Point Judith Pond.*

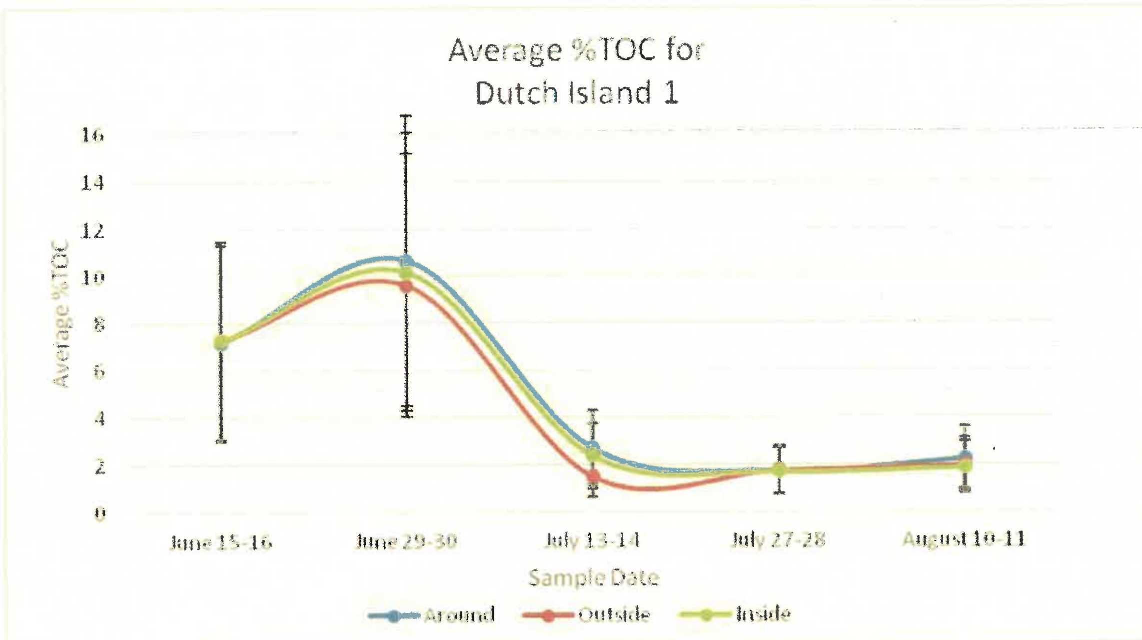

Figure 3: The mean and SEM %TOC from June to August for site 1-NB in Dutch Island Harbor.

Discussion

Collectively, the data from all 12 oyster farm sites in Rhode Island waters show that there is no buildup of carbon-rich biodeposits attributable to the farms themselves. However, there is evidence that carbon-rich buildup of biodeposits from the oysters is prevented by rapid oxidative processes during the summer months. In a study of biodeposition by oysters in mesocosms, Pietros and Rice (2003) demonstrated that most all biodeposits produced by oysters held at densities typical oyster farms in Narragansett Bay are rapidly decomposed and remineralized during the summer months. These field observations of low sediment carbon around the oyster farms at all the Narragansett Bay and coastal salt pond lagoon sites support the findings from the previous mesocosm study.

Data showing high sediment carbon during the late spring at Narragansett Bay sites suggests that sediment carbon may build up during the winter. Rudnick and Oviatt (1986) demonstrated natural build-up of sediment carbon Narragansett Bay sediments during the fall and winter months and there is an annual cycle of winter-spring carbon enrichment and summer-fall decomposition and remineralization. Our data are consistent with this pattern, with the magnitude of the winter-summer carbon fluctuation being much greater than the spatial differences in sediment carbon within all 12 oyster farms and their adjacent control sites.

The results from this study support the similar findings of the Raso (2001) study. Figure 4 shows the overall mean TOC percentage in sediments at 14 Rhode Island oyster farm sites in 2001. Like the current study, there was no significant difference among sediment carbon within farm sites, adjacent to farm sites and at control sites 100 m away from the oyster farming gear. A major difference in the data is that the overall mean TOC in the 2001 study is roughly half or about 1.5% TOC as an overall mean in comparison to about 3% in the current study. This discrepancy can be explained that the 2001 study was conducted during the late summer months when baseline levels of TOC at all sites are at a minimum.

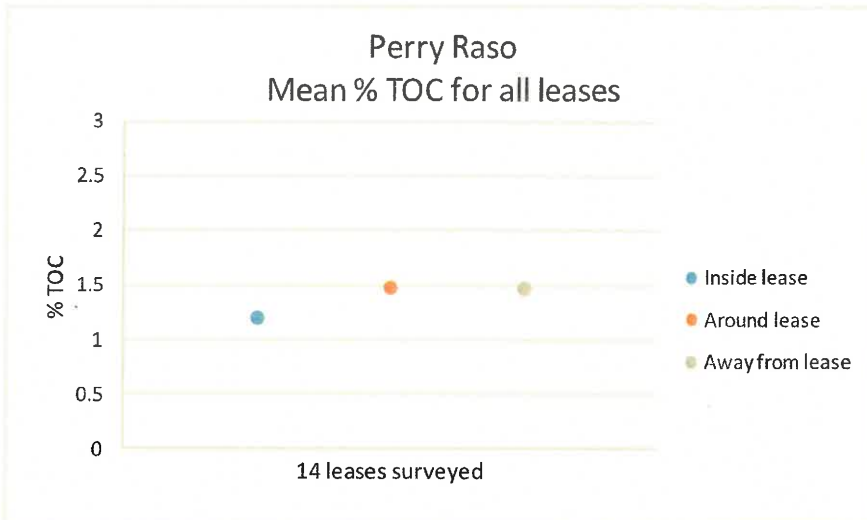

Figure 4: *The average %TOC at all 14 Rhode Island leases surveyed by Perry Raso for outside the lease, around the lease, and inside the lease area. Sites were predominantly in RI Coastal Ponds with sandy sediments with sampling done in July and August 2001, during the time period of minimum TOC. Farm sites in common between the 2001 and 2019 studies are 1-SP, 3-SP, and 4-NB. (Data from Raso, 2001)*

The results from this study suggests that shellfish aquaculture in Rhode Island waters, has not significantly caused buildup of carbon-rich biodeposits since 2001 despite a 15-fold increase in oyster production since that time. Studies suggest that the production and ecological carrying capacity for oyster aquaculture in Rhode Island waters is at least 100 times the current production level (Pietros and Rice, 2003; Byron et al., 2011a, 2011b) suggesting that much greater oyster production can occur in Rhode Island waters before any negative environmental consequences would occur.

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