Water Quality Reports
2015

Includes:
Norwalk River
Norwalk Harbor Juvenile Benthic Marine Fish
Norwalk Harbor Dissolved Oxygen Profile Survey
Silvermine River
Keeler’s Brook
Five Mile River
Pequonnock River; Monroe and Trumbull

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Water Quality Data Report
For
Norwalk River Watershed
October 2014 through April 2015

Frozen water at site NR15

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Introduction:

Purpose of Study: The Earthplace Harbor Watch Program was funded by the Connecticut Department of Environmental Protection (CT DEP; now the Department of Energy and Environmental Protection, CT DEEP) to conduct water quality monitoring on the Norwalk River for six years, June 1998 through June 2005. HW initially collected and analyzed water samples for fecal coliform bacteria at 21 sites, eleven of them along the main stem of the Norwalk River and one on the Silvermine River (Figure 1).

Background: From June 1998 through May 1999, Harbor Watch conducted a first-year water quality monitoring study in the Norwalk River Watershed. This study was funded by the CT DEP and was intended to provide water quality information in support of the Norwalk River Watershed Initiative. The purpose of the study was to obtain data on the levels of fecal coliform bacteria, dissolved oxygen, and conductivity at selected locations in the Norwalk River and in its major tributaries (Silvermine River, Comstock Brook and Cooper Brook). The study indicated that fecal coliform bacteria levels frequently exceeded the state’s water quality criterion for Class B water at a number of sites along the Norwalk River. Most sites met the dissolved oxygen level CT DEP criterion for Class B waters. The first year study also showed that conductivity levels were consistently higher in the upper reaches of the watershed than in the lower watershed. Based upon the water quality data collected, Harbor Watch determined that the water quality in the Norwalk River Watershed was moderately impaired.

The CT DEP and Harbor Watch executed a contract for a second year funding in September 1999 (from September 1, 1999 through November 30, 2000). Harbor Watch was authorized to begin testing for Escherichia coli (E. coli) bacteria in November 1999. Sampling was then limited to 12 of the 21 most impacted sites along the Norwalk River. Monthly reports were prepared and submitted to the CT DEP and disseminated to the seven towns comprising the Norwalk River Watershed as well as to the Norwalk River Watershed Initiative Advisory Committee and all contributing organizations.

Funding was then made available by the CT DEP to continue testing on the Norwalk River for a third summer (April 1 to September 30, 2001) based on a continuing interest by Norwalk River Watershed Advisory Committees and the CT DEP. The same testing protocols, used in 2000 by Harbor Watch, were again used under the original QAPP. This QAPP was extended on April 25, 2001 to September 30, 2001 by the EPA’s Office of Environmental Measurement and Evaluation.

During 2002, the CT DEP switched to E. coli bacteria as the “preferred” indicator species for freshwater, as it is a more specific indicator of fecal material arising from humans and other warm-blooded animals. Presently the Norwalk River is monitored on a year round basis with weekly testing at 12 test sites from May 1st through September 30th and monthly testing from October through April.

Additional 319 funding was allocated to continue the Harbor Watch testing regime on the Norwalk River for twenty-three months beginning July 2002 and ending June 30, 2004. The last contract with the CT DEP expired on 6/30/05. Harbor Watch again renewed testing of the Norwalk River and its tributaries on May 1, 2005 thanks to the interest and generosity of the Town of Wilton, The Norwalk Mayor’s Water Quality Committee, The Wilton Inland Wetlands Commission, King Industries, Norwalk River Watershed Association, Inc., NRG-Manresa, Town of Ridgefield, Norm Bloom, Leslie Bloom-Miklovich, and Trout Unlimited (both the Mianus and Nutmeg chapters) have collectively continued to provide additional funds to support the 2014/2015 monitoring season.

Although these monthly reports are submitted to the CT DEEP for review and comment, Harbor Watch is solely responsible for the collection, analysis and interpretation of the water quality data.
Figure 1 Location of 12 Norwalk River monitoring sites
**Methods and Procedures:** Water monitoring is carried out under Quality Assurance Project Plan (QAPP) RFA#10160 approved by CT DEEP and EPA on 9/10/10 for five years. Monitoring teams leave Earthplace in Westport at 9:30am and return at 11:00am. The team is comprised of a fully trained Harbor Watch employees and volunteers. Water samples are collected at 12 (Figure 1) monitoring sites along the length of the river. These sites, which represent the more impacted sites and developed areas, were selected in concert with the CT DEEP, because results from the first year’s study consistently demonstrated elevated fecal coliform bacteria counts at these locations.

The following tests are run *in situ*: dissolved oxygen (QAPP Appendix A3.2) and conductivity (QAPP Appendix A3.3). Water and air temperatures, as well as general observations and storm events are also recorded at each site visit. Observations are recorded (QAPP Appendix 5) on the Harbor Watch data sheet.

Upon return to the lab, fecal coliform bacteria membrane filtration tests (QAPP Appendix A3.5) are performed and *E. coli* testing is carried out according to Standard Methods, 22nd edition (9222D & 9222G) and recorded (QAPP Appendix 5) on the Harbor Watch bacteria log. During the monitoring period, sites were monitored once per month.

*E. coli* bacteria will be evaluated using the criteria published in the CT DEEP Surface Water Quality Standards, 10/10/13. The CT DEEP *E. coli* criterion for Class AA, A, and B water is established at three levels (Table 1).

The Norwalk River is classified for “all other recreational uses” because people do not bathe in or drink the river water and it is too shallow for swimming. The report will focus on *E. coli* bacteria levels, because it is the indicator bacteria of choice by the CT DEEP.

<table>
<thead>
<tr>
<th>Designated Use Recreation</th>
<th>Class</th>
<th>Indicator</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designated Swimming</td>
<td>AA, A, B</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126CFU/100mLs; Single Sample Maximum 235CFU/100mLs</td>
</tr>
<tr>
<td>Non-designated Swimming</td>
<td>AA, A, B</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126CFU/100mLs; Single Sample Maximum 410CFU/100mLs</td>
</tr>
<tr>
<td>All Other Recreational Uses</td>
<td>AA, A, B</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126CFU/100mLs; Single Sample Maximum 576CFU/100mLs</td>
</tr>
</tbody>
</table>

CFU stands for Colony Forming Units. A colony is raised from a single bacterium to a visible colony for counting by providing the preferred heat range and media for 24 hours.

**Results:** Observed *E. coli* geomeans exceeded the CT DEEP geomean criterion for a class B river of <126CFUs/100mLs at site NR22 and NR 20 (Figure 2, Table 2). Four sites (NR22, NR21, NR20, and NR15) exceeded the CT DEEP single sample maximum (SSM) of <10% over 576 CFU/100mL of all samples taken at a single site for a Class B river (Table 2). The remaining eight sites passed both CT DEEP criteria.

All twelve sites passed the CT DEEP minimum of 5mg/L for dissolved oxygen with one exception; on 10/9/14, an individual reading was observed at 4.7mg/L.
Conductivity means ranged from a maximum of 1517µS at NR23 and a minimum of 289µS at SM3. The widest conductivity range was observed at NR15 with a range of 2838µS and narrowest at SM3 with a range of 113µS (Figure 4).

Observed water temperature values range from a minimum of 0°C at NR20, NR15, NR9.5, NR6, NR4, SM3, and NR1 to 17.6°C at site NR22 (Figure 5).

**Figure 2** Maximum, geomean, and minimum *E. coli* values for twelve sites in the Norwalk River watershed from October 2014 through April 2015.

**Figure 3** Maximum, average, and minimum dissolved oxygen values for twelve sites in the Norwalk River watershed from October 2014 through April 2015.
Figure 4  Maximum, average, and minimum conductivity values for twelve sites in the Norwalk River watershed from October 2014 through April 2015.

Figure 5  Maximum, average, and minimum water temperature values for twelve sites in the Norwalk River watershed from October 2014 through April 2015.
Figure 6 Rainfall for the monitoring period October 2014 through April 2015. Error reported at standard error.

Table 2 Observed *E. coli* counts on each sampling date, geomeans, and % frequency exceeding 576 CFUs/100mLs for each site in the Norwalk River watershed from October 2014 through April 2015

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td>NR23</td>
<td>112</td>
<td>108</td>
<td>62</td>
<td>4</td>
<td>No Access</td>
<td>28</td>
<td>32</td>
<td>37</td>
<td>0%</td>
</tr>
<tr>
<td>NR22</td>
<td>1</td>
<td>400</td>
<td>1200</td>
<td>300</td>
<td>16000</td>
<td>8500</td>
<td>900</td>
<td>562</td>
<td>57%</td>
</tr>
<tr>
<td>NR21</td>
<td>108</td>
<td>70</td>
<td>360</td>
<td>26</td>
<td>No Access</td>
<td>590</td>
<td>92</td>
<td>125</td>
<td>17%</td>
</tr>
<tr>
<td>NR20</td>
<td>60</td>
<td>190</td>
<td>390</td>
<td>22</td>
<td>2180</td>
<td>250</td>
<td>64</td>
<td>166</td>
<td>14%</td>
</tr>
<tr>
<td>NR15</td>
<td>4</td>
<td>170</td>
<td>280</td>
<td>12</td>
<td>1040</td>
<td>10</td>
<td>1</td>
<td>1</td>
<td>14%</td>
</tr>
<tr>
<td>NR13</td>
<td>52</td>
<td>98</td>
<td>170</td>
<td>8</td>
<td>12</td>
<td>4</td>
<td>1</td>
<td>20</td>
<td>0%</td>
</tr>
<tr>
<td>NR9.5</td>
<td>28</td>
<td>68</td>
<td>160</td>
<td>6</td>
<td>16</td>
<td>18</td>
<td>1</td>
<td>18</td>
<td>0%</td>
</tr>
<tr>
<td>NR9</td>
<td>60</td>
<td>44</td>
<td>104</td>
<td>2</td>
<td>14</td>
<td>12</td>
<td>12</td>
<td>20</td>
<td>0%</td>
</tr>
<tr>
<td>NR6</td>
<td>84</td>
<td>28</td>
<td>124</td>
<td>16</td>
<td>32</td>
<td>22</td>
<td>24</td>
<td>36</td>
<td>0%</td>
</tr>
<tr>
<td>NR4</td>
<td>20</td>
<td>44</td>
<td>150</td>
<td>1</td>
<td>44</td>
<td>14</td>
<td>292</td>
<td>30</td>
<td>0%</td>
</tr>
<tr>
<td>SM3</td>
<td>52</td>
<td>76</td>
<td>106</td>
<td>2</td>
<td>10</td>
<td>24</td>
<td>4</td>
<td>19</td>
<td>0%</td>
</tr>
<tr>
<td>NR1</td>
<td>28</td>
<td>46</td>
<td>90</td>
<td>6</td>
<td>12</td>
<td>22</td>
<td>120</td>
<td>30</td>
<td>0%</td>
</tr>
<tr>
<td>Rain (in)</td>
<td>1.12</td>
<td>2.15</td>
<td>5.38</td>
<td>0.02</td>
<td>0.06</td>
<td>1.12</td>
<td>0.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days Prior</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Bold/Italic Values:** Actual observed count is zero, but geomean cannot be calculated with zeros so they were changed to one.

**Discussion:** Monthly rainfall averaged at 4.49 inches per month (Figure 6). Late-winter and early-spring saw a lot of variability in accumulation, but we observed no relationship between rainfall and bacteria counts (Figure 6, Table 2). The winter of 2015 saw numerous large snowfalls. Heavy accumulation paired with the cold weather prompted a slow and drawn out snow melt.

With the exception of NR22, the sites monitored on the Norwalk River met the CT DEEP geomean criterion for a class B river of <126CFUs/100mLs (Figure 2, Table 2). Site NR22 is the effluent pipe for the
Ridgefield Wastewater Treatment Plant. Elevated counts observed here are attributed to the NPDES permit which requires the Ridgefield Wastewater Treatment Plant to have their ultraviolet lights for sanitizing the effluent stream on from May through September. This means that during the winter months the plant is allowed to turn their lights off and the effluent does not get sanitized. The treatment plant does extend the length of time they keep their lights on beyond the permit regulations which is seen by the observed \(E. coli\) counts of 0CFU/100mLs in October (Table 2). During the months when the UV lights are on, Harbor Watch has observed \(E. coli\) counts of 0CFU/100mLs every week (Harbor Watch Records). The sites that exceed the CT DEEP single sample maximum can be attributed to the elevated \(E. coli\) bacteria counts observed at the wastewater treatment plant effluent pipe (NR22) on 2/19/15 and 3/19/15 and traveling down-river through NR 21, NR20, and NR15 (Table 2).

Observed dissolved oxygen means met the CT DEEP criteria at all twelve sites. On 10/9/14, an individual reading was observed at 4.7mg/L at site NR21. This low value may be related to the large area of The Great Swamp that the water slowly travels through before returning to normal river conditions. River flow appeared low and did not oxygenate the water well.

Conductivity values tend to be higher in the upper portion of the Norwalk River due to the presence of limestone beds on the river banks in Ridgefield which contribute ions to the water during rain events. The conductivity values begin to drop at NR13 which is just downstream of the confluence small tributaries such as Cooper Brook and Branchville Brook. All the sites, with the exception of NR23, showed great stability throughout the winter (Figure 4). Although there were many snow storms which led to the use of road salt, the weather stayed freezing for long periods of time which slowed snow melt over the months so there was never a large disposal of salt-laden runoff into the river.

Water temperature was observed to have wide ranges over the monitoring period as the weather changed, but stayed relatively constant from site to site throughout the length of the river. The only exception is observed temperatures at NR22 approximately 5°C warmer than the other 11 sites (Figure 5). This is due to the fact that the water is coming directly out of the Ridgefield Wastewater Treatment Plant effluent pipe which spends a portion of its time underground or indoors and passing through UV lights.
### Appendix A

**Table A1** Site number identification, site location and town for sampling and testing (headwaters to mouth), *=tributary to the Norwalk River

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Site Area</th>
<th>Town</th>
<th>GPS Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR23</td>
<td>Steep Brook next to South Street WTP</td>
<td>Ridgefield</td>
<td>Latitude: N 41° 17’ 24.3”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Longitude: W 73° 29’ 35.6”</td>
</tr>
<tr>
<td>NR22</td>
<td>South Street WTP outfall</td>
<td>Ridgefield</td>
<td>Latitude: N 41° 17’ 26.8”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Longitude: W 73° 29’ 29.6”</td>
</tr>
<tr>
<td>NR21</td>
<td>Farmingville Road at the Great Swamp outlet</td>
<td>Ridgefield</td>
<td>Latitude: N 41° 17’ 40.2”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Longitude: W 73° 29’ 18.5”</td>
</tr>
<tr>
<td>NR20</td>
<td>Danbury Road north of Farmingville Road intersection</td>
<td>Ridgefield</td>
<td>Latitude: N 41° 17’ 52.1”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Longitude: W 73° 29’ 32.2”</td>
</tr>
<tr>
<td>NR15</td>
<td>Stonehenge Road at the top of the dam</td>
<td>Ridgefield</td>
<td>Latitude: N 41° 18’ 32.0”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Longitude: W 73° 28’ 8.3”</td>
</tr>
<tr>
<td>NR13</td>
<td>Branchville at the railroad station (Route 7)</td>
<td>Ridgefield/Wilton</td>
<td>Latitude: N 41° 15’ 55.8”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Longitude: W 73° 26’ 27.2”</td>
</tr>
<tr>
<td>NR 9.5</td>
<td>Downstream of the Georgetown Wastewater Treatment Plant -- Old Mill Road</td>
<td>Wilton</td>
<td>Latitude: N 41° 14’ 46.0”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Longitude: W 73° 26’ 2.5”</td>
</tr>
<tr>
<td>NR9</td>
<td>School Road</td>
<td>Wilton</td>
<td>Latitude: N 41° 12’ 15.3”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Longitude: W 73° 25’ 51.6”</td>
</tr>
<tr>
<td>NR6</td>
<td>Near Wolfpit Road in back of the Wilton Corporate Office Complex</td>
<td>Wilton</td>
<td>Latitude: N 41° 11’ 0.1”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Longitude: W 73° 25’ 18.4”</td>
</tr>
<tr>
<td>NR4</td>
<td>Upstream of Route 15 (Glover Avenue) and downstream of the Merritt 7 Office Complex</td>
<td>Norwalk</td>
<td>Latitude: N 41° 8’ 3.5”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Longitude: W 73° 25’ 35.8”</td>
</tr>
<tr>
<td>SM3*</td>
<td>James Street (on the Silvermine River)</td>
<td>Norwalk</td>
<td>Latitude: N 41° 8’ 10.3”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Longitude: W 73° 26’ 4.0”</td>
</tr>
<tr>
<td>NR1</td>
<td>Post Road (US Route 1) adjacent to the Ash Creek Grille Restaurant</td>
<td>Norwalk</td>
<td>Latitude: N 41° 7’ 10.8”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Longitude: W 73° 25’ 1.3”</td>
</tr>
</tbody>
</table>
Water Quality Data Report
For
Norwalk River Watershed
May through September 2015

Interns collecting data on the Norwalk River at site NR4.

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Introduction:

Purpose of Study: Presently the Norwalk River is monitored on a year round basis with weekly testing at 12 test sites from May 1st through September 30th and monthly testing from October through April. This project was a continuation of research on a selection of 21 sites within the Norwalk River Watershed which began in 1998.

Background: From June 1998 through May 1999, Harbor Watch conducted a first-year water quality monitoring study in the Norwalk River Watershed. This study was funded by the Connecticut Department of Environmental Protection and was intended to provide water quality information in support of the Norwalk River Watershed Initiative. The purpose of the study was to obtain data on the levels of fecal coliform bacteria, dissolved oxygen, and conductivity at selected locations in the Norwalk River and in its major tributaries (Silvermine River, Comstock Brook and Cooper Brook). The study indicated that fecal coliform bacteria levels frequently exceeded the state’s water quality criterion for Class B water at a number of sites along the Norwalk River. Most sites met the dissolved oxygen level CT DEP criterion for Class B waters. The first year study also showed that conductivity levels were consistently higher in the upper reaches of the watershed than in the lower watershed. Based upon the water quality data collected, Harbor Watch determined that the water quality in the Norwalk River Watershed was moderately impaired.

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Funding was then made available by the CT DEP to continue testing on the Norwalk River for a third summer (April 1 to September 30, 2001) based on a continuing interest by Norwalk River Watershed Advisory Committees and the CT DEP. The same testing protocols, used in 2000 by Harbor Watch, were again used under the original QAPP. This QAPP was extended on April 25, 2001 to September 30, 2001 by the EPA’s Office of Environmental Measurement and Evaluation (Table 1).

During 2002, the CT DEP switched to *E. coli* bacteria as the “preferred” indicator species for freshwater, as it is a more specific indicator of fecal material arising from humans and other warm-blooded animals.

Additional 319 funding was allocated to continue the Harbor Watch testing regime on the Norwalk River for twenty-three months beginning July 2002 and ending June 30, 2004. The last contract with the CT DEP expired on 6/30/05. Harbor Watch again renewed testing of the Norwalk River and its tributaries on May 1, 2005 thanks to the interest and generosity of our municipal partners, watershed organizations, and environmental organization that have collectively continued to provide additional funds to support the monitoring season. Although these monthly reports are submitted to the CT DEEP for review and comment, Harbor Watch is solely responsible for the collection, analysis and interpretation of the water quality data.
Figure 1. Location of 12 monitoring sites in the Norwalk River Watershed.
Methods: Water monitoring is carried out under Quality Assurance Project Plan (QAPP) RFA#10160 approved by CT DEEP and EPA on 9/10/10 for five years. Monitoring teams leave Earthplace in Westport in the mid-morning and return within 2-3 hours. The team is comprised of a fully trained Harbor Watch employees and volunteers. Water samples are collected at 12 (Figure 1) monitoring sites along the length of the river. These sites, which represent the more impacted sites and developed areas, were selected in concert with the CT DEEP, because results from the first year’s study consistently demonstrated elevated fecal coliform bacteria counts at these locations.

The following tests are run in situ: dissolved oxygen (QAPP Appendix A3.2) and conductivity (QAPP Appendix A3.3). Water and air temperatures, as well as general observations and storm events are also recorded at each site visit. Observations are recorded (QAPP Appendix 5) on the Harbor Watch data sheet.

Upon return to the lab, fecal coliform bacteria membrane filtration tests (QAPP Appendix A3.5) are performed and E. coli testing is carried out according to Standard Methods, 22nd edition (9222D & 9222G) and recorded (QAPP Appendix 5) on the Harbor Watch bacteria log. During the monitoring period represented in this report, sites were monitored once per week.

E. coli bacteria were evaluated using the criteria published in the CT DEEP Surface Water Quality Standards, 10/10/13. The CT DEEP E. coli criterion for Class AA, A, and B water is established at three levels (Table 1).

The Norwalk River is classified for “all other recreational uses” because people do not bathe in or drink the river water and it is too shallow for swimming. The report will focus on E. coli bacteria levels, because it is the indicator bacteria of choice by the CT DEEP.

### Table 1. CT DEEP criterion for E. coli bacteria levels as applied to recreational use, effective 10/10/13

<table>
<thead>
<tr>
<th>Designated Use Recreation</th>
<th>Class</th>
<th>Indicator</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designated Swimming</td>
<td>AA, A, B</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126 CFU/100mLs; Single Sample Maximum 235 CFU/100mLs</td>
</tr>
<tr>
<td>Non-designated Swimming</td>
<td>AA, A, B</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126 CFU/100mLs; Single Sample Maximum 410 CFU/100mLs</td>
</tr>
<tr>
<td>All Other Recreational Uses</td>
<td>AA, A, B</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126 CFU/100mLs; Single Sample Maximum 576 CFU/100mLs</td>
</tr>
</tbody>
</table>

CFU stands for Colony Forming Units. A colony is raised from a single bacterium to a visible colony for counting by providing the preferred heat range and media for 24 hours.

Results and Discussion:

Bacteria

Observed E. coli geometric means exceeded the CT DEEP E. coli criterion for a class B river of < 126 CFUs/100mLs at site NR21, NR20, NR9, NR6, and NR1 (Figure 2, Table 2). In addition, NR21, NR20, NR9, and NR1 exceeded the CT DEEP single sample maximum of < 10% over 576 CFU/100mL of all samples taken at a single site for a Class B river (Table 2). Samples taken on 9/10/15 saw a large increase in...
bacteria concentrations due to the 1.41 inches of rain that fell prior to sample collection and analysis (Table 2). Other elevated counts which attributed to the failure of the single sample maximum criteria were observed on days that saw minimal rainfall the day of sampling as well as on days that were dry for at least 7 days. Causes for these observed elevated counts are unknown.

It should be noted that site NR22 is the effluent for the Ridgefield Wastewater Treatment Plant. This is the reason for the geometric mean value of 5 CFU/100mL and the consistent observed result of 0 CFU/100mLs. From April through October the plant treats the effluent with UV light before it leaves the plant in order to kill bacteria. Occasional observed counts above 0 CFU/100mL can be linked to rainfall events which may have caused the plant to have to process more than their capacity and reduce their efficiency.

*Figure 2.* Maximum, geometric means, and minimum *E. coli* values for twelve sites in the Norwalk River watershed from May through September 2015. Red line indicates CTDEEP geometric mean criterion.
<table>
<thead>
<tr>
<th></th>
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<td>560</td>
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<td>1</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>72</td>
<td>600</td>
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<td>228</td>
<td>88</td>
<td>40</td>
<td>152</td>
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<td>220</td>
<td>660</td>
<td>40</td>
<td>320</td>
<td>220</td>
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<td>112</td>
<td>164</td>
<td>32</td>
<td>60</td>
<td>60</td>
<td>200</td>
<td>184</td>
<td>140</td>
<td>240</td>
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<tr>
<td>NR13</td>
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<td>24</td>
<td>36</td>
<td>64</td>
<td>44</td>
<td>212</td>
<td>68</td>
<td>36</td>
<td>148</td>
<td>170</td>
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<td>168</td>
<td>280</td>
<td>192</td>
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<td>156</td>
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<td>220</td>
<td>272</td>
<td>500</td>
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<td>120</td>
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<td>192</td>
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<td>108</td>
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<td>148</td>
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<td>380</td>
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<td>69</td>
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<td>% Freq over 576 CFU/100mL</td>
<td>260</td>
<td>65</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>5%</td>
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<td>140</td>
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<td>140</td>
<td>120</td>
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<td>72</td>
<td>50400</td>
<td>48</td>
<td>200</td>
<td>164</td>
</tr>
<tr>
<td>Rain (in)</td>
<td>0.33</td>
<td>0.68</td>
<td>0.54</td>
<td>2.11</td>
<td>0.01</td>
<td>0.34</td>
<td>0</td>
<td>1.41</td>
<td>1.85</td>
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<tr>
<td>Days Prior</td>
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<td>7</td>
<td>0</td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>
**Dissolved Oxygen**

All twelve sites passed the CT DEEP mean minimum of 5 mg/L for dissolved oxygen (Figure 3). However, there were two sites, NR21 and NR20, that fell below 5 mg/L on multiple days (Table 3). These low values may be attributable to the low flow within the watershed due to low rainfall during the monitoring season. Although the low readings on 7/9/15 and 9/10/15 were observed on days with recent rainfall, it is possible that the rainfall was responsible for moving the already-hypoxic water downriver rather than aerating it. Sites NR21 and NR20 are located below the “Great Swamp” in Ridgefield. In this part of the river, the water moves slowly and is exposed to prolonged sunlight and heat throughout the summer months which may contribute to low oxygen levels downstream. The increase in mean dissolved oxygen at NR4 may be related to the substantial algal growth observed at that site which increases dissolved oxygen the water through photosynthesis.

![Figure 3](image.png)

**Figure 3.** Maximum, average, and minimum dissolved oxygen values for twelve sites in the Norwalk River watershed from May through September 2015. Red line indicates CT DEEP minimum criterion for dissolved oxygen.

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>DO (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR21</td>
<td>7/9/2015</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>9/10/2015</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>9/17/2015</td>
<td>4.6</td>
</tr>
<tr>
<td>NR20</td>
<td>7/9/2015</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>9/10/2015</td>
<td>3.9</td>
</tr>
</tbody>
</table>

**Conductivity**

Mean conductivity values across sites ranged from a maximum of 1236 µS at NR23 to a minimum of 333 µS at SM3. The widest conductivity range within a site across the season was observed at NR23 with a
range of 1208 µS and narrowest at NR9 and SM3 with ranges of 174 µS (Figure 5). Wide conductivity ranges are anticipated in the upper Norwalk River watershed due to the presence of limestone beds which add natural ions to the water. Ranges begin to narrow as the river flows south due to the influence of tributaries such as Comstock Brook, Cooper Brook, and Branchville Brook which dilute the sites sequentially. Lower levels of rainfall can increase the stability of conductivity throughout the watershed by reducing the amount of ions entering the river through runoff. The wide range observed at NR4 may have been caused by construction of an apartment complex that was occurring on the riverbank adjacent to the site with runoff inputs from the excavation and building materials.

Figure 4. Maximum, average, and minimum conductivity values for twelve sites in the Norwalk River watershed from May through September 2015.

Water Temperature and Rainfall

Water temperatures throughout the watershed remained relatively consistent from site to site. Temperature ranges remained similar over the course of the monitoring season. Slight variations in temperature from site to site may be attributed to differences in canopy cover (Figure 5). Sites such as NR21, NR13, and NR4 do not have canopy cover and receive direct sunlight all day which may explain the elevated water temperatures at those sites. Site NR22 is the effluent discharge for the Ridgefield Wastewater Treatment Plant and increased water temperature at that site may be attributed to the time spent by the water being processed within the plant.

The monitoring season from May through September 2015 was very dry compared to previous years. The average monthly rainfall was only 3.2 inches of rain with June receiving the highest at 5.67 inches total and May receiving the lowest at 1.64 inches total (Figure 6).
Conclusions: These data suggest that a pollution source is contaminating the water upstream of site NR9 which may also be driving the *E. coli* geomean at NR6 to exceed the CT DEEP criteria as well. Harbor Watch will begin investigating the river above site NR9 in order to identify a possible source. Investigation will include Harbor Watch scientists walking the river and surveying the bank for any sign of pollution input such as grey water or discharge pipes. Additional sample sites will also be added to identify where the bacteria concentrations decrease.

Acknowledgements: Harbor Watch appreciates the support of the Norwalk River Watershed Initiative, Town of Wilton, The City of Norwalk and the Norwalk Mayor’s Water Quality Committee, King Industries, Norwalk River Watershed Association, NRG-Manresa, Town of Ridgefield, Copps Island Oysters, Atlantic Clam Farms, Leslie Bloom-Miklovich, Trout Unlimited (Mianus Chapter and Nutmeg chapter), Newman’s Own Foundation, Sun Hill Foundation, and private donors.
## Appendix A

**Table A1.** Sample location coordinates and description, Asterisk indicates that the site is on a tributary to the Norwalk River

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Site Area</th>
<th>Town</th>
<th>GPS Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR23</td>
<td>Steep Brook next to South Street WTP</td>
<td>Ridgefield</td>
<td>Latitude: N 41°17’ 24.3” Longitude: W 73°29’ 35.6”</td>
</tr>
<tr>
<td>NR22</td>
<td>South Street WTP outfall</td>
<td>Ridgefield</td>
<td>Latitude: N 41°17’ 26.8” Longitude: W 73°29’ 29.6”</td>
</tr>
<tr>
<td>NR21</td>
<td>Farmingville Road at the Great Swamp outlet</td>
<td>Ridgefield</td>
<td>Latitude: N 41°17’ 40.2” Longitude: W 73°29’ 18.5”</td>
</tr>
<tr>
<td>NR20</td>
<td>Danbury Road north of Farmingville Road intersection</td>
<td>Ridgefield</td>
<td>Latitude: N 41°17’ 52.1” Longitude: W 73°29’ 32.2”</td>
</tr>
<tr>
<td>NR15</td>
<td>Stonehenge Road at the top of the dam</td>
<td>Ridgefield</td>
<td>Latitude N 41°18’ 32.0” Longitude: W 73°28’ 8.3”</td>
</tr>
<tr>
<td>NR13</td>
<td>Branchville at the railroad station (Route 7)</td>
<td>Ridgefield/Wilton</td>
<td>Latitude: N 41°15’ 55.8” Longitude: W 73°26’ 27.2”</td>
</tr>
<tr>
<td>NR 9.5</td>
<td>Downstream of the Georgetown Wastewater Treatment Plant -- Old Mill Road</td>
<td>Wilton</td>
<td>Latitude: N 41°14’ 46.0” Longitude: W 73°26’ 2.5”</td>
</tr>
<tr>
<td>NR9</td>
<td>School Road</td>
<td>Wilton</td>
<td>Latitude: N 41°12’ 15.3” Longitude: W 73°25’ 51.6”</td>
</tr>
<tr>
<td>NR6</td>
<td>Near Wolfpit Road in back of the Wilton Corporate Office Complex</td>
<td>Wilton</td>
<td>Latitude: N 41°11’ 0.1” Longitude: W 73°25’ 18.4”</td>
</tr>
<tr>
<td>NR4</td>
<td>Upstream of Route 15 (Glover Avenue) and downstream of the Merritt 7 Office Complex</td>
<td>Norwalk</td>
<td>Latitude: N 41°8’ 3.5” Longitude: W 73°25’ 35.8”</td>
</tr>
<tr>
<td>SM3*</td>
<td>James Street (on the Silvermine River)</td>
<td>Norwalk</td>
<td>Latitude: N 41°8’ 10.3” Longitude: W 73°26’ 4.0”</td>
</tr>
<tr>
<td>NR1</td>
<td>Post Road (US Route 1) adjacent to the Ash Creek Grille Restaurant</td>
<td>Norwalk</td>
<td>Latitude: N 41°7’ 10.8” Longitude: W 73°25’ 1.3”</td>
</tr>
</tbody>
</table>
Harbor Watch, a Program of Earthplace
Report on Norwalk Harbor Juvenile Benthic Marine Fish
May through October 2015

Wilton High School Marine Biology Club advisor holds up an angelwing found in the trawl net

Authors:
Sarah Crosby, Ph.D., Principal Investigator, Director of Harbor Watch, Earthplace, Westport CT
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Peter Fraboni, Associate Director of Harbor Watch, Earthplace Westport CT
Nicole Cantatore, Laboratory Director, Harbor Watch, Earthplace, Westport CT
Joshua Cooper, Laboratory Director, Harbor Watch, Earthplace, Westport CT
Introduction:
Harbor Watch is a program within a larger non-profit called Earthplace, The Nature Discovery and Environmental Learning Center. The mission of Earthplace is to build passion in the community for nature and the environment through education, experience and action. Harbor Watch was founded in 1986 as a citizen science organization dedicated to improving the health of Connecticut’s waterways and has established a strong reputation for successful partnerships in our community. Our program goal is to provide the people of Connecticut with the data, knowledge, and field expertise necessary to safeguard our waterways, educate our communities about watershed issues, and train volunteers and student interns through hands-on research. We accomplish this goal through (1) basic and applied water quality research, (2) high school and college student internship programs, (3) a public outreach and volunteer program, and (4) partnering with local municipalities to restore degraded ecosystems.

Harbor Watch has been trawling in the Norwalk River Estuary for over 25 years, with support from a dedicated network of volunteers including the Wilton High School Marine Biology Club. The program began in 1990 under the guidance of the State of Connecticut’s Department of Environmental Protection (now known as the CT Department of Energy and Environmental Protection, or CT DEEP) Fisheries Bureau. A trawling program was devised using a one meter beam trawl and a grid system which divides the harbor into 300m$^2$ sampling quadrants (Figure 1). The survey targeted the sample collection of juvenile benthic marine fish that live on the harbor floor or spend many months on the harbor floor before heading out to sea. The abundance and diversity of juvenile benthic fish can be used to assess the health of the harbor.

Full trawling history:
1990-1994: The early ’90s show a harbor floor rich in species diversity with an extensive population of winter flounder. Large numbers of juvenile flounder were caught from the I-95 Bridge down to the Maritime Center where it was not unusual to find up to 50 flounder in a single tow.

1995-1997: The HW vessel RV Annie was laid up for extensive repairs.

1998-2001: Trawling was conducted on the apron outside the harbor from Norwalk west to Scott’s Cove based on a CT DEEP request. Results were minimal numbers of benthic fish caught.

2002: HW returned to trawling inside Norwalk Harbor, although only a few trips resulted due to engine problems. The catch per unit of effort (CPU) was very small.

2003-2005: Benthic fish begin a strong recovery both in number of species and population. Recruitment of juveniles was doing well in 2005 especially in the “other” category with good numbers of Tom Cod, Microgadus tomcod, and Grubby, Myoxocephalus aeneus, recovered.

In mid-August of 2005 a large (one million+) fish kill occurred in the upper harbor when blue fish, Pomatomus saltatrix, chased a very large school of menhaden, Brevoortia tyrannus, upstream into a zone depleted of dissolved oxygen (<3 ppm, HW records) between the I-95 Bridge and Wall Street. The mass of dead fish sank and did not refloat. Previous fish kills were observed to refloat due to gas generated inside the decomposing fish and were subsequently moved out of the harbor on ebb tide (author’s observations).
Extensive dredging began in the upper harbor which was protracted into early spring 2006. This in conjunction with masses of dead fish on the harbor floor curtailed juvenile benthic recruitment in 2006. Recovery was further hampered by another, although smaller, menhaden kill in July of 2006 of approximately 10,000 fish.

2007: The benthic fish population began to recover again with a CPU of 3.65.

2008-2009: The recovery stalled for reasons unknown. Possible rising water temperatures on the bottom were retarding the winter flounder spawning.

2010: Dredging occurred in the outer harbor. A blue crab, *Callinectes sapidus*, invasion by the thousands was found on the harbor floor which possibly helped consume available benthic fish. Only 27 winter flounder were recovered during the monitoring season.

2011: A modest recovery began in winter flounder with 95 juveniles caught during the year. This is attributed to cold water supplied by the winter of 2010/2011. A few more species begin to appear, i.e. Inshore Lizardfish (2), *Synodus foetens*, Tom Cod (1), *Microgadus tomcod*, and Black Fish (4), *Tautoga onitis*. The CPU for 2011 was 1.84 fish. The cold water also reduced the blue crab population to normal levels which may have eliminated a possible level of high predation by these crustaceans.

2012: Although no great improvement to the harbor was seen, there appeared to be no loss in CPU from 2011 to 2012, 1.8 for both years. Black Fish, a species under pressure, had returned for a second year which is a promising sign for the estuary. Many experts expected a blue crab invasion due to the warm winter of 2011-2012, but the crabs did not appear in any large numbers to damage to the fisheries.

2013: The monitoring season started off strong by way of fish recovered, especially winter flounder. 462 winter flounder were recovered during the monitoring season, with a fish total of 521, the largest CPU since 2007 (Table 3). A decline in catch was recorded again from August through October due to unknown reasons.

2014: Out of a 156 total fish caught, 60 were Winter Flounder, and the CPU was 1.97. Low water temperatures from a cold winter and poor oxygen conditions throughout the summer are speculation as to why the observed CPU returned to levels seen from 2008-2012.
Figure 1. Location of trawl boxes within Norwalk Harbor. Each box was trawled multiple times during the study season (see Table 2).
Methods:
Trawling is conducted from the R.V. Annie, a 26’ converted oyster scow equipped with a winch and pulley for trawl retrieval. The crew is comprised of 2 Harbor Watch staff members that fulfil roles as pilot and deck hand and possess Connecticut boating licenses. They are joined by up to 6 additional trained volunteers to assist the deck hand. A grid system which divides the harbor into twenty 300m² sampling quadrants (Figure 1) was devised by the CT DEEP. During each trawling session, 3 boxes are selected to trawl, 1 in the upper harbor (box A-F), one in the middle harbor (box G-N), and one in the outer harbor (box O-T). When in proper position within a box, the 1m beam trawl is launched off the starboard stern. The trawl, which is connected to the winch by approximately 13 meters of line, is equipped with a tapered 0.25-in mesh net, tickler chain, and rescue buoy. Each box is trawled for 3 minutes at 3 miles per hour. Coordinates are recorded for where the trawl was launched and where it was retrieved. At the end of 3 minutes, the trawl is pulled back onto the boat via the winch. The net is removed from the trawl and emptied into a sorting bin. The catch is recorded by species and the number of individuals caught.

Over the years there has been slight variance in data collection due to weather patterns, fish kills, boat repairs, and a request from the CT DEEP to trawl outside of Norwalk Harbor which disrupted trawling activity. In order to maintain some comparison from year to year all catches are reported as catch per unit of effort (CPU) or the total number of fish caught in a period of time divided by the total number of trawls conducted during that same time period.

Results and Discussion:
The harbor has seen a rise and fall in CPU over the length of the study. In the early 1990s, we observed CPUs between 5 and 17, whereas since the early 2000s CPUs below 5 have often been observed with the exception of 2005, 2013, and 2015. The causes of these increases in catch are unknown. Our hypotheses include reduction in predators in the harbor (the water being too cold for blue crabs), or the water temperature in a given year being favorable for recruitment of *Pseudopleuronectes americanus* (winter flounder) and other benthic species.

In 2015, 17 species of fish were caught in Norwalk Harbor. In total, 499 fish were recovered over 75 trawls. Winter Flounder were the most abundant fish caught, totaling 216 individuals caught (Figure 2, Figure 3, Table 3). The CPU was 6.65 in 2015, the highest recorded in our study since 2005 (Figure 5, Table 3). Winter Flounder, *Pseudopleuronectes americanus*, was the most abundant species followed by Northern Se­arobin, *Prionotus carolinus*, and Black Sea Bass, *Centropristis striata*. Winter flounder were observed in 18 of the 19 boxes trawled, with Box L being the most abundant with 65 individuals caught (Figure 3). However, a seasonal pattern was also observed as Winter Flounder were not observed in September or October. Twelve different species of crab were caught in Norwalk Harbor along with 3 species of shrimp. The most abundant crabs were Black Fingered Mud Crab, *Panopeus herbstii*, with 611 individuals caught (Figure 4). Schools of bunker, *Brevoortia tyrannus*, were observed swimming near the surface, especially in September and October during the trawling trips. On occasion, there were reports of dead Bunker, but never in large numbers. Overall, Norwalk Harbor supports a diverse assemblage of fish and crustaceans with complex spatiotemporal patterns in abundance and community composition.
Figure 2. Total number of fish caught by species in Norwalk Harbor, May through October 2015.

Figure 3. Breakdown of number of each species caught in each box in Norwalk Harbor, May through October 2015.
Table 1 Legend for Figure 2 and 3 with common names for each coded color

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<th>Code</th>
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<td>Summer Flounder</td>
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<td>Eel</td>
<td>SMF</td>
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<td>Grubby</td>
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<td>Tomcod</td>
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<td>PGY</td>
<td>Porgy</td>
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Figure 4. Total number of crustaceans caught by species in Norwalk Harbor, May through October 2015.

Table 2. Total number of trawls in Norwalk Harbor broken down by box, May through September 2014

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<td>J</td>
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Table 3. Catch per unit of effort of primary species caught for each trawling season over the last 25 years in Norwalk Harbor

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<td>6.06</td>
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Figure 5. Catch per unit of effort from 1990 to 2015 in Norwalk Harbor.
Harbor Watch, a Program of Earthplace
Report on Dissolved Oxygen Conditions in Norwalk Harbor
May – October 2015

High School Interns gather data in Norwalk Harbor

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Introduction:
The mission of Harbor Watch is to provide the people of Connecticut with the data, knowledge, and field expertise necessary to safeguard our waterways, educate our communities about watershed issues, and train volunteers and student interns through hands-on research. Harbor Watch has conducted monitoring of Norwalk Harbor (Norwalk, CT) for the past 29 years from May through October. Here, we present a study of dissolved oxygen at multiple sites in the inner and outer harbor (Figure 1).

Figure 1. Map of Norwalk Harbor showing the locations of the inner harbor monitoring stations (NH1A-5) monitored by Harbor Watch staff and volunteers and the outer harbor stations (Buoys 1, 2A, G3, R8, G5, R24, and Sheffield Harbor) monitored by volunteers from the US Coast Guard Auxiliary Flotilla 72.

Methods:
Weekly Harbor Surveys
Seasonal monitoring was conducted in Norwalk Harbor from 5/21/2015 - 10/1/2015. A total of 20 dissolved oxygen survey trips were completed by Harbor Watch staff, high school and college interns, and volunteers. Additional dissolved oxygen surveys were conducted by members of Coast Guard Auxiliary Flotilla 72 on the areas outside Norwalk Harbor in partnership with
Harbor Watch (Figure 1). Physical monitoring of Norwalk Harbor was conducted using protocols and procedures contained in EPA Quality Assurance Project Plan RFA#14057 as approved on 5/30/14 for five years. Seven established harbor monitoring stations (Figure 1, sites NH-1A-NH-5) were visited weekly by Harbor Watch and crew where profiles of the water column for dissolved oxygen, salinity and water temperatures were taken at surface, half meter and full meter lengths to the bottom. Ancillary data collection included readings for barometric pressure (first and last station only), wind speed and direction with a Dwyer wind speed gauge, water clarity with a Secchi disk, air temperature with a Fisher brand pocket thermometer and a visual estimate of wave height.

Harbor Watch staff members and volunteers departed the Copps Island Oysters facility dock (home port for the RV Annie) at 7 Edgewater place in Norwalk at approximately 7:30 AM on Thursday of each sampling week. The vessel proceeded to the northern most station (NH1A) in the harbor to begin testing. Probes were lashed to a weighed PVC platform to facilitate lowering the probes through the water column perpendicularly. Monitoring was conducted sequentially downstream at all stations until all 7 had been profiled. The calibration was checked on the dissolved oxygen meter at the end of the run to assure that significant calibration drift (+ 5%) did not occur. The time to complete each sampling cycle for this estuary was approximately 2 hours. The Coast Guard Flotilla volunteers followed the same protocols for data collection, except their departure times and vessel differed.

Continuous-Recording Probe Deployment
Harbor Watch received reports that dissolved oxygen levels were occasionally approaching 2 mg/L or less during the early morning hours in July and August usually on ebb tides near the Norwalk Maritime Aquarium. To better understand this situation, Harbor Watch deployed its own continuously-recording probe at a nearby location across the harbor (east side, between Station NH-2 and Station NH-3) for two time periods. The first period was from 8/12 through 8/18/15 with a recording interval set at every three hours and the second period was from 8/31 through 9/6/15 with the recording interval set at two hours. A YSI Sonde Model 600 XLM data logger (dissolved oxygen, salinity, pH, and temperature) was deployed to a depth of 0.5 meters off a dock piling located at the Coastwise Marina (11 Goldstein Place, Norwalk CT) to verify these reports of hypoxic conditions occurring overnight on periods of ebb tide.

Results and Discussion:
Hypoxic conditions (< 3 mg/L) were observed at Stations NH-1A, NH-1, NH-2 and NH-3 as early as 5/28/15 (Figure 4, Appendix 1). Observed conditions of low dissolved oxygen were acute at Stations NH-1A ranging from 0.1 mg/L to 0.3 mg/L (Figure 3, Appendix 1) at a half meter below the surface from 7/1 through 9/9. Observed dissolved oxygen values at Station NH1, while still hypoxic, were in the range of 0.3 mg/L to 4.5 mg/L for the same period (Figure 3, Appendix 1). Hypoxic conditions were also observed at Station NH-2A, where the continuous-recording data logger documented dissolved oxygen concentrations as low as 1 mg/L on 8/12 to 8/15/15 (Figure 4 and Figure 5). It is important to note that the relatively lower concentrations observed at more inland sites are likely to be an artifact of sampling design, as stations were sampled in order from inland (NH-1A) outward (to NH-5) beginning early in the morning and continuing into the late morning. As a result, bottom water concentrations may have been lower.
at the stations further downstream than what was observed in this study due to the impact of daylight on dissolved oxygen (via photosynthesis).

On 9/9/15, the lowest dissolved oxygen values of the season were observed on a rising tide at 8:00 AM at Station NH-1A. The surface dissolved oxygen concentration was 2.7 mg/L in the overlying water from the Norwalk River, however, at a depth of one-half meter the dissolved oxygen concentration dropped to 0.3 mg/L and concentrations continued to decline all the way to the bottom (Appendix 1). The summer of 2015 was noteworthy for its lack of rainfall (Figure 2), elevated water temperatures (reaching 26 °C) at several stations, and an influx of filter-feeding menhaden (also known as bunker).

![Figure 2](image-url)

**Figure 2.** Rainfall (inches) for the months of May through September 2015.
Figure 3. Mean surface dissolved oxygen concentrations and mean bottom dissolved oxygen concentrations at seven stations in the Norwalk Harbor from May 21, 2015 to October 1, 2015. Error bars represent standard error. Please note that the relatively lower concentrations observed at more inland sites are likely to be an artifact of sampling design, as stations were sampled in order from inland (NH-1A) outward (to NH-5) beginning early in the morning and continuing into the late morning. As a result, bottom water concentrations may have been lower at the stations further downstream than what was observed in this study due to the impact of daylight on dissolved oxygen (via photosynthesis). Values below the red dashed line indicate hypoxic conditions (below 3 mg/L).
Figure 4. Continuous dissolved oxygen concentrations (mg/L) recorded from August 12, 2015 to August 18, 2015 at three hour intervals with a YSI Sonde 600 XLM at the Coastwise Marina dock piling, which is located between Station NH-2 and NH-3 in the Norwalk Harbor. Values below the red dashed line indicate hypoxic conditions (below 3 mg/L).
Figure 5. Continuous dissolved oxygen concentrations (mg/L) recorded from August 31, 2015 to September 6, 2015 at two hour intervals with a YSI Sonde 600 XLM at the Coastwise Marina dock piling, which is located between Station NH-2 and NH-3 in the Norwalk Harbor.
Figure 6. Mean surface dissolved oxygen concentrations and mean bottom dissolved oxygen concentrations at nine stations in the outer Norwalk Harbor between June 13, 2015 and August 26, 2015. Error bars represent standard error.

Observations of dissolved oxygen, salinity, and temperature by Coast Guard Auxiliary Flotilla 72 showed good quality marine waters (dissolved oxygen >5 mg/L) at all their monitoring stations throughout their testing cycle (Figure 6).

Norwalk Harbor suffers from poor flushing as well as other environmental problems, which often leads to poor water quality. The harbor once had extensive acres of wetlands along both banks which may have helped reduce the impact of people on water quality (Figure 7), but these valuable ecosystems were replaced beginning in the early 1800’s to accommodate shipping, industry, and private homes. As a result, the upper harbor is now a long ditch flanked by extensive bulk heading and landfills. The original commercial aspects of the harbor are now giving way to marinas and new housing developments built along its banks.
Figure 7. Norwalk Harbor estuary in 1847 showing extensive wetlands on both sides of the harbor. Image Credit: Norwalk Historical Society.
Figure 8. Lateral diagram of Norwalk Harbor from the toe of the estuary (right) to the harbor mouth a showing highly stratified tidal wedge and overlying Norwalk River flow.

With the filling in of the wetlands, flood tides can no longer spread the millions of gallons of incoming salt water over the surrounding landscape to provide the extensive volume needed on ebb tide to help flush the estuary. As a result, the underlying tidal wedge is almost totally dependent on the freshwater flow from the Norwalk River to move the underlying marine water masses seaward by frictional drag (Figure 8). This process is occasionally augmented by a seasonal drop in air temperature which can cause downwelling in the water column to restore dissolved oxygen at the bottom. Evidence of downwelling has been observed on some past Harbor Watch monitoring trips.

This harbor as restructured by man has developed a perpetual, seasonal zone of hypoxia at its northern end at Harbor Watch Station NH-1A (Appendix 1) which is typically observed each summer. Elevated water temperatures, dry weather and the presence of large schools of menhaden seeking refuge from predation in the harbor waters can accelerate this hypoxia. This oxygen-depleted water serves as a trap for schools of fish and can lead to large fish kills. Station NH-1A marks the toe of the tidal wedge and is at the entry point of the Norwalk River (Appendix 1). One of the last in a series of large fish kills occurred in the summer of 2005, when up to two million fish perished in the upper estuary after consuming the remaining dissolved oxygen available in the surface layer (mostly brackish river water).
Unfortunately, Norwalk Harbor did experience another large fish kill in the summer of 2015. As surface and bottom water temperatures became elevated over 26 °C in combination with greatly reduced rainfall during the summer months (Figure 9), the hypoxia spread downstream toward the I-95 Bridge at Station NH-1. By the end of August, available dissolved oxygen in the water column was reaching critically low levels (Figure 3, Appendix 1). Very large schools of menhaden were seen from south of the Bascule road bridge moving slowly upstream towards the I-95 Bridge in early August. A large school of peanut bunker (juvenile menhaden) moved into the hypoxic zone at Station NH-1A on 9/9 at 8:00 AM. This happened to be the very moment when the Harbor Watch vessel was on site taking dissolved oxygen readings and observing the most advanced case of hypoxia at Station NH-1A during the entire season (Figure 3 and Appendix 1). Within minutes, dead menhaden started floating to the surface. Fifty dead fish became hundreds, and hundreds became thousands within 20 minutes. Harbor Watch reported the event to the Connecticut Department of Energy and Environmental Protection (CT DEEP) Fisheries Bureau.

![Figure 10](image_url)

**Figure 10.** Maximum, mean, minimum surface and maximum, mean, and minimum bottom temperatures at the seven monitoring stations in Norwalk Harbor
The first period of continuously-recorded dissolved oxygen values showed four episodes of hypoxia from 8/12 through 8/15 with two more hypoxic events occurring on 8/18 (Figure 5). The second recording period showed no hypoxic events with most observed dissolved oxygen concentrations above 5 mg/L (Figure 6). We hypothesize that potential causes of the observed low dissolved oxygen values could include rainfall impacts, sewage pollution, eutrophication, or other ecosystem-scale drivers. For example, a period of heavy rainfall on 8/11 (2.1 inches) may have impacted the dissolved oxygen levels observed on 8/12 and 8/13. The Norwalk River’s flow increased with heavy rain and may have increased movement of the underlying tidal wedge seaward with frictional drag. More of the oxygen-depleted mass of marine water at Station NH1A could have been shifted downstream on ebb tide and may have led to hypoxic water passing the more downstream stations. However, there is no rainfall event to support the hypoxia observed on 8/18. Rainfall can also flush land-derived fertilizer into the river, which can increase hypoxia by the stimulation and subsequent decomposition of algal growth. Episodes of illegal sewage dumping from septic tank maintenance trucks or boats have occurred in the past and can decrease dissolved oxygen. However, no visible signs of human waste were found in the harbor. More research will be needed to locate the causes of hypoxia in this system which may prove to be difficult based on the seemingly random nature of these events. Additional data collection through long term deployment of the continuously-recording probe may to elucidate these drivers. Considering the elevated water temperatures (Figure 10), the atypically low rainfall, and the presence of large schools of menhaden, the Norwalk Estuary fared about as well as could be expected with respect to hypoxia this season.

Acknowledgements:
We thank Norm Bloom and Son LLC (Copps Island Oysters) for dock space for our research vessel, laboratory space, funding, and donations of scientific equipment. We also thank the many volunteers who participated in monitoring the Norwalk Harbor this season, including Joe Racz, Dick Auber, Betsy Burleson, Julian Garrison, Corrine Vietorisz, Claire Musico, Zachary Azadlian, Jeremy Philbrick, Meggy Adorno, and Tom Kelley. Also we extend our thanks to Steve Schmidt, doctoral candidate at the University of Connecticut for his help on several monitoring trips.
Appendix

Surface and bottom dissolved oxygen levels at each of six stations in Norwalk Harbor during the 2015 monitoring season. **Please note that the relatively lower concentrations observed at more inland sites are likely to be an artifact of sampling design, as stations were sampled in order from inland (NH-1A) outward (to NH-5) beginning early in the morning and continuing into the late morning. As a result, bottom water concentrations may have been lower at the stations further downstream than what was observed in this study due to the impact of daylight on dissolved oxygen (via photosynthesis).**
Water Quality Report for the Silvermine River
May - August 2015

SC Crosby,1 PJ Fraboni1, NL Cantatore1, JR Cooper1

1Harbor Watch, Earthplace, Westport, CT 06880

Stream bank erosion at Site SM3.7 (Zone B) in the Silvermine River
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</tr>
<tr>
<td>Table 3</td>
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<td>10</td>
</tr>
<tr>
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<td>12</td>
</tr>
<tr>
<td>Table 5</td>
<td>Maximum values means, minimum, values, and ranges for conductivity at six sites in Zone B of the Silvermine River from May to August 2015.</td>
<td>13</td>
</tr>
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<td></td>
</tr>
<tr>
<td>Table A2</td>
<td>Site numbers, descriptions and GPS coordinates for six monitoring sites in Zone B of the Silvermine River</td>
<td></td>
</tr>
</tbody>
</table>
Introduction:
The mission of Harbor Watch is to provide the people of Connecticut with the data, knowledge, and field expertise necessary to safeguard our waterways, educate our communities about watershed issues, and train volunteers and student interns through hands-on research. Harbor Watch has conducted monitoring of rivers and streams in Norwalk, Connecticut for the past 29 years. Here, we present a study of indicator bacteria and physical parameters at multiple sites in the Silvermine River (Figure 1). The objective of this water quality monitoring was to assist in the location of sources of bacterial, Escherichia coli (E. coli), pollution from point and non-point sources.

Research Zones of the Silvermine River
During the summer of 2015, testing in the Silvermine River Watershed focused on two areas referred to as Zone A and Zone B (Figure 1). Zone A monitoring sites (Table A1, Appendix A) encompassed the watershed area from Borglum Road to the former Silvermine Tavern at Perry Avenue. This section of the Silvermine River and Belden Hill Brook has been monitored by Harbor Watch for 8 years to determine the effect of runoff from a large hobby farm on the water quality in that area. The farm property, situated between two water bodies, has the potential for a large impact on water quality resulting from the presence of the farm animals. The Silvermine River and Belden Hill Brook form a confluence at the southern end of the farm property (Figure 2). In recent years, water quality has slowly improved as farm animals (including two llamas) were relocated and in 2011 the original farm owners moved away, along with the rest of the farm animals. The new property owners have shown little interest in boarding farm animals on the property. This change of ownership has proved to be very beneficial to water quality of Belden Hill Brook. Additionally the closing of the Silvermine Tavern Restaurant has also resulted in improvement of the water quality in the vicinity of SM6.

Zone B monitoring sites (Table A2, Appendix A) are located in an area of the watershed starting at the Silvermine elementary school property, which borders the river and flows south to James Street (Figure 2). Zone B was first explored in detail by the 2008 Norwalk Mayor’s Water Quality Committee interns because of elevated E. coli bacteria counts found at site SM3 (Figure 2). In addition, new sites were established in the slower moving ponds that characterize the Silvermine River in that section south of the Merritt Parkway Bridge downstream (south) to James Street (Figure 2).
Figure 1. Map of the Silvermine River showing six testing sites (SM9, SM8, SM7, SM6.3, SM6.1, and SM6) from Borglum Road South to the Perry Avenue Bridge, and three sites (BH6.4D, BH6.4B, and BH6.4A) on Belden Hill Brook) in Zone A, and showing six sites (SM5, SM3.7, SM3.6, SM3.5, SM3.3, and SM3) from the Silvermine Elementary School to James Street in Zone B.
Methods:
Testing protocols in the Harbor Watch EPA approved Quality Assurance Project Plan (QAPP #10160, approved 9/16/2010) for the Norwalk River were used to monitor water quality in the Silvermine River. Conductivity (QAPP Appendix A3.8) and dissolved oxygen (QAPP Appendix A3.3) are measured in situ with YSI field meters, and general observations, time, water temperature, and air temperature were also recorded at each site, (QAPP Appendix A5.1). Water samples were also collected at each site (QAPP Appendix A1.1) and transported to the Harbor Watch laboratory at Earthplace, where they were analyzed using the membrane filtration method (Standard Methods, 21st edition, 9222D and 922G) for indicator bacteria (fecal coliform and E. coli bacteria) levels.

E. coli bacteria levels were evaluated using criteria published in the CT DEEP Surface Water Quality Standards, 10/10/13. The CT DEEP E. coli criterion for Class AA, A, and B water is established at three levels (Table 1). The water quality of the Silvermine River was evaluated against the “all other recreational uses” section: failure was indicated by a bacteria geometric mean exceeding 126 CFUs/100mL or greater than 10% of samples exceeding a single sample maximum (SSM) of 576 CFUs/100mL.
Table 1. CT DEEP criterion for *E. coli* bacteria levels as applied to recreational use effective 2/25/11, CFU denotes Colony Forming Unit

<table>
<thead>
<tr>
<th>Designated Use</th>
<th>Class</th>
<th>Indicator</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Designated</td>
<td>AA,</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126/100 CFU;*Single</td>
</tr>
<tr>
<td>Swimming</td>
<td>A, B</td>
<td>(<em>E. coli</em>)</td>
<td>Sample Maximum 235/100</td>
</tr>
<tr>
<td>Non-designated</td>
<td>AA,</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126/100 CFU; Single</td>
</tr>
<tr>
<td>Swimming</td>
<td>A, B</td>
<td>(<em>E. coli</em>)</td>
<td>Sample Maximum 410/100</td>
</tr>
<tr>
<td>All Other</td>
<td>AA,</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126/100 CFU; Single</td>
</tr>
<tr>
<td>Recreational</td>
<td>A, B</td>
<td>(<em>E. coli</em>)</td>
<td>Sample Maximum 576/100</td>
</tr>
</tbody>
</table>

Results and Discussion, Zone A:
Four sites in Zone A exceeded the CT DEEP geometric mean criterion (SM9, SM7, BH6.4D, BH6.4A, and SM6.1), but only two sites (BH6.4B and BH6.4D) failed the CT DEEP Single Sample Maximum (SSM) criterion (Figure 3 and Table 2). Bacteria levels were high at all Zone A sites on June 2, 2015, which was most likely due to a significant rainfall event (2.95 inches) and the resulting runoff increasing bacteria in the water prior to the sample collection.

Dissolved oxygen concentrations were at healthy levels at all sites in Zone A and met the CT DEEP minimum criterion of 5 mg/L (Figure 4). There is riparian vegetation present along the Silvermine in this zone, which helps to shade the waterway from direct sunlight and the water moves over several rocky riffle areas; both help to maintain high dissolved oxygen concentrations in the water.

Observed conductivity values were fairly similar in Zone A (Figure 4). Mean conductivity values ranged from a maximum of 332 µS at site SM6.1 to a minimum of 267 µS at site BH6.4A. The widest conductivity range (107 µS) was observed at site BH6.4B, and the narrowest conductivity range (37 µS) was observed at site BH6.4A (Table 3). The mean conductivity for Zone A was 285 µS (standard deviation = 20.2).

Rainfall during the monitoring period averaged 3.42 inches per month. June had the highest rainfall total at 5.67 inches of rain and August had the lowest rainfall total of 2.49 inches (Figure 6). Although low precipitation amounts reduced the flow and height of the Silvermine River in Zone A, dissolved oxygen concentrations remained high, and conductivity ranges at most site sites did not fluctuate much.

As monitoring commenced in May and proceeded into the summer, water temperatures increased from the beginning of the monitoring period until the end as expected (Figure 7). Site SM6.3 exhibited the highest water temperature (23.2 °C) at the end of the monitoring period, and the lowest temperatures at sites BH6.4A and BH6.4B (13.3 °C) at the beginning of the monitoring period. The mean water temperature for Zone A was 18.75 °C, (standard deviation = 0.52)
Figure 3. Maximum values, geometric means, and minimum values for *E. coli* bacteria concentrations at six monitoring sites in the Silvermine River and three sites in Belden Hill Brook in Zone A from May to August 2015, dotted red line denotes the CT DEEP geometric mean criterion (126 CFU/100 mL) for a Class B river.

Table 2. *E. coli* bacteria concentrations, geometric means, % frequency exceeding 576 CFU/100mL and rainfall amounts at six monitoring sites in the Silvermine River, and three sites in Belden Hill Brook in Zone A from May to August 2015

<table>
<thead>
<tr>
<th>Sites</th>
<th>6/2/2015</th>
<th>7/6/2015</th>
<th>8/4/2015</th>
<th>Geomean</th>
<th>% Frequency exceeding 576 CFU/100mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM9</td>
<td>440</td>
<td>128</td>
<td>52</td>
<td>143</td>
<td>0%</td>
</tr>
<tr>
<td>SM8</td>
<td>320</td>
<td>60</td>
<td>20</td>
<td>73</td>
<td>0%</td>
</tr>
<tr>
<td>SM7</td>
<td>340</td>
<td>36</td>
<td>188</td>
<td>132</td>
<td>0%</td>
</tr>
<tr>
<td>SM6.3</td>
<td>280</td>
<td>76</td>
<td>52</td>
<td>103</td>
<td>0%</td>
</tr>
<tr>
<td>BH6.4D</td>
<td>580</td>
<td>640</td>
<td>188</td>
<td>412</td>
<td>67%</td>
</tr>
<tr>
<td>BH6.4B</td>
<td>580</td>
<td>28</td>
<td>104</td>
<td>119</td>
<td>33%</td>
</tr>
<tr>
<td>BH6.4A</td>
<td>500</td>
<td>48</td>
<td>108</td>
<td>137</td>
<td>0%</td>
</tr>
<tr>
<td>SM6.1</td>
<td>440</td>
<td>36</td>
<td>540</td>
<td>205</td>
<td>0%</td>
</tr>
<tr>
<td>SM6</td>
<td>500</td>
<td>48</td>
<td>40</td>
<td>99</td>
<td>0%</td>
</tr>
<tr>
<td>Rain (in)</td>
<td>2.95</td>
<td>0.68</td>
<td>0.51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days Prior</td>
<td>0^3</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 4. Maximum values, means, and minimum values for dissolved oxygen at six monitoring sites in Zone A of the Silvermine River and three sites in Belden Hill Brook from May to August 2015, the dotted red line denotes the CT DEEP minimum value (5 mg/L) for a Class B river.

Figure 5. Maximum values, means, and minimum values for conductivity at six monitoring sites in Zone A of the Silvermine River and three sites in Belden Hill Brook from May to August 2015.
Table 3. Maximum value, means, minimum values and ranges for conductivity at six monitoring sites in Zone A of the Silvermine River and three sites on Belden Hill Brook from May through August 2015

<table>
<thead>
<tr>
<th></th>
<th>SM9</th>
<th>SM8</th>
<th>SM7</th>
<th>SM6.3</th>
<th>BH6.4D</th>
<th>BH6.4B</th>
<th>BH6.4A</th>
<th>SM6.1</th>
<th>SM6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>308</td>
<td>309</td>
<td>309</td>
<td>304</td>
<td>293</td>
<td>360</td>
<td>289</td>
<td>364</td>
<td>304</td>
</tr>
<tr>
<td>Mean</td>
<td>278</td>
<td>278</td>
<td>278</td>
<td>277</td>
<td>269</td>
<td>301</td>
<td>267</td>
<td>332</td>
<td>277</td>
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<tr>
<td>Minimum</td>
<td>232</td>
<td>231</td>
<td>232</td>
<td>232</td>
<td>254</td>
<td>253</td>
<td>252</td>
<td>288</td>
<td>235</td>
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<tr>
<td>Range</td>
<td>76</td>
<td>77</td>
<td>77</td>
<td>72</td>
<td>39</td>
<td>107</td>
<td>37</td>
<td>76</td>
<td>69</td>
</tr>
</tbody>
</table>

Figure 6. Monthly rainfall amounts and average rainfall and normal average rainfall for monitoring the period from May to August 2015.

Figure 7. Water temperatures at six monitoring sites of the Silvermine River and three sites on Belden Hill Brook in Zone A from May through August 2015.
Results and Discussion, Zone B:
Five of the six monitoring sites (SM3.7, SM3.6, SM3.5, SM3.3 and SM3) in Zone failed the CT DEEP geometric mean criterion of < 126 CFU/100 mL (Figure 8 and Table 4). Only site SM5 did not fail this criterion during the testing period. All sites exceeded the SSM criterion (576 CFU/100 mL) at a frequency of more than 10% (Table 4). The higher bacteria levels in Zone B may indicate that bacteria may be entering the water through septic system failures and increased infiltration during high volume rainfall events. One such event occurred on sampling day, August 11, 2015, when over two inches of rainfall fell prior to sample collection. All of the monitoring sites in Zone B on this day exhibited elevated counts. Land use in Zone B can be considered suburban and residential, however, there are more impervious surfaces in this area than in Zone A. Impervious surfaces transport contaminants more quickly into receiving waters during rainfall events, which can result in elevated bacteria levels. The density of houses is also higher in Zone B, and many property owners have manicured lawns (rather than natural vegetative buffers) in close proximity to the river. Streambank erosion, such as that observed at site SM3.3, can contribute to increased runoff of contaminants into the river. More investigation will be needed to pinpoint possible sources of this contamination.

![Figure 8](image.png)

**Figure 8.** Maximum values, geometric means, and minimum values for *E. coli* at six monitoring sites in Zone B of the Silvermine River from May to August 2015, dotted red line denotes the CT DEEP geometric mean criterion for a Class B river.

The observed dissolved oxygen mean values at all sites in Zone B met the CT DEEP criterion of ≥ 5mg/L for dissolved oxygen (Figure 9). Like sites in Zone A, all sites in this area had no individual dissolved oxygen readings that were below 5 mg/L and levels remained healthy throughout the entire monitoring period. The riparian canopy in Zone B is fairly extensive, which helps to provide shade for the water and to keep it out of warming effects of direct sunlight.
Table 4. *E. coli* bacteria concentrations, geometric means, % frequency exceeding 576 CFU/100mL, and rainfall amounts at six monitoring sites in Zone B of the Silvermine River from May to August 2015

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SM5</td>
<td>92</td>
<td>208</td>
<td>104</td>
<td>20</td>
<td>2300</td>
<td>20</td>
<td>111</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>SM3.7</td>
<td>64</td>
<td>300</td>
<td>176</td>
<td>300</td>
<td>9200</td>
<td>144</td>
<td>319</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td>SM3.6</td>
<td>48</td>
<td>720</td>
<td>140</td>
<td>88</td>
<td>130</td>
<td>2500</td>
<td>108</td>
<td>204</td>
<td>14%</td>
</tr>
<tr>
<td>SM3.5</td>
<td>200</td>
<td>248</td>
<td>96</td>
<td>88</td>
<td>130</td>
<td>2500</td>
<td>108</td>
<td>204</td>
<td>14%</td>
</tr>
<tr>
<td>SM3.3</td>
<td>132</td>
<td>560</td>
<td>128</td>
<td>280</td>
<td>3300</td>
<td>n/a</td>
<td>224</td>
<td>354</td>
<td>29%</td>
</tr>
<tr>
<td>SM3</td>
<td>164</td>
<td>380</td>
<td>500</td>
<td>172</td>
<td>100</td>
<td>5800</td>
<td>24</td>
<td>257</td>
<td>14%</td>
</tr>
<tr>
<td>Rain (in)</td>
<td>0.16</td>
<td>1.39</td>
<td>1.49</td>
<td>0.6</td>
<td>0.17</td>
<td>2.11</td>
<td>0.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days Prior</td>
<td>1</td>
<td>1⁺⁴</td>
<td>3⁺²</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 9. Maximum values, means, and minimum values for dissolved oxygen at six monitoring sites in Zone B of the Silvermine River from May to August 2015, the dotted red line denotes the CT DEEP minimum value for a Class B river.

Average conductivity in Zone B ranged from 869 µS at site SM3.5 to 196 µS at SM3.3. The widest conductivity range was observed at site SM3.5 (392 µS), and the narrowest range was observed at SM5 with a range of 65 µS (Figure 10, Table 5). The mean conductivity for Zone B was 362 µS (standard deviation 159.13), however, if site SM3.5 is removed the mean calculation the conductivity mean (297 µS, Standard deviation = 13.22) closely resembles that of Zone A. Further investigation around site SM3.5 may be necessary to discover the reason for higher conductivity values and ranges at this site. Low
precipitation in July and August certainly contributed to the low flow rate and volume in the river and may have contributed to higher conductivity values observed at site SM3.5.

![Figure 10](image)

**Figure 10.** Maximum values, means, and minimum values for conductivity at six monitoring sites in Zone B in the Silvermine River from May to August 2015.

**Table 5.** Maximum values means, minimum, values, and ranges for conductivity at six sites in Zone B of the Silvermine River from May to August 2015

<table>
<thead>
<tr>
<th></th>
<th>SM5</th>
<th>SM3.7</th>
<th>SM3.6</th>
<th>SM3.5</th>
<th>SM3.3</th>
<th>SM3</th>
</tr>
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<tr>
<td>Maximum value</td>
<td>327</td>
<td>329</td>
<td>330</td>
<td>869</td>
<td>339</td>
<td>352</td>
</tr>
<tr>
<td>Mean</td>
<td>294</td>
<td>288</td>
<td>284</td>
<td>686</td>
<td>302</td>
<td>317</td>
</tr>
<tr>
<td>Minimum value</td>
<td>265</td>
<td>202</td>
<td>203</td>
<td>477</td>
<td>196</td>
<td>287</td>
</tr>
<tr>
<td>Range</td>
<td>62</td>
<td>127</td>
<td>127</td>
<td>392</td>
<td>143</td>
<td>65</td>
</tr>
</tbody>
</table>

Water temperatures trended upward for Zone B, as expected, as monitoring progressed from the beginning to the end of the period (Figure 11). Site SM3.5 had lower water temperatures during this study, and the other sites had water temperatures that were fairly similar (Figure 11). The mean water temperature for Zone B was 19.8 °C (standard deviation = 2.5).
Figure 11. Water temperatures at six monitoring sites in Zone B of the Silvermine River from May to August 2015.

References:
## Appendix

### Table A1. Site numbers, descriptions and GPS coordinates for six monitoring sites on Silvermine River and three sites on Belden Hill Brook

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Site Description</th>
<th>GPS Coordinates</th>
</tr>
</thead>
<tbody>
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<td>SM9</td>
<td>Borglum Road Bridge</td>
<td>Latitude: N 41° 09’ 35.0”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Longitude: W 73° 27’ 09.8”</td>
</tr>
<tr>
<td>SM8</td>
<td>Silvermine Ave next to Red Barn</td>
<td>Latitude: N 41° 09’ 24.2”</td>
</tr>
<tr>
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<td></td>
<td>Longitude: W 073° 26’ 59.0”</td>
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<tr>
<td>SM7</td>
<td>Silvermine Ave</td>
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<tr>
<td>BH6.4D</td>
<td>Musket Ridge Road</td>
<td>Latitude: N 41° 09’ 28.0”</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td>BH6.4B</td>
<td>#11 Mail Coach Drive downstream from the former Silvermine Sanctuary, upstream of BH6.4A</td>
<td>Latitude: N 41° 09’ 12.7”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Longitude: W 73° 26’ 51.4”</td>
</tr>
<tr>
<td>BH6.4A</td>
<td>#11 Mail Coach Drive downstream from Silvermine Sanctuary, near confluence with Silvermine River</td>
<td>Latitude: N 41° 09’ 11.9”</td>
</tr>
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<td>SM6.3</td>
<td>Confluence of Belden Hill Brook and the Silvermine River</td>
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<td></td>
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</tr>
<tr>
<td>SM6.1</td>
<td>Side stream next to Silvermine Tavern</td>
<td>Latitude: N 41° 09’ 03.9”</td>
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<tr>
<td></td>
<td></td>
<td>Longitude: W73° 26’ 49.1”</td>
</tr>
<tr>
<td>SM6</td>
<td>Perry Avenue Bridge</td>
<td>Latitude: N 41° 09’ 05.0”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Longitude: W 073° 26’ 44.4”</td>
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</table>

### Table A2. Site numbers, descriptions and GPS coordinates for six monitoring sites in Zone B of the Silvermine River

<table>
<thead>
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<th>Site No.</th>
<th>Site Description</th>
<th>GPS coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM5</td>
<td>Silvermine Elementary School</td>
<td>Latitude: N 41° 08’ 50.7”</td>
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<td></td>
<td>Longitude: W 73° 26’ 35.2”</td>
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<td>SM3.7</td>
<td>#184 Silvermine Avenue north of the Merritt Parkway overpass</td>
<td>Latitude: N 41° 08’ 21.4”</td>
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<td>SM3.6</td>
<td>#184 Silvermine Avenue, north of the Merritt Parkway overpass</td>
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<td>SM3.5</td>
<td>Just south of the Merritt Parkway overpass</td>
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<td>SM3.3</td>
<td>Bridge at the CT DMR facility</td>
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<td></td>
<td></td>
<td>Longitude: W 073° 26’ 21.4”</td>
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<td>SM3</td>
<td>James Street</td>
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<tr>
<td></td>
<td></td>
<td>Longitude: W 073° 26’ 6.1”</td>
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Acknowledgements

Two college students, Perri Sheinbaum (Oberlin University) and Amelia Romero (Bucknell University) were hired to be interns for the Norwalk Health Department and Norwalk Shellfish Commission for the 2015 summer season. In addition to their primary responsibility of monitoring indicator bacteria levels at the various bathing beach in Norwalk for the Health Department, they were also assigned to work with Harbor Watch to assist on its investigations on the health of the Silvermine and Norwalk River Watersheds. Harbor Watch wishes to thank the Norwalk Shellfish Commission and the Norwalk Health Department under the direction of the Mayor’s Water Quality Committee for providing funding and manpower for Harbor Watch to conduct this monitoring. Our thanks especially go to Tom Cloister, Norwalk Health Department, for his help in coordinating the summer internships for Harbor Watch. We also thank Perri Sheinbaum and Amelia Romero for their assistance in collecting field data and analyzing bacteria samples for this study.
Water Quality Report for Keeler’s Brook  
May – September, 2015  

SC Crosby¹, PJ Fraboni¹, NL Cantatore¹ and JR Cooper¹  

¹Harbor Watch, Earthplace, Westport CT 06880  

A sample site located within Ledgebrook Condominiums in Norwalk, CT.  

Funding for this project was provided by a CT DEEP 319NPS Grant
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Introduction:
The mission of Harbor Watch is to provide the people of Connecticut with the data, knowledge, and field expertise necessary to safeguard our waterways, educate our communities about watershed issues, and train volunteers and student interns through hands-on research. Here, we present a study of water quality in Keeler’s Brook, located in Norwalk, Connecticut (Figure 1). Funding for this project was generously provided by a grant from the Connecticut Department of Energy and Environmental Protection through the Federal Clean Water Act 319 funding program. Nine field sites were monitored for indicator bacteria, dissolved oxygen, water temperature, and conductivity from May-September, 2015.

Harbor Watch program of Earthplace began monitoring six sites on Keeler’s Brook in 2009. Financial support for this work was provided by the Connecticut Department of Agriculture for three years and then under contract with the Connecticut Department of Energy and Environmental Protection (CT DEEP) Federal Clean Water Act 319 funding. Our past research showed that the waterway is impacted by bacterial pollution. Because Keeler’s Brook is a tributary of the Five Mile River, remedial work on this waterway would not only improve the water quality of Keeler’s Brook, but also of the Five Mile River and its estuary. Locating pollution sources in Keeler’s Brook has proven to be difficult because much of the waterway flows through areas that are severely overgrown. This makes it very difficult to conduct stream walks between sites to identify possible point sources (Figure 1). Since 2009, three sites have been added to the upper end of the brook in hopes of pinpointing pollution sources, but no sources have been identified. Since 2013, very dry conditions have existed during the summer months in the Keeler’s Brook Watershed that result in severely reduced flow in the brook, and even eliminating flow completely at some sites.

Figure 1. Map of Keeler’s Brook site locations.
Methods:
Water quality monitoring was carried out under the guidance of a Quality Assurance Project Plan (QAPP) RFA#13057 approved by CT DEEP and EPA on 5/6/13 for five years. Monitoring teams were comprised of trained volunteers from Harbor Watch and two college interns hired by the City of Norwalk Health Department. Testing began at the end of May at nine sampling sites which were tested weekly for dissolved oxygen, conductivity, and temperature in situ. Water samples were also taken for *E. coli* bacteria analysis that was conducted in the Earthplace Laboratory (PH #0264), which is certified by the State of CT Dept. of Public Health for bacteria testing. Storm events were also recorded in relationship to monitoring dates and observations were recorded (QAPP Appendix 5) on the Harbor Watch data sheets. When research teams returned to the lab, the membrane filtration method was employed for quantifying fecal coliform bacteria (QAPP Appendix 3, Para. A3.13). Testing for *Escherichia coli* (*E. coli*) bacteria was performed using the partition method protocol (Standard Methods, 22nd edition, Para. 9222D & 9222G) and results were recorded (QAPP Appendix 5) on the Harbor Watch bacteria log. *E. coli* bacteria data was evaluated using the criteria published in the CT DEEP report Surface Water Quality Standards, 10/10/13. The CT DEEP *E. coli* criterion for Class AA, A, and B waterways is established at three levels (Table 1). The Five Mile River/Keeler’s Brook waterway is classified for “all other recreational uses”.

### Table 1. CT DEEP criterion for *E. coli* bacteria levels as applied to all other recreational uses, effective 10/10/13

<table>
<thead>
<tr>
<th>Designated Use Recreation</th>
<th>Class</th>
<th>Indicator</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designated Swimming</td>
<td>AA, A, B</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126 CFU/100mL; Single Sample Maximum 235 CFU/100mL</td>
</tr>
<tr>
<td>Non-designated Swimming</td>
<td>AA, A, B</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126 CFU/100mL; Single Sample Maximum 410 CFU/100mL</td>
</tr>
<tr>
<td>All Other Recreational Uses</td>
<td>AA, A, B</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126 CFU/100mL; Single Sample Maximum 576 CFU/100mL</td>
</tr>
</tbody>
</table>

Results and Discussion:
Eight of the nine sites on Keeler’s Brook exceeded the CT DEEP *E. coli* geomean criteria of < 126 CFU/100mL. Site *Ledge* had an observed geomean below the maximum. All nine sites exceeded the single sample maximum, which indicates that no more than 10% of the samples taken at a single site are allowed exceed 576 CFU/100mL (Figure 2, Table 2). Site *KB2* had the highest observed geometric mean, 3038 CFU/100mL, and highest percentage of sampling dates exceeding 576 CFU/100mL, at 95%. The cause for the elevated counts is not known, but is consistent with findings of previous years (Harbor Watch records). In the past, congregation of water fowl just upstream of site *KB2* were observed and thought to be contributing to the problem, but water fowl were not observed at this location during the 2015 monitoring season. Site *Rampart* is located next to a sewage pumping station on Connecticut Ave in Norwalk, CT (Figure 1). Further investigation to this area is needed to identify if the pump station is contributing to elevated *E. coli* counts that are observed. Site *Pond2* had the third highest observed geomean during 2015 (Figure 2, Table 2). Unfortunately, due to lack of rainfall during the monitoring period, Harbor Watch was unable to successfully collect upstream data because the brook was completely dry with no flow for an extended period, specifically at site Twin Ledge (Figure 6, Table 2). Harbor Watch plans to continue to work to identify pollution sources, focusing first on conducting a
stream walk between sites Donna and KB2 as well as taking multiple samples upstream and downstream in a short distance adjacent to the sewage pump station located at site Rampart on Connecticut Avenue. In addition, Harbor Watch will contact Norwalk WPCA and Public Works to gain access to storm and sanitary sewer maps to help identify possible sources of infiltration to Keeler’s Brook.

Figure 2. Maximum, geometric mean, and minimum E. coli values for 9 sites in Keeler’s Brook from May through September 2015. Red line indicates CT DEEP geomean maximum criteria of 126 CFU/100mL.

Table 2. E. coli counts on each sampling date, geometric means, and % frequency exceeding 576 CFUs/100mL for each site in Keeler’s Brook from May through September 2015

<table>
<thead>
<tr>
<th>Date</th>
<th>Twin Ledge</th>
<th>Gillies</th>
<th>Pond 2</th>
<th>Ledge</th>
<th>Donna</th>
<th>KB2</th>
<th>Rampart</th>
<th>KB1</th>
<th>Rain (in)</th>
<th>Days Prior</th>
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<td>no sample</td>
<td>no sample</td>
<td>72</td>
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<td>1000</td>
<td>540</td>
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<td>800</td>
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<td>560</td>
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<td>72</td>
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<td>1600</td>
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<td>120</td>
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<table>
<thead>
<tr>
<th>Date</th>
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<th>Gillies</th>
<th>Pond 2</th>
<th>Ledge</th>
<th>Donna</th>
<th>KB2</th>
<th>Rampart</th>
<th>KB1</th>
<th>Rain (in)</th>
<th>Days Prior</th>
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<td>Dry 3000</td>
<td>Dry 260</td>
<td>Dry 10</td>
<td>Dry 380</td>
<td>Dry</td>
<td>Dry 5000</td>
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<td>Dry 380</td>
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<td>Dry 5000</td>
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<td>Dry 3000</td>
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<th>Ledge</th>
<th>Donna</th>
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<th>Rampart</th>
<th>KB1</th>
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</tbody>
</table>

5
Dissolved oxygen readings met the CT DEEP minimum criterion of 5mg/L at two sites, *KB1* and *Rampart* which are both located south of Connecticut Ave (Figure 1, Figure 3). The remaining seven sites had means which fall below 5mg/L (Figure 3). Lack of rainfall during the monitoring season had an impact on the rate of flow throughout the brook, which may have contributed to the reduced oxygen levels at all sites. Many sites experienced sufficiently low flow that they became standing ponds or dried up completely.

![Figure 3](image3.png)

**Figure 3.** Maximum, average, and minimum dissolved oxygen (DO) values for 9 sites in Keeler’s Brook from May through September 2015. Red line indicates CT DEEP minimum criteria of 5 mg/L.

Conductivity mean values range from a minimum 149µS at *Gillies* to a maximum of 602µS at *KB1* (Figure 4). Site *KB1* has the widest range observed at 822µS where *Gillies* has the narrowest observed range of 46µS (Figure 4). The wide range observed at *KB1* may be attributed to well-manicured lawns in the area which were noted by the field teams. Algae were observed to be growing on the rocks in the river bed which can be an indication of high levels of nutrient inputs to the system.

![Figure 4](image4.png)

**Figure 4.** Maximum, average, and minimum conductivity values for 9 sites in Keeler’s Brook from May through September 2015.
There was little variation in water temperature at each of the nine sites monitored over the course of the study (Figure 5). From May through September, the brook saw a 10.2° difference in temperature from the highest observed reading to the lowest.

![Figure 5](image)

**Figure 5.** Maximum, average, and minimum water temperature values for 9 sites in Keeler’s Brook from May through September 2015.

The average monthly rainfall during the May through September 2015 monitoring season was 3.43 in. The largest monthly rainfall total was observed during June, with a total of 5.67 in during the month (Figure 5). Rainfall appeared to impact *E. coli* bacteria readings at these sites, as can be seen in Table 2. Sampling dates that received rainfall within 2 days prior to sampling also had consistently elevated bacteria counts. Due to the low frequency of storms, but increased volume of rainfall, many of the sites that became dry remained so even after rain because the water did not have time to permeate the soil and washed right through the brook into Five Mile River.

![Figure 6](image)

**Figure 6.** Monthly rainfall for May through September 2015.
Water Quality Report for the Five Mile River Watershed
May – August, 2015

SC Crosby¹, PJ Fraboni¹, NL Cantatore¹ and JR Cooper¹

¹Harbor Watch, Earthplace, Westport CT 06880
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Introduction:
Harbor Watch conducted water quality monitoring in the Five Mile River Watershed from May through August of 2015. Funding for this project was generously provided by a grant from Patagonia, Inc. Sixteen monitoring sites were monitored for bacteria, dissolved oxygen, water temperature, and conductivity.

Figure 1. Map of Five Mile River Watershed monitoring sites. Each monitoring site is shown as a red diamond.
Methods:
Water monitoring was carried out under QAPP RFA#10160 (Quality Assurance Project Plan) approved by CT DEEP and EPA on 9/16/10 for five years. Monitoring teams left Earthplace in Westport between 9:30am and 10:00am and returned in the early afternoon. Water samples were collected at 16 (Figure 1) monitoring sites along the length of the river biweekly between May and August. These sites, which represent the more impacted sites in developed areas, were selected by Harbor Watch personnel with guidance from the CT DEEP Water Management Bureau. Conductivity, air and water temperatures, and dissolved oxygen were measured at each site in the field. Water samples for bacteria analyses were collected and analyzed in the laboratory.

*E. coli* bacteria were evaluated using the criteria published in the CT DEEP Surface Water Quality Standards, 2/25/11. The CT DEEP *E. coli* criterion for Class AA, A, and B water is established at three levels (Table 1). Five Mile River is classified for all other recreational uses because people do not bathe in or drink the river water.

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<th>Designated Use:</th>
<th>Class</th>
<th>Indicator</th>
<th>Criteria</th>
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<td>AA, A, B</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126/100; Single Sample Maximum 235/100</td>
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<td>Designated</td>
<td>AA, A, B</td>
<td><em>Escherichia coli</em></td>
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<td><em>Escherichia coli</em></td>
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<td>Recreational</td>
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</table>

Results:
For the monitoring period from 5/7/15 to 8/25/15 sites FM6, FM5, FM2, KB1, and FM1 all failed the CT DEEP geometric mean criterion of < 126CFU/100mL for a Class B river. Sites FM7.2, FM2, and KB1 failed the CT DEEP single sample maximum criterion of < 10% over 576 CFU/100mL of all samples taken at a single site for a Class B river (Table 2). For dissolved oxygen, while no sites failed the CT DEEP mean criterion of >5mg/L, sites FM7.2 and FM1 had individual readings which failed the 5 mg/L limit. Site FM7.2 had an observed oxygen level of 1.8 mg/L on 8/25/15 and FM1 had observed oxygen readings of 4.9 and 2.5 mg/L on 8/13/15 and 8/25/15, respectively.

Mean conductivity values ranged from a high of 22,982 µS at FM1 to a low of 252 µS at FM9. The widest conductivity range was observed at site FM1 with a range of 38,014 µS, while the narrowest range was at site FM9 with a range of 48 µS. During the testing period average rainfall totaled 3.43 inches, with June being the wettest month with 5.67 inches and August being the driest month with 2.49 inches.
Figure 2. Maximum, geometric mean and minimum E. coli values for sixteen sites in the Five Mile River watershed from May to August 2015. CT DEEP geometric mean criterion shown.

Table 2. Observed E. coli counts on each sampling date, geomeans, and % frequency exceeding 576 CFUs/100mL for each site in the Five Mile River watershed from May through August 2015

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<td>390</td>
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<td>2</td>
<td>4</td>
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Figure 3. Maximum, average, and minimum dissolved oxygen values for sixteen sites in the Five Mile River Watershed from May through August 2015. CT DEEP limit criterion shown.
Figure 4. Maximum, average, and minimum conductivity values for sixteen sites in the Five Mile River watershed from May through August 2015. For FM1, only the minimum value is shown. The maximum value for this site was 39,290µS and the average was 22,982µS.

Figure 5. Total monthly rainfall for May through August 2015.

Discussion:
The bacteria criteria failure of sites FM7.2, FM6, FM5, FM2, KB1, and FM1 suggest that bacteria pollution is entering into the watershed at various points along the system. Visual examination of the sites and surrounding area has not provided any obvious sources of pollution, so the sources of bacteria
remain unclear. The density of housing in these areas suggests that it may be due to leaking septic or sewer systems, however pet or wildlife waste may also be contributing to the high bacteria levels observed. Additional track down work will need to be done to identify these sources so that they can be remediated by the local municipality or property owner.

Dissolved oxygen values were largely good in the watershed during the testing period despite the dryness during periods of the summer. This may be due to water levels remaining high enough to promote good flow in the river as well as generally good tree cover which reduces the heating effects of sunlight. The high conductivity values observed at site FM1 are likely due to infiltration of salt water at high tide. The generally similar ranges of the other sites in the watershed suggest that the Five Mile River is relatively resilient to sources of ions. This may be due to riparian buffers found along the length of much of the river. There is generally a lower density of housing in the northern portion of the watershed which likely helps to reduce these inputs.

Generally, water quality on the Five Mile River watershed appears to be healthy. Further monitoring work and more concentrated track down studies should be conducted at the failing sites to identify sources of pollution such that bacteria concentrations can be reduced.

Acknowledgements:
We would like to thank the Patagonia’s Westport Location. Without their generous support the work conducted on the Five Mile River would not have been possible.
Water Quality Report for the Pequonnock River in Monroe
May – September, 2015

SC Crosby¹, PJ Fraboni², NL Cantatore³ and JR Cooper³

¹Harbor Watch, Earthplace, Westport CT 06880

Algal growth at site WP2 in Wolfe Park in Monroe
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<td>Figure 5</td>
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<td>Table A1</td>
<td>Site number identification, GPS coordinates, and site description for sampling locations</td>
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Introduction:
The mission of Harbor Watch is to provide the people of Connecticut with the data, knowledge, and field expertise necessary to safeguard our waterways, educate our communities about watershed issues, and train volunteers and student interns through hands-on research. Here, we present a study of water quality in the Pequonnock River in Monroe, CT (Figure 1).

Harbor Watch performed a water quality survey of the Pequonnock River in Monroe, CT during the summer seasons in 2013, 2014 and 2015. The project was supported by EPA’s 604b funding administered by The Connecticut Department of Energy and Environmental Protection (CT DEEP). The goal of this project is to track down pollution sources using repetitive Escherichia coli bacteria surveys under variable weather conditions to define “hot spots” for remediation by the Town of Monroe.

The request for this survey comes from Monroe’s Town Government which has little funding or resources to adequately survey the head waters of the Pequonnock River with its many feeder streams and wetlands. The land around Monroe is lightly developed with older houses, a few newer housing developments and scattered commercial establishments which could possibly be polluting the river with discharges from compromised septic systems. A preliminary indicator bacteria survey by Harbor Watch indicated that this concern by town officials may be valid.

The headwaters of the Pequonnock River begins in Monroe, CT and consists of two major, south-flowing branches. The eastern branch begins as a series of marshes, old gravel pits and small creeks, which converge to the north of Smith Pond to form a larger river (Figure 1). The river then enters Smith Pond on its west side and leaves from the south shore to flow two miles south to Great Hollow Lake in William E. Wolfe Park (Figure 1). The Great Hollow Lake receives the Pequonnock River on its northeast corner while a smaller unnamed creek enters the lake on the northwest corner. The Pequonnock River leaves the southern end of the lake to flow to the south across Purdy Hill Road and makes a confluence with the Pequonnock’s west branch in an industrial park located on the Monroe/Trumbull border (Figure 1).

The western branch of the Pequonnock River begins as a series of wetlands and small creeks as it flows south in a direction roughly parallel with Garder Road (Figure 1). The river flows under and then parallel to Pepper Street as it runs to the southwest and then flows along Main Street (Rte. 25) to a confluence with the east branch approximately one quarter mile to the south of Purdy Hill Road in an industrial park (Figure 1). An abandoned rail line follows the western branch of the Pequonnock to approximately one quarter mile south of Cutler’s Farm Road where the road bed bends to the south and runs down past the west shore of Great Hollow Lake to an abandoned station below West Purdy Road (Figure 1).
Methods:
Ten sites were visited biweekly in the Monroe section of the Pequonnock River from May through September (Figure 1). These sites, which represent the more impacted sites and developed areas, were selected in concert with the CT DEEP, because results from the first year’s study consistently demonstrated elevated fecal coliform bacteria counts at these locations. Water monitoring was carried out under Quality Assurance Project Plan (QAPP) RFA#13058 approved by CT DEEP and EPA on 5/6/13 for three years.

The following tests were run in situ: dissolved oxygen (QAPP Appendix A3.2) and conductivity (QAPP Appendix A3.3). Water and air temperatures, as well as general observations and storm events were also recorded at each site visit. Hardness was also determined using a HACH Hardness Field Kit-Model HA-71A. Observations were recorded (QAPP Appendix 5) on the Harbor Watch data sheet.

Upon return to the lab, fecal coliform bacteria membrane filtration tests (QAPP Appendix A3.5) were performed and *E. coli* testing was carried out according to Standard Methods, 22nd edition (9222D & 9222G) and recorded (QAPP Appendix 5) on the Harbor Watch bacteria log. Iron, ammonia-nitrogen and reactive phosphorous concentrations were determined using HACH colorimetric methods: 8008, 8155, and 8048 respectively. *E. coli* bacteria were be evaluated using the criteria published in the CT DEEP
Surface Water Quality Standards, 3/10/13. The CT DEEP *E. coli* criterion for Class AA, A, and B water is established at three levels (Table 2).

The Pequonnock River is classified for “all other recreational uses” because people do not bathe in or drink the river water and it is too shallow for swimming. The report will focus on *E. coli* bacteria levels, because it is the indicator bacteria of choice by the CT DEEP.

**Table 1.** CT DEEP criteria for *E. coli* bacteria levels as applied to recreational use, effective 10/10/13

<table>
<thead>
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<th>Designated Use Recreation</th>
<th>Class</th>
<th>Indicator</th>
<th>Criteria</th>
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<td>Designated Swimming</td>
<td>AA, A, B</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126CFU/100mL; Single Sample Maximum 235CFU/100mL</td>
</tr>
<tr>
<td>Non-designated Swimming</td>
<td>AA, A, B</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126CFU/100mL; Single Sample Maximum 410CFU/100mL</td>
</tr>
<tr>
<td>All Other Recreational Uses</td>
<td>AA, A, B</td>
<td><em>Escherichia coli</em></td>
<td>Geometric Mean less than 126CFU/100mL; Single Sample Maximum 576CFU/100mL</td>
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</table>

**Results and Discussion:**

Two sites, PQ10 and PQ8 exceeded the CT DEEP geometric mean criterion (<126 CFU/100mL) for *E. coli* bacteria for a Class A river (Figure 2). None of the sites exceeded the CT DEEP Single Sample Maximum (SSM) *E. coli* bacteria criterion of <10% samples taken at each site being >576CFU/100mL (Table 2). The results indicate that a pollution source likely exits somewhere in the vicinity of PQ10, which is located on the branch of the river that enters the eastern portion of Great Hollow Lake (Figure 1). Similar to the past two summers of monitoring, the relative dryness of the summer may have limited the levels of bacteria entering the water through storm water runoff (Figure 5). The comparatively low population density in Monroe may have contributed to improved *E. coli* levels.

**Figure 2.** Observed maximum, geometric mean, and minimum *E. coli* values for ten sites in the Monroe Pequonnock River Watershed from May through September 2015. Red line indicates CT DEEP geometric mean limit for a Class B River.
Table 2. Observed *E. coli* counts on each sampling date, geomeans, rainfall amounts, and % frequency exceeding 576CFU/100mLs for each site in the Monroe Pequonnock River Watershed during the May to September 2015

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</tr>
<tr>
<td>PQ8</td>
<td>46</td>
<td>112</td>
<td>140</td>
<td>780</td>
<td>140</td>
<td>188</td>
<td>64</td>
<td>264</td>
<td>460</td>
<td>169</td>
<td>0%</td>
</tr>
<tr>
<td>Rain (in)</td>
<td>0.45</td>
<td>1.00</td>
<td>0.99</td>
<td>0.65</td>
<td>0.30</td>
<td>0.11</td>
<td>0.04</td>
<td>0.00</td>
<td>0.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days Prior</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The mean dissolved oxygen levels for all monitoring sites except site PQ14 met the CT DEEP minimum dissolved oxygen criterion of 5 mg/L (Figure 3). In addition to PQ14 two sites, PQ10 and PQ9 had individual dissolved oxygen readings below the 5 mg/L limit. Site PQ14 had individual readings below 5 mg/L on 5/12, 6/3, 6/16, 7/1, and 7/15. Site PQ 10 had individual readings observed below 5 mg/L on 7/1, 7/15, 8/19, and 9/2. Lastly, site PQ9 saw individual readings drop below 5 mg/L in 8/19 and 9/2 (Table 3). The failing dissolved oxygen levels observed at sites PQ14, PQ10, and PQ9 are most likely due to the stagnant, slow moving water present at these sites. The lack of rainfall, especially during the latter months of the monitoring season, contributed to the slow moving water at this site (Figure 5).

**Figure 3.** Observed maximum, mean, and minimum dissolved oxygen values for ten sites in the Monroe Pequonnock River Watershed from May through September 2015. Red line indicates CT DEEP minimum limit for a Class B River.
Table 3. Observed individual dissolved oxygen readings which fell below 5mg/L

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>DO (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PQ14</td>
<td>5/12/2015</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>6/3/2015</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>6/16/2015</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>7/1/2015</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>7/15/2015</td>
<td>1.0</td>
</tr>
<tr>
<td>PQ10</td>
<td>7/1/2015</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>7/15/2015</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>8/19/2015</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>9/2/2015</td>
<td>4.1</td>
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<tr>
<td>PQ9</td>
<td>8/19/2015</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>9/2/2015</td>
<td>3.7</td>
</tr>
</tbody>
</table>

Mean conductivity among the study sites ranged from a minimum of 120 µS at site WP1 to a maximum of 311 µS at PQ8 (Figure 4, Table 4). The narrowest conductivity range was observed at site WP1 with a range of 20 µS, and the widest conductivity range was observed at site PQ8 with a range of 190 µS (Figure 4, Table 4). The less stable sites in regards to conductivity, PQ14, PQ11, and PQ8 are possibly due to increased development around those sites. PQ14 is bordered by the construction equipment storage site and the Housatonic Valley Rail-Trail, and PQ11 and PQ8 are in a more commercially developed area of Monroe near the Trumbull border. This disruption of natural environment provides numerous ways for conductivity elevating ions to enter the river. The relative stability of the rest of the sites on the river is likely due to the lower population density and lesser degree of commercial and residential development and a greater riparian buffer along the banks of the river.

Figure 4. Observed maximum, mean, and minimum conductivity values for ten sites in the Monroe Pequonnock River Watershed from May through September 2015.
Table 4. Conductivity values for ten sites in the Monroe Pequonnock River Watershed from May to September 2015

<table>
<thead>
<tr>
<th></th>
<th>PQ14</th>
<th>PQ13</th>
<th>PQ12</th>
<th>PQ11</th>
<th>PQ10</th>
<th>PQ9</th>
<th>WP1</th>
<th>WP2</th>
<th>WP3</th>
<th>PQ8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>276</td>
<td>259</td>
<td>303</td>
<td>386</td>
<td>299</td>
<td>197</td>
<td>128</td>
<td>259</td>
<td>205</td>
<td>403</td>
</tr>
<tr>
<td>Avg</td>
<td>211</td>
<td>232</td>
<td>285</td>
<td>281</td>
<td>248</td>
<td>170</td>
<td>120</td>
<td>221</td>
<td>189</td>
<td>311</td>
</tr>
<tr>
<td>Min</td>
<td>124</td>
<td>200</td>
<td>265</td>
<td>207</td>
<td>188</td>
<td>115</td>
<td>108</td>
<td>184</td>
<td>170</td>
<td>213</td>
</tr>
<tr>
<td>Range</td>
<td>153</td>
<td>59</td>
<td>38</td>
<td>179</td>
<td>111</td>
<td>82</td>
<td>20</td>
<td>75</td>
<td>36</td>
<td>190</td>
</tr>
</tbody>
</table>

Rainfall averaged 0.95 inches per month during the monitoring period. June was the wettest month with a rainfall totaling 2.77 inches, and August was the driest month with a total rainfall of 0.24 inches (Figure 5). Measured rainfall in September data shown only includes precipitation events up to 9/22/15.

![Graph showing rainfall from May to September 2015](image)

Figure 5. Rainfall for monitoring period from May to September 2015 (up to 9/22/15).

![Graph showing water temperature variation from May to September 2015](image)

Figure 6. Observed maximum, mean, and minimum water temperature values for ten sites in the Monroe Pequonnock River Watershed from May through September 2015.
### Table 1A. Site number identification, GPS coordinates, and site description for sampling locations

<table>
<thead>
<tr>
<th>Station Number</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Comments/Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>PQ14</td>
<td>N41° 21’ 8.7”</td>
<td>W073° 15” 22.5”</td>
<td>On the Housatonic Valley Rail Trail off of Pepper Street</td>
</tr>
<tr>
<td>PQ13</td>
<td>N41° 20’ 24.4”</td>
<td>W073° 14’ 46.0”</td>
<td>This site is located at the junction of Jockey Hollow Road and Pepper Street. This site is on the upper section of the West Branch of the Pequonnock after it exits the Industrial Park on the border of Monroe and Newtown.</td>
</tr>
<tr>
<td>PQ12</td>
<td>N41° 20’ 19.7”</td>
<td>W073° 13” 53.8”</td>
<td>Located on West Maiden Lane, this site is downstream from Jockey Hollow Lake on the East Branch of the Pequonnock River.</td>
</tr>
<tr>
<td>PQ11</td>
<td>N41° 19’ 18.6”</td>
<td>W073° 15’ 41.6”</td>
<td>This West Branch site is located on Peeper Street near the junction with Brooks Street.</td>
</tr>
<tr>
<td>PQ10</td>
<td>N41° 19’ 13.5”</td>
<td>W073° 14’ 26.0”</td>
<td>Site is located on Cutler’s Farm Road prior to the river’s entrance at William E. Wolfe Park.</td>
</tr>
<tr>
<td>WP1</td>
<td>N41° 18’ 47.1”</td>
<td>W073° 14’ 53.3”</td>
<td>This site is located approximately 300 feet from the beach of Great Hollow Lake. Located to the right of the pavilion.</td>
</tr>
<tr>
<td>WP2</td>
<td>N41° 18’ 43.8”</td>
<td>W073° 14’ 41.4”</td>
<td>This site is at the end of the East Branch of the Pequonnock River before it enters Great Hollow Lake. Located to the left of the pavilion.</td>
</tr>
<tr>
<td>WP3</td>
<td>N41° 18’ 31.3”</td>
<td>W073° 14’ 47.3”</td>
<td>The site is situated at the exit point of Great Hollow Lake in William E. Wolfe Park.</td>
</tr>
<tr>
<td>PQ9</td>
<td>N41° 18’ 14.7”</td>
<td>W073° 14’ 41.1”</td>
<td>Pequonnock River site at Purdy Hill Road. The site is off the road bridge as the river exits William E. Wolfe Park.</td>
</tr>
<tr>
<td>PQ8</td>
<td>N41° 18’ 03.7”</td>
<td>W073° 14’ 55.9”</td>
<td>West Branch of Pequonnock at Maple Drive Bridge</td>
</tr>
</tbody>
</table>
Water Quality Report for the Pequonnock River in Trumbull
May – September, 2015

SC Crosby¹, PJ Fraboni¹, NL Cantatore¹ and JR Cooper¹

¹Harbor Watch, Earthplace, Westport CT 06880

Site PQ6.1 located in Pequonnock State Park
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</table>

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<td>7</td>
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<td>8</td>
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<td>9</td>
</tr>
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<td>Monthly rainfall (inches) amounts during the testing period (May-August).</td>
<td>10</td>
</tr>
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<td>CT DEEP criterion for <em>E. coli</em> bacteria levels as applied to recreational use, effective 3/10/13</td>
<td>4</td>
</tr>
<tr>
<td>Table 2</td>
<td>Observed <em>E. coli</em> counts on each sampling event (six total with two extra tests on PQ7) geometric means, rainfall amounts, and % frequency exceeding 576 CFUs/100mL for each monitoring site and % frequency exceeding 410 CFUs/100 mL at selective sites in the Trumbull section of the Pequonnock River Watershed.</td>
<td>5</td>
</tr>
<tr>
<td>Table 3</td>
<td>Conductivity (uS) maximum, mean, minimum, and range values for ten monitoring sites in the Trumbull section of the Pequonnock River Watershed</td>
<td>7</td>
</tr>
<tr>
<td>Table 4</td>
<td>Water hardness classification at six of the ten Trumbull Pequonnock River monitoring sites in terms of mg/L CaCO₃</td>
<td>8</td>
</tr>
<tr>
<td>Table 5</td>
<td>Maximum, mean and minimum concentrations for ammonia-nitrogen at sites PQ7.1, PQ7.01, PQ7, PQ6.5, and PQ6.1</td>
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</tr>
<tr>
<td>Table 6</td>
<td>Maximum, mean and minimum concentrations for phosphate-phosphorous at sites PQ7.1, PQ7.01, PQ7, PQ6.5, and PQ6.1</td>
<td>9</td>
</tr>
<tr>
<td>Table 7</td>
<td>Maximum, mean and minimum concentrations for iron at sites PQ7.1, PQ7.01, PQ7, PQ6.5, and PQ6.1</td>
<td>10</td>
</tr>
</tbody>
</table>
Introduction
The mission of Harbor Watch is to provide the people of Connecticut with the data, knowledge, and field expertise necessary to safeguard our waterways, educate our communities about watershed issues, and train volunteers and student interns through hands-on research. Harbor Watch has conducted monitoring of Fairfield County waterways for the past 29 years. Here, we present a study of The Pequonnock River in Trumbull, Connecticut.

The Pequonnock River watershed, which begins in the Town of Monroe, encompasses an area of over 15,000. The river is 16.7 miles long and flows from Monroe through the Town of Trumbull and finally into the City of Bridgeport terminating in the estuary of the Bridgeport Harbor. The CT Department of Energy and Environmental Protection (DEEP) has divided the main stem of the Pequonnock River into 5 segments (Water body ID numbers CT7105-00_01, CT7105-00_02, CT7105-00_03, CT7105-00_04, and CT7105-00_05). One segment CT7105-00_03 (from Daniels Farm Road to Monroe Turnpike, CT Route 111 at the intersection of CT Route 25) is 4.19 miles, and lies totally within the boundaries of Trumbull. The segment (CT7105-00_04) to the north of CT7105-00_03 is located partially in Trumbull and is approximately 0.9 miles in length. Segment CT7105-00_02 lies to the south of Segment CT7105-00_03 and is partially in Trumbull and Bridgeport. The river in the Trumbull portion of this segment is approximately 2 miles of the 2.92 of the total segment’s length. The west branch of the Pequonnock River (CT7105-01_01) is 1.51 miles in length, and is located entirely in the Town of Monroe (CT DEEP 2012).

![Figure 1. Map of the Trumbull section of the Pequonnock River showing the location of the ten monitoring sites.](image)
Methods

Ten sites were visited biweekly in the Trumbull section of the Pequonnock River from May through September (Figure 1). Water monitoring was conducted following testing protocols in Quality Assurance Project Plan (QAPP) for the Pequonnock River Watershed (RF#13058). The QAPP was approved by CT DEEP and EPA on 5/6/13 and is effective for three years. In situ data was gathered and water samples were collected at each of these sites (Figure 1) for the analysis of indicator bacteria (fecal coliform and Escherichia coli).

The following tests were run in situ: dissolved oxygen (QAPP Appendix A3.2) and conductivity (QAPP Appendix A3.3). Water and air temperatures, as well as general observations and storm events were also recorded at each site visit. Hardness was also determined using a HACH Hardness Field Kit-Model HA-71A. Observations were recorded (QAPP Appendix 5) on the Harbor Watch data sheet.

Upon return to the lab, fecal coliform bacteria membrane filtration tests (QAPP Appendix A3.5) were performed and E. coli testing was carried out according to Standard Methods, 22nd edition (9222D & 9222G) and recorded (QAPP Appendix 5) on the Harbor Watch bacteria log. Iron, ammonia-nitrogen and reactive phosphorous concentrations were determined using HACH colorimetric methods: 8008, 8155, and 8048 respectively. E. coli bacteria were be evaluated using the criteria published in the CT DEEP Surface Water Quality Standards, 3/10/13. The CT DEEP E. coli criterion for Class AA, A, and B water is established at three levels (Table 2).

With respect to concentrations of E. coli most of the Pequonnock River is classified for “all other recreational uses” because the public does not bathe in or drink the river water (Table 1). However, in Trumbull several of the testing sites (PQ6.5, PQ6.3, PQ6.1 and PQ 5.9) are located in state and municipal parks where the public could be able to wade into the shallow streams. This report will focus on E. coli bacteria levels, because it is the indicator bacteria of choice by the CT DEEP.

Table 1. CT DEEP criterion for E. coli bacteria levels as applied to recreational use, effective 3/10/13

<table>
<thead>
<tr>
<th>Designated Use Recreation</th>
<th>Class</th>
<th>Indicator</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designated Swimming</td>
<td>AA, A, B</td>
<td>Escherichia coli</td>
<td>Geometric Mean less than 126CFU/100mL; Single Sample Maximum (SSM) 235CFU/100mL</td>
</tr>
<tr>
<td>Non-designated Swimming</td>
<td>AA, A, B</td>
<td>Escherichia coli</td>
<td>Geometric Mean less than 126CFU/100mL; SSM 410CFU/100mL</td>
</tr>
<tr>
<td>All Other Recreational Uses</td>
<td>AA, A, B</td>
<td>Escherichia coli</td>
<td>Geometric Mean less than 126CFU/100mL; SSM 576CFU/100mL</td>
</tr>
</tbody>
</table>

Results

Indicator bacteria (E. coli) levels for the 10 monitoring sites (and one storm drain pipe) are contained in Table 2 and Figure 2. Eight of the ten monitoring sites exceeded the CT DEEP geometric mean criterion (<126 CFUs/100 mL) for a Class B river. Site PQ 6.2, however, was only slightly above (136 CFUs/100 mL) this criterion. Generally, E. coli levels were low at the start of the monitoring period, but levels rose on subsequent testing days. Indicator bacteria levels were very high at all monitoring sites on the final testing day when significant rainfall (1.51 inches) fell one day before sampling. Two sites PQ 7.1 and PQ
6.3 never exceeded the SSM, (576 CFUs/100 mL) criterion for *E. coli*, and also exhibited the lowest geometric means 64 CFUs/100 mL and 43 CFUs/100 mL respectively (Table 2).

**Table 2.** Observed *E. coli* counts on each sampling event (six total with two extra tests on PQ7) geometric means, rainfall amounts, and % frequency exceeding 576 CFUs/100mL for each monitoring site and % frequency exceeding 410 CFUs/100 mL at selective sites in the Trumbull section of the Pequonnock River Watershed

*indicates rainfall amounts were additive of consecutive days for that sampling event

---

**Figure 2.** Observed maximum, geomean, and minimum *E. coli* values for the ten monitoring sites in the Trumbull section of the Pequonnock River Watershed. Red dashed line indicates the CT DEEP geometric mean limit for a Class B river.
Mean dissolved oxygen concentrations at all of the monitoring sites were above the CT DEEP minimum dissolved oxygen criterion of 5 mg/L (Figure 3). However, on several occasions site PQ 7.1 and site PQ7 exhibited dissolved oxygen concentrations below the CT DEEP minimum criterion. These sites both were shallow and had partially stagnant conditions, which may have contributed to these low dissolved oxygen concentrations.

![Dissolved oxygen concentrations for ten monitoring sites in the Trumbull section of the Pequonnock River Watershed](image)

**Figure 3.** Dissolved oxygen maximum, mean, and minimum concentrations for ten monitoring sites in the Trumbull section of the Pequonnock River Watershed. Red dashed line indicates the CT DEEP minimum of 5mg/L.

Similar to observations in 2014, conductivity was lowest (154 μS) at PQ7.1, a site which is located in a residential area in the northern Trumbull section of the Pequonnock River watershed near the Monroe town line. Site PQ6.1 exhibited higher conductivity values when compared to the other monitoring sites. Conductivity at this site ranged from a high of 1454 - 1049 μS during the study period. Most of the other monitoring sites except the storm drain site (PQ7.01), Site PQ7 and Site PQ6.1 had fairly narrow conductivity ranges from a low of 65 - 138 μS (Table 3).
Figure 4. Conductivity maximum, mean, and minimum values for ten monitoring sites in the Trumbull section of the Pequonnock River Watershed.

Table 3. Conductivity (uS) maximum, mean, minimum, and range values for ten monitoring sites in the Trumbull section of the Pequonnock River Watershed

<table>
<thead>
<tr>
<th>Site</th>
<th>Maximum</th>
<th>Mean</th>
<th>Minimum</th>
<th>Range</th>
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<tbody>
<tr>
<td>PQ7.1</td>
<td>221</td>
<td>184</td>
<td>154</td>
<td>67</td>
</tr>
<tr>
<td>PQ7</td>
<td>548</td>
<td>460</td>
<td>372</td>
<td>176</td>
</tr>
<tr>
<td>PQ6.5</td>
<td>449</td>
<td>396</td>
<td>330</td>
<td>119</td>
</tr>
<tr>
<td>PQ6.4</td>
<td>471</td>
<td>402</td>
<td>333</td>
<td>138</td>
</tr>
<tr>
<td>PQ6.3</td>
<td>376</td>
<td>338</td>
<td>311</td>
<td>65</td>
</tr>
<tr>
<td>PQ6.2</td>
<td>413</td>
<td>373</td>
<td>311</td>
<td>102</td>
</tr>
<tr>
<td>PQ6.1</td>
<td>1454</td>
<td>1301</td>
<td>1049</td>
<td>405</td>
</tr>
<tr>
<td>PQ6</td>
<td>413</td>
<td>383</td>
<td>325</td>
<td>88</td>
</tr>
<tr>
<td>PQ5.9</td>
<td>395</td>
<td>351</td>
<td>319</td>
<td>76</td>
</tr>
<tr>
<td>PQ5.8</td>
<td>407</td>
<td>364</td>
<td>317</td>
<td>90</td>
</tr>
</tbody>
</table>

Maximum, mean and minimum water temperatures for each of the sites are displayed in Figure 5. Storm drain site PQ7.01 had the lowest mean water temperature (16.1 °C), and the narrowest range (2.1 °C). Site PQ5.9 had the highest mean water temperature (20.8 °C). Most of the sites had narrow temperature ranges (3.7 °C to 5.0 °C). Site PQ 7 had the widest temperature range (11.3 °C) from 22.7 °C to 11.4 °C (Figure 5).
Water temperatures (°C) maximum, mean, and minimum for the ten monitoring sites and one storm drain site in the Trumbull section of the Pequonnock River Watershed. Site PQ7.01 is a storm drain site.

Water hardness was measured at six of the ten monitoring sites. Using the US Department of Interior and Water Quality Association standards, water hardness in the Trumbull section of the Pequonnock River can be classified as “slightly hard” to “moderately hard”. However, Site PQ6.1 which also has high conductivity levels can be classified as “hard” (Table 4).

**Table 4.** Water hardness classification at six of the ten Trumbull Pequonnock River monitoring sites in terms of mg/L CaCO₃

<table>
<thead>
<tr>
<th>Site</th>
<th>Hardness, mg/L as CaCO₃</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>PQ7.1</td>
<td>51.3</td>
<td>Slightly Hard</td>
</tr>
<tr>
<td>PQ6.5</td>
<td>102.6</td>
<td>Moderately Hard</td>
</tr>
<tr>
<td>PQ6.3</td>
<td>85.5</td>
<td>Moderately Hard</td>
</tr>
<tr>
<td>PQ6.2</td>
<td>85.5</td>
<td>Moderately Hard</td>
</tr>
<tr>
<td>PQ6.1</td>
<td>136.8</td>
<td>Hard</td>
</tr>
<tr>
<td>PQ5.8</td>
<td>85.5</td>
<td>Moderately Hard</td>
</tr>
</tbody>
</table>

A preliminary survey of phosphate-phosphorous, ammonia-nitrogen and iron concentrations was conducted on a subset of the monitoring sites in Trumbull (Figure 6). Phosphate-phosphorous (PO₄) was fairly uniform in the Trumbull section with concentrations ranging from 0.05-0.09 mg/L except for the storm drain site PQ7.01 which had a PO₄ concentration of 2.36 mg/L. Ammonia (NH₃) concentrations were high (>0.1 mg/L) at three monitoring sites (PQ7.01, PQ7, and PQ6.5) in the Trumbull section (Figure 6). The concentration of NH₃ at Site PQ 7.01 was 2.00 mg/L and may have affected the concentration level at downstream Site PQ7 (0.29 mg/L) and Site PQ6.5 (0.13 mg/L).
Iron concentrations were measured and were found to be high at Sites PQ7.01, PQ7, PQ6.5, and PQ3 (Figure 6). The highest iron levels were at PQ7.01 (2.29 mg/L). Because of the limited scope for this project, subsequent nutrient and iron testing focused on Sites PQ7.1, PQ7.01, PQ 7, and PQ6.5. Site PQ6.1 was added in an effort to understand the high conductivity levels at that site (Table 5, Table 6, and Table 7).

**Figure 6.** Concentrations of phosphate-phosphorous, iron, and ammonia-nitrogen at 9 monitoring sites and one storm drain site in the Trumbull section of the Pequonnock River, on June 10, 2015.

**Table 5.** Maximum, mean and minimum concentrations for ammonia at sites PQ7.1, PQ7.01, PQ7, PQ6.5, and PQ6.1

<table>
<thead>
<tr>
<th>Site</th>
<th>PQ7.1</th>
<th>PQ7.01</th>
<th>PQ7.0</th>
<th>PQ6.5</th>
<th>PQ6.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum concentration</td>
<td>0.09</td>
<td>2.45</td>
<td>1.70</td>
<td>0.25</td>
<td>0.09</td>
</tr>
<tr>
<td>Mean</td>
<td>0.09</td>
<td>2.05</td>
<td>0.87</td>
<td>0.14</td>
<td>0.04</td>
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<tr>
<td>Minimum concentration</td>
<td>0.07</td>
<td>1.80</td>
<td>0.29</td>
<td>0.03</td>
<td>0.00</td>
</tr>
</tbody>
</table>

**Table 6.** Maximum, mean and minimum concentrations for phosphate-phosphorous at sites PQ7.1, PQ7.01, PQ7, PQ6.5, and PQ6.1

<table>
<thead>
<tr>
<th>Site</th>
<th>PQ7.1</th>
<th>PQ7.01</th>
<th>PQ7.0</th>
<th>PQ6.5</th>
<th>PQ6.1</th>
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</thead>
<tbody>
<tr>
<td>Maximum concentration</td>
<td>0.12</td>
<td>2.35</td>
<td>0.07</td>
<td>0.09</td>
<td>0.08</td>
</tr>
<tr>
<td>Mean</td>
<td>0.08</td>
<td>0.81</td>
<td>0.03</td>
<td>0.04</td>
<td>0.06</td>
</tr>
<tr>
<td>Minimum concentration</td>
<td>0.02</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.04</td>
</tr>
</tbody>
</table>
Table 7. Maximum, mean and minimum concentrations for iron at sites PQ7.1, PQ7.01, PQ7, PQ6.5, and PQ6.1

<table>
<thead>
<tr>
<th></th>
<th>PQ7.1</th>
<th>PQ7.01</th>
<th>PQ7.0</th>
<th>PQ6.5</th>
<th>PQ6.1</th>
</tr>
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<tr>
<td>Maximum</td>
<td>0.30</td>
<td>15.70</td>
<td>1.99</td>
<td>0.60</td>
<td>0.20</td>
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<tr>
<td>concentration</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.29</td>
<td>5.44</td>
<td>0.99</td>
<td>0.52</td>
<td>0.15</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.27</td>
<td>0.77</td>
<td>0.50</td>
<td>0.46</td>
<td>0.11</td>
</tr>
<tr>
<td>concentration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 7. Monthly rainfall (inches) amounts during the testing period (May-August).

Discussion
Indicator bacteria (*E. coli*) levels were low (except for site PQ5.8) at monitoring sites in the Trumbull section during the two sampling events in May (Table 2). *E. coli* levels were higher at most Trumbull sites on the next four sampling events which resulted in eight of the ten Trumbull sites failing the CT DEEP geometric mean criterion (> 126 CFUs/100 mL) for *E. coli* concentrations (Table 2, Figure 3). Only sites PQ 7.1 (in a residential neighborhood) and PQ 6.3 (in Indian Ledge Park) had geometric mean below the CT DEEP geometric mean criterion. A significant rainfall (1.51 inches) occurred one day prior to the final sampling event on 8/11/2015 which likely contributed to the increase in the geometric means for these sites. Sites PQ7.1 and PQ6.3 also had *E. coli* levels below the CT DEEP SSM of 576 CFUs/100 mL, but site PQ 6.3 had levels over 410 CFUs/100 mL once during the 6 sampling events (Table 3). This higher criterion was also used because site PQ6.3 in Indian Ledge Park might provide a wading area for park visitors.

Like last year site PQ6.5 located in Old Mine Park had elevated *E. coli* levels, exceeding the SSM (410 CFUs/100 mL) on 50% of the six sampling events. Additional investigation will be needed to understand what is causing these high bacteria levels. Waterfowl have been observed swimming in the pond upstream from the sampling site and feces from these birds may be contributing to the observed bacteria levels, however, storm drain infiltration is also a possible cause.

Site PQ7.1 on Coventry Lane again exhibited low indicator bacteria levels, having 0% frequency over the SSM concentration of 576 CFUs/100 mL and a geometric mean concentration of 64 CFUs/100 mL. This
site located on North Farrar Brook, a tributary located west of the Pequonnock River had very low flow in the latter part of the testing period because of the lack of rainfall in July and August (Figure 7). Unlike as observed in 2014, sites in the southern section (PQ6, PQ5.9 and PQ5.8) generally exhibited high indicator bacteria levels (Table 3 and Figure 2). Geometric means were >126 CFUs/100 mL and the % frequency over 576 CFUs/100 mL for the SSM were 50%, 33.3% and 50%, respectively. If the 410 CFUs/100 mL SSM criterion is used for site PQ5.9, because this site is located in Unity Park were visitors could wade into the water, the SSM frequency rises to 50% (Table 2).

Most of the Pequonnock River monitoring sites were characterized with rapidly moving water so it was not surprising that dissolved oxygen mean levels were above the CT DEEP criterion of 5 mg/L. Sites PQ7.1 and PQ7 did have dissolved oxygen concentrations falling below the 5 mg/L criterion during the final sampling event on August 12. The water flows at these sites were slow moving during this dry period, which may have contributed to these lower dissolved oxygen conditions.

Fairly narrow ranges for conductivity levels (Table 4) were observed at most Pequonnock River monitoring sites in the Trumbull section, which would suggest that they are not being greatly affected by inputs from storm water runoff. However, one site, PQ6.1, stood out from the rest of the sites with elevated conductivity values (Figure 4 and Table 4). The presence of iron slime bacteria and the characteristic orange precipitate was again observed at site PQ7.01. It was also observed that some of this orange precipitate broke off from this location and flowed into the Pequonnock River at site PQ7, probably after heavy precipitation events. This input could certainly have an effect on raising the conductivity downstream at site PQ7 located on Spring Hill Road.

Site PQ6.1 as stated previously stated, exhibited extremely high conductivity. Although the conductivity never rose to the high level observed last year (2290 uS), the mean conductivity (1301 uS) at this site was over three times higher than the means of the other monitoring sites. Unlike site PQ7 where conductivity levels could be a product of high iron concentrations in the water, site PQ6.1 exhibited low iron levels (Table 7). Because site PQ6.1 also exhibited high indicator bacteria levels (Table 2), this site warrants further study.

Water temperatures at the monitoring sites increased as expected from May to August as air temperature increased in the summer months. At site PQ7 both the highest water temperature (22.7 °C) and the lowest water temperature (11.4 °C) were recorded (Figure 5). However this site had a temperature range of 11.3 °C. The two sites with the lowest mean water temperatures were site PQ7.01 and site PQ6.1. Site PQ7.01 also exhibited a very narrow temperature range (2.1 °C) during the course of the monitoring period. Water at site PQ7.01 is likely flowing underground and through pipes away from the exposure of sunlight, which may explain the lower temperatures. Site PQ6.1 may also be flowing through underground infrastructure, but confirming this would need additional investigation.

Nutrient concentrations appeared to be higher in the upper river sites: PQ7.01, PQ7 and PQ6.5 (Figure 6, Table 5, Table 6, and Table 7). Site PQ7.01, a feeder stream with possible storm water inputs, exhibited significantly elevated levels of ammonia-nitrogen, phosphate-phosphorous and iron levels. The mean ammonia concentration was 2.05 mg/L, a level that exceeds the EPA criterion for chronic toxicity (EPA 2013).

Chronic ammonia-nitrogen toxicity levels have been shown to cause damage to gills, skin, and reproductive tissues in many species of fish, even after short exposures (EPA 2013). Ammonia levels at site PQ7, which were shown to exhibit levels ranging from 1.70 mg/L to 0.29 mg/L, may be due to
ammonia-nitrogen enriched water flowing into it from site PQ7.01. Ammonia-nitrogen at sites from site PQ6.2 south to PQ5.8 was low ranging from concentration from a maximum of 0.1 mg/l to a minimum of 0.04 mg/L. The toxicity of ammonia-nitrogen is also dependent on pH and temperature. The higher the pH and temperature the more toxic ammonia-nitrogen will become (Floyd et al. 2012). Although levels in the Trumbull section did not reach toxic levels, it is important for the health of Long Island Sound to keep excess nitrogen from entering freshwater waterways, which flow into the Sound. Phosphate-phosphorous levels were also highest at site PQ7.01. Phosphorous is the limiting nutrient for freshwater and concentrations greater than 0.1 mg/L can often cause aquatic plant growth especially in slow moving and stagnant waters (Correll 1998). Concentrations at most of the Trumbull site were generally 0.1 mg/L or less. However site PQ7.01 had a maximum phosphate-phosphorous concentration level of 2.35 mg/L. The mean concentration at this site was 0.81 mg/L. Water flowing through this site comes from an upstream location where the Trumbull Transfer Station is located. Nutrients certainly could enter this stream from run-off flowing through the large amount of organic waste deposited at this location.

Site PQ7.01 (mean concentration of 5.44 mg/L) also stood out for its high concentrations of iron (Figure 5 and Table 7). This site could be the source of elevated iron levels observed at sites PQ7 (mean concentration of 0.99 mg/L) and PQ6.5 (mean concentration of 0.52 mg/L). Iron concentrations at the other monitoring sites were low (< 0.3 mg/L). As stated previously, high iron concentrations at site PQ7.01 fostered the growth of iron-slime bacteria there and downstream at site PQ7. Although these bacteria are not toxic, when they proliferate they can produce large amounts of orange brown gelatinous slime that can precipitate onto the stream substrate. When this precipitation is pervasive in the streams it can smother the rocky substrate, which will exclude macroinvertebrates from using this habitat.

The water quality conditions observed in the Trumbull section of the Pequonnock River were generally good. Healthy levels of dissolved oxygen exist throughout this section and good riparian buffers are evident at most monitoring sites, especially where the river passes through parks and open spaces. In contrast to last year’s results indicator bacteria levels were higher during year 2 monitoring with most sites exceeding the CT DEEP geometric mean criterion of 126 CFUs/100 mL. Sites PQ 7 and PQ7.01 warrant further study to understand potential sources of bacteria and nutrients. High conductivity levels at Site PQ6.1 also warrant a track down survey upstream of this site.
Acknowledgements
Harbor Watch would like to acknowledge and thank the Trumbull Parks and Recreation Department for allowing vehicular access to the monitoring sites within the Trumbull Town Parks each year. We extend our thanks to Earthplace Trustee and Trumbull resident Mary Ellen Lemay for her assistance.

References
CT DEEP, Water Quality Standards 3/10/13
CT DEEP, Pequonnock River Watershed TMDL, September 2012
EPA, Aquatic Life- Ambient Water Quality Criteria for Ammonia in freshwater, EPA-822-R-13-001 April 2013
Floyd, R., C. Watson, D. Petty, and D. Pounder. 2012 Ammonia in Aquatic Systems, University of Florida Extension FA 16
Fuss and O'Neill, Pequonnock River Watershed Based Plan, September 2011
Appendix: Photos of select monitoring sites in the Trumbull Section of the Pequonnock River

Figure A1. Water exiting a corrugated metal pipe (Site PQ7.01) again exhibited signs of iron-slime bacteria during this monitoring period. This was confirmed by detecting elevated iron concentrations in the discharge water.
Figure A2. Site PQ7 showing the effects of iron-laden discharge water from Site PQ7.01 (right side of photo).
Figure A3. Sampling at Site PQ 6.2 in Pequonnock River Valley State Park.
Table A1. Monitoring site numbers and GPS coordinates in the Trumbull section of the Pequonnock River

<table>
<thead>
<tr>
<th>Sampling Sites</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>PQ7.1</td>
<td>41.29294</td>
<td>-73.2548</td>
<td>Site on North Farrar Brook on Coventry Lane</td>
</tr>
<tr>
<td>PQ7.01</td>
<td>41.294236</td>
<td>-73.2401</td>
<td>Temporary site from a nearby storm drain outfall that empties at Site PQ7 (not on map)</td>
</tr>
<tr>
<td>PQ7</td>
<td>41.29381</td>
<td>-73.2407</td>
<td>Site on Spring Hill Road off the bridge</td>
</tr>
<tr>
<td>PQ6.5</td>
<td>41.28725</td>
<td>-73.2284</td>
<td>Site in Old Mine Park</td>
</tr>
<tr>
<td>PQ6.4</td>
<td>41.28069</td>
<td>-73.2217</td>
<td>Site on Whitney Avenue off bridge near Riverside Drive</td>
</tr>
<tr>
<td>PQ6.3</td>
<td>41.28025</td>
<td>-73.2183</td>
<td>Site in Indian Ledge Park</td>
</tr>
<tr>
<td>PQ6.2</td>
<td>41.25469</td>
<td>-73.2071</td>
<td>Site in Indian Ledge State Park</td>
</tr>
<tr>
<td>PQ6.1</td>
<td>41.25061</td>
<td>-73.2051</td>
<td>Site flowing into the Pequonnock from a storm drain outfall</td>
</tr>
<tr>
<td>PQ6</td>
<td>41.24681</td>
<td>-73.1971</td>
<td>Site where the Pequonnock crosses on Daniels Farm Road bridge</td>
</tr>
<tr>
<td>PQ5.9</td>
<td>41.23356</td>
<td>-73.1839</td>
<td>Site within Unity Park</td>
</tr>
<tr>
<td>PQ5.8</td>
<td>41.22878</td>
<td>-73.1811</td>
<td>Site at the end of Cottage Place</td>
</tr>
</tbody>
</table>