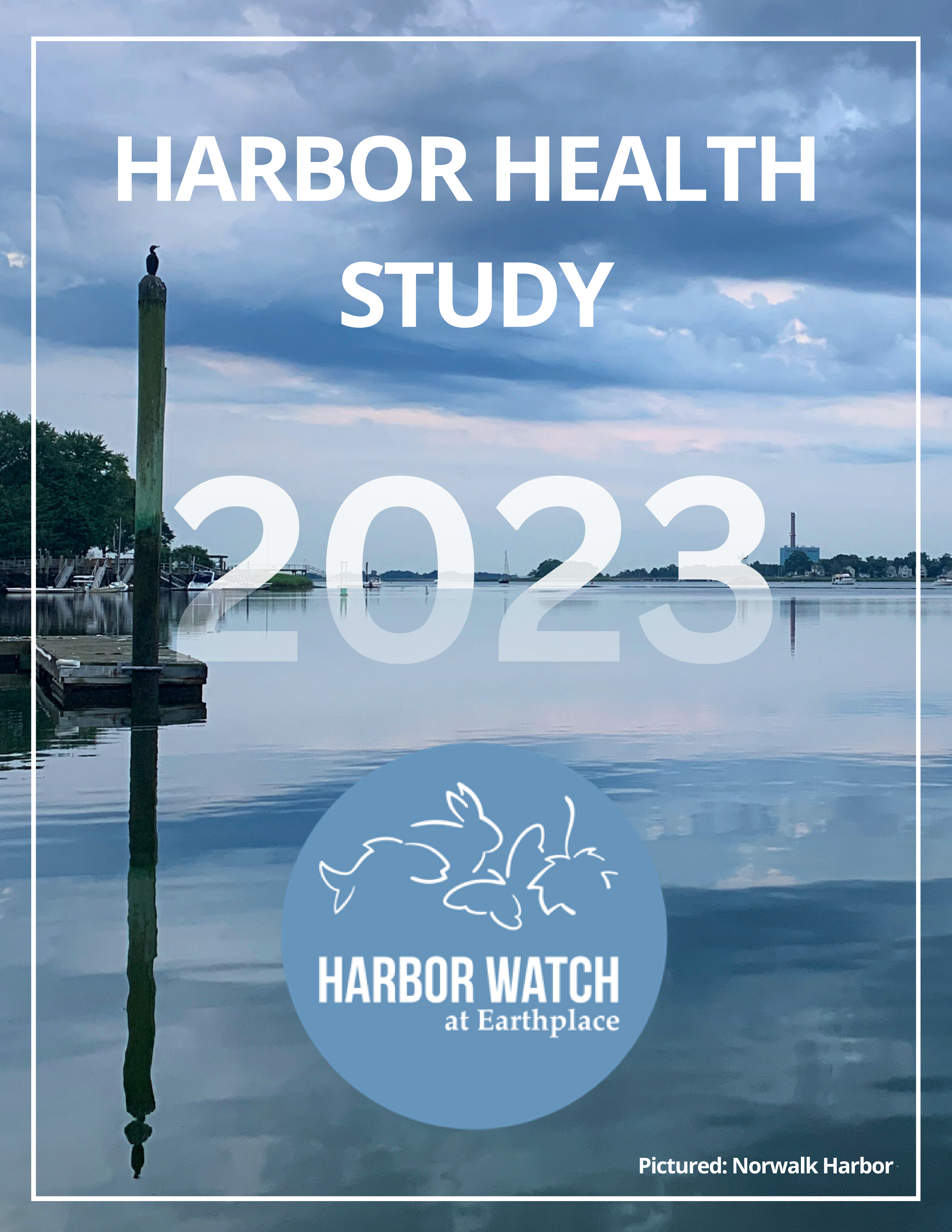
HARBOR HEALTH STUDY

2023



HARBOR WATCH
at Earthplace

Pictured: Norwalk Harbor

Contents

Harbor Health Study: 2023

The Harbor Health Study is a collaborative effort between ***Harbor Watch, Copps Island Oysters, and East Norwalk Blue*** *to collect data on the ecosystem health of local embayments.*

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This report includes data on:
Demersal fish in Norwalk Harbor and water quality in Stamford Harbor, Five Mile River Harbor, Norwalk Harbor, Saugatuck Harbor, Bridgeport Harbor (Johnsons Creek and Lewis Gut), Housatonic River, and New Haven Harbor (Quinnipiac River)

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1. About Harbor Watch

The mission of Harbor Watch is to improve water quality and ecosystem health in Connecticut.

Each day we strive to reach this goal through research in the lab and field, collaboration with our municipal partners, and education of students and the public. Harbor Watch addresses pollution threats to Long Island Sound and educates the next generation of scientists through hands-on research and experiential learning. As part of the larger organization of Earthplace, the work performed by Harbor Watch also supports the mission of Earthplace to build a passion in our community for nature and the environment through education, experience, and action.

Since its inception, Harbor Watch has trained over 1,000 high school students, college interns, and adult volunteers in the work of protecting and improving the biological integrity of Long Island Sound and has monitored hundreds of sites for a variety of physical and biological parameters.

Visit www.harborwatch.org for more information!

2. About East Norwalk Blue

A non-profit focused on pollution prevention in the Western Long Island Sound through on-the-water and land-based programs which serve to protect natural resources in the local coves and bays.

We work to redirect marine based pollution to the proper wastewater treatment facilities through our on-the-water free mobile pumpout service operating along the North Shore of the Western portion of the Long Island Sound. Localized water degradation from vessel waste tank dumping in the Sound creates environmental and health issues to shellfish consumers, swimmers and boaters. We also support monitoring activities to help identify polluters, provide advocacy in teaching the boating community best practices in boating cleanliness, facilitate island cleanups among the many islands in the western portions of the Sound, and assist local not-for-profits in their endeavors to achieve a swimmable and fishable Long Island Sound.

Visit www.eastnorwalkblue.org for more information!

3. Acknowledgements

The authors would like to thank Eram Alava, Afroz Ali, Richard Baer, Owen Boberski, Ryan Burns, Danielle Buttermor, Brendan Byrne, David Cella, Katie Chan, Katherine Day, Piper Dean, Noah Divon, Doug Donato, Tristan Ebrahimi, Matthew Ferine, Jill Fernandez, Elijah Florian, Stacey Fowle, Lily Gardella, Daniel Goldberg, Ben Haisley, John Hare, Claire Hare, Madeline Jung, Lukas Koutsoukos, Matthew Krauss, Jake Lipkin, Avalina Long, Grace Molina, Alicia Mozian, Ellen Ou, Joe Racz, Nandan Raman, Cosmo Randazzo, Tiffany Rivera, Ryan Rodriguez, Vito Romano, Annabella Rosa, Guiseppina Santandrea, Sofia Sarak, Anne Smith, Madelyn Stein, Andre Sun, Aryanna Sweeney, Margo West, Bill Wright, and Annabelle Zheng for all of their help with the work presented in this report.

We would like to extend a special thanks to Peter Fraboni who put over 100 hours of enthusiastic volunteer time. Due to his extensive efforts and equipment knowledge, we were able to complete over 50 harbor surveys, which would not have been possible without him. A special thanks also goes to Grayson Schottmuller, a senior at Boston University who assisted with almost every harbor survey. He was an enthusiastic and quick learner with a great future in science ahead of him and an asset to our monitoring team. We are also very grateful for Bill Donovan and the Westport VFW Post 399 for their donation of a dock slip. Lastly, we would like to extend our gratitude to Norm Bloom, Jimmy Bloom, Charles Pogany, and everyone at Copps Island Oysters for their tremendous support, including donation of a dock slip and vessels for the 2023 season.

Support for this research project was provided by Copps Island Oysters, City of Norwalk, Elizabeth Raymond Ambler Trust, King Industries, Long Island Sound Futures Fund, National Fish and Wildlife Foundation, New Canaan Community Foundation, Norwalk Mayor's Water Quality Commission, Norwalk River Watershed Association, Town of Ridgefield, Town of Wilton, and Upwell Coffee. Additional support was provided by the generosity of individual donors. We thank our funders for their generous support, without which this work would not be possible!

4. Introduction

Harbor Watch is a water quality research and education program based out of Earthplace in Westport, CT. Our mission is to improve water quality and ecosystem health in Connecticut. In this report, we present data from monitoring conducted in 2023 on the fish and invertebrate community in Norwalk Harbor, Connecticut, led by Harbor Watch and monitoring of water quality conditions in 7 harbors along the Connecticut coast, led by Copps Island Oysters and East Norwalk Blue.

Harbor Watch began conducting a dissolved oxygen profile study in Norwalk Harbor in 1986. A fish study of that harbor was added in 1990 under the guidance of the State of Connecticut's Department of Environmental Protection (now known as the Department of Energy and Environmental Protection) Fisheries Bureau. Since then, the program has grown to include the study of 7 harbors annually for dissolved oxygen conditions and a study of the Norwalk Harbor for species diversity and abundance.

From April through September 2023, water quality data were collected in 7 harbors (Stamford, Five Mile River, Norwalk, Saugatuck, Bridgeport, Housatonic Estuary, and New Haven Harbor), and, from May through October, the fish study was conducted in one harbor (Norwalk). All 7 harbors were monitored for dissolved oxygen, salinity, water temperature, and water clarity. Dissolved oxygen is important for the survival of estuarine species; low oxygen or "hypoxic" conditions can impede the use of a harbor as habitat. Water temperature is another critical ecosystem parameter because many species require specific temperature ranges for spawning and survival. Additionally, fish can be used as an indicator of harbor health and the harbor's functionality as a refuge.

5. Norwalk Harbor Fish Survey

Report written by: Marisa Olavarria and Nicole C. Spiller (Harbor Watch, Earthplace Inc., Westport, CT 06880)

Norwalk Harbor is an active harbor, used year-round both commercially and recreationally. The harbor is most recognized for its renowned shellfishing industry, which has risen to national prominence since the 1800s. Within the local community, the harbor is also known for its beaches, dining, boating, and other attractions. Positioned just outside the harbor are the Norwalk Islands, which help to protect the inner harbor from the effects of extreme weather events like hurricanes. These islands are part of the Stewart B. McKinney National Wildlife Refuge and serve valuable and important environmental roles to the harbor (Steadman et al., 2016).

During Harbor Watch's 33 years of studying fish in the harbor, there has been a notable increase in development along the harbor banks. As a result of shoreline hardening, there has been a reduction in riparian buffer and loss of salt marshes (personal observations, R. Harris). These factors have potentially contributed to an altered composition of the benthos, from healthy microalgal populations to a silty bottom, particularly in the upper harbor. A shift in animal species found in Norwalk Harbor has also been observed. There appears to have been an increase of Canada geese, osprey, swans, and cormorants with a noticeable decline in black-crowned night herons, green herons, and snowy egrets (personal observations, R. Harris). Similarly, Harbor Watch has observed changes in fish diversity since 1990 (Figure 5.1).

Estuaries are one of the most productive ecosystems on Earth, rivaling tropical rainforests (Havens et al., 2012). These ecosystems have high biodiversity, meaning they support a great number of species by providing refuge, habitat, food, and other services. Some of these species are commercially important such as Winter Flounder (*Pseudoplueronectes americanus*), which rely on the proper functioning of the entire estuary in order to be healthy and abundant. Therefore, the health of estuaries is very important, and because of their sensitivity to environmental conditions, fish can be used as an indicator of estuarine health. Unfortunately, during recent years, abundance (catch per trawl) has declined dramatically for Winter Flounder, demonstrating a shift in the health of the Norwalk Harbor (Crosby et al., 2018c).

Harbor Watch and a dedicated network of volunteers, including the Wilton High School Marine Biology Club, have been quantifying the abundance and species composition of fish and invertebrates in Norwalk Harbor, focusing on demersal species. Sampling was conducted from 1990 through 1994, and then again from 2002 to today. It should be noted that the inner harbor was dredged in 2006 and the outer harbor was dredged in 2010 which may have impacted the study (Figure 5.1). In 2020, the monitoring season did not begin until July due to the COVID-19 pandemic which resulted in a shorter season than other years.

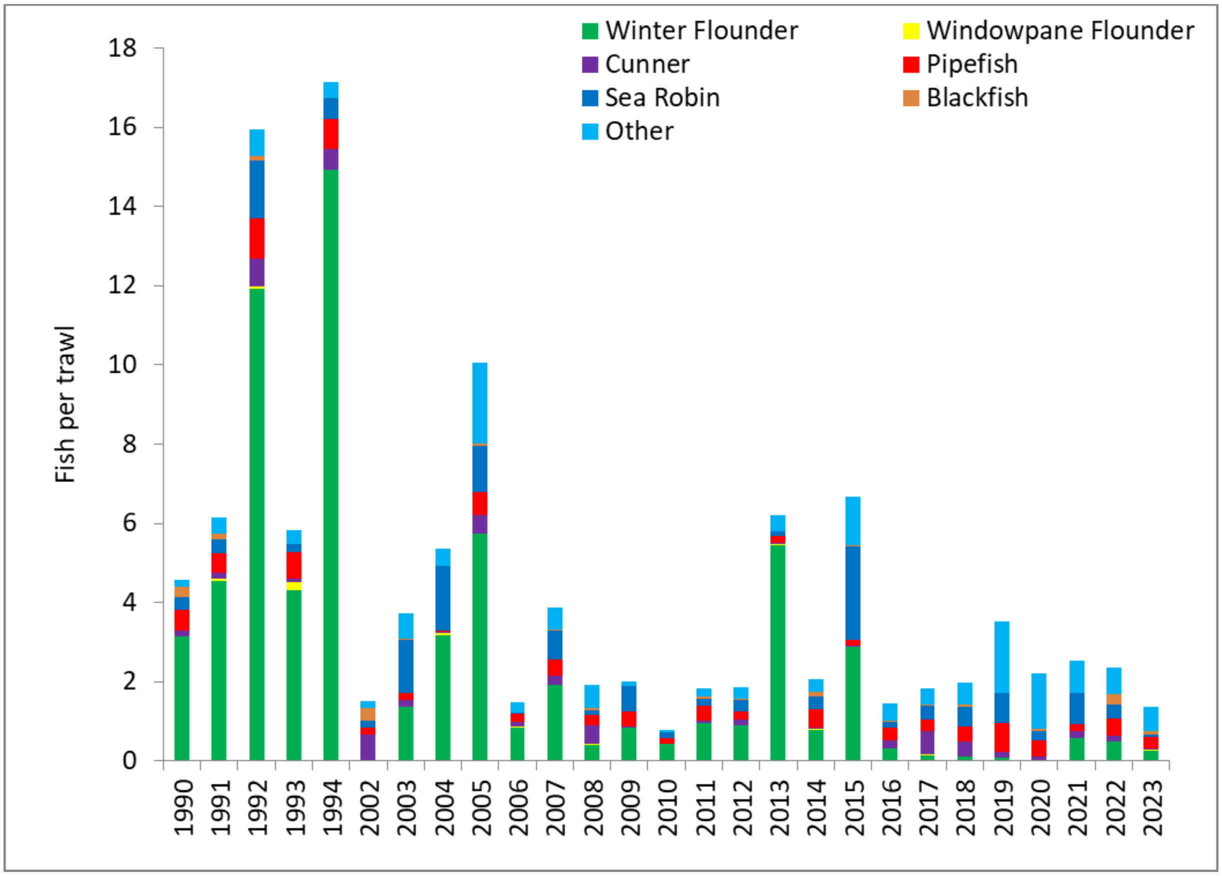


Figure 5.1. Number of fish caught per trawl (total number of individuals divided by total number of trawls) of select species of interest from 1990 to 2023 in Norwalk Harbor.

A. Norwalk Harbor Fish Survey Methods

Protocols used in trawling events followed those in Quality Assurance Project Plan (QAPP) QA Tracking #23075 for 1m Beam Trawl Harbor Survey in Norwalk Harbor approved by the EPA on 3/9/23.

Trawling was conducted from a 28' Brockway Scow equipped with a pot hauler for trawl retrieval. The crew was comprised of 2 Harbor Watch staff members who served as pilot and deck hand. They were joined by up to 6 additional staff and/or trained volunteers to assist the deck hand. A grid system that divided the harbor into twenty 300m² sampling areas (Figure 5.2) was used to identify the location in the harbor where each trawl was conducted. This grid system was established by the CT DEEP in 1990 when the study started. During each trawling session, typically a minimum of 3 of those 20 "boxes" were selected to trawl. An attempt was made to sample from each of the upper harbor (box A-F), middle harbor (box G-N), and outer harbor (box O-T), but due to the height of the vessel, sometimes the upper harbor was inaccessible because the vessel could not fit under the bridge during high tide. When the research vessel was positioned within the selected box using a SIMRAD navigational system, the

1m beam trawl was launched off the port stern. The trawl, which was connected to the boat by approximately 13 meters of line, was equipped with a tapered ¼" mesh net, tickler chain, and rescue buoy. Each box was trawled for 3 minutes at 3 miles per hour. Coordinates were recorded where the trawl was launched and where it was retrieved. At the end of 3 minutes, the trawl was pulled back onto the boat using the pot hauler. The net was removed from the trawl beam and emptied into a sorting bin. The catch was recorded by species and the number of individuals caught. The total length of each individual fish caught was also recorded to the nearest millimeter using a ruler. Invertebrates were also identified and counted. All organisms present in each trawl net were returned to the harbor following identification and counting.

Over the study's 33 years, there has been slight variance in data collection due to weather patterns, fish kills, boat repairs, occasional requests from the CT DEEP for Harbor Watch to trawl outside of Norwalk Harbor, and a pandemic which disrupted trawling activity. To standardize the data and enable comparisons from year to year, data are reported as "catch per trawl" 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 (Figure 5.1).

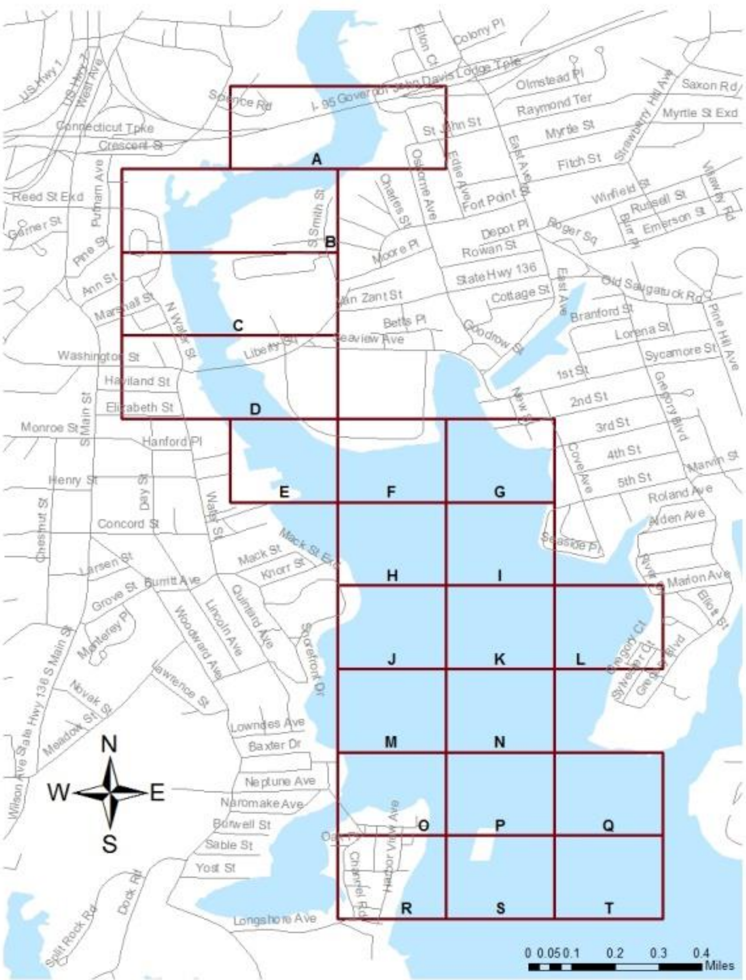


Figure 5.2. Location of trawl sampling areas or "boxes" within Norwalk Harbor.

B. Norwalk Harbor Fish Survey Results and Discussion

Fish

During the 2023 sampling season, 162 individual fish from 18 different species were caught in Norwalk Harbor (Figure 5.3). The 3 most abundant species caught in 2023 were Pipefish (*Syngnathus spp.*), Winter Flounder (*Pseudopleuronectes americanus*), and Goby (*Gobiosoma spp.*), which accounted for 56% of the total number of individuals (Figure 5.3). Fish were observed in all of the 19 boxes sampled (Figure 5.4). Box I had the greatest number of fish per trawl during 2023 with 32 individuals caught in seven trawls. One trawl was conducted in two boxes (D/E) due to submarine cables and railroad bridge construction. No trawls were conducted in Box C due to submarine cables as well. While sampling was typically conducted in the upper, middle, and outer harbor during each trawling trip, tidal cycles impeded access to particular boxes (Table 5.1).

Table 5.1. Total number of trawls per box, May through October 2023.

Box	Number of Trawls
A	6
B	6
C	0
D	5
E	7
F	6
G	7
H	8
I	7
J	6
K	6
L	6
M	5
N	7
O	6
P	7
Q	7
R	4
S	6
T	7
D/E	1

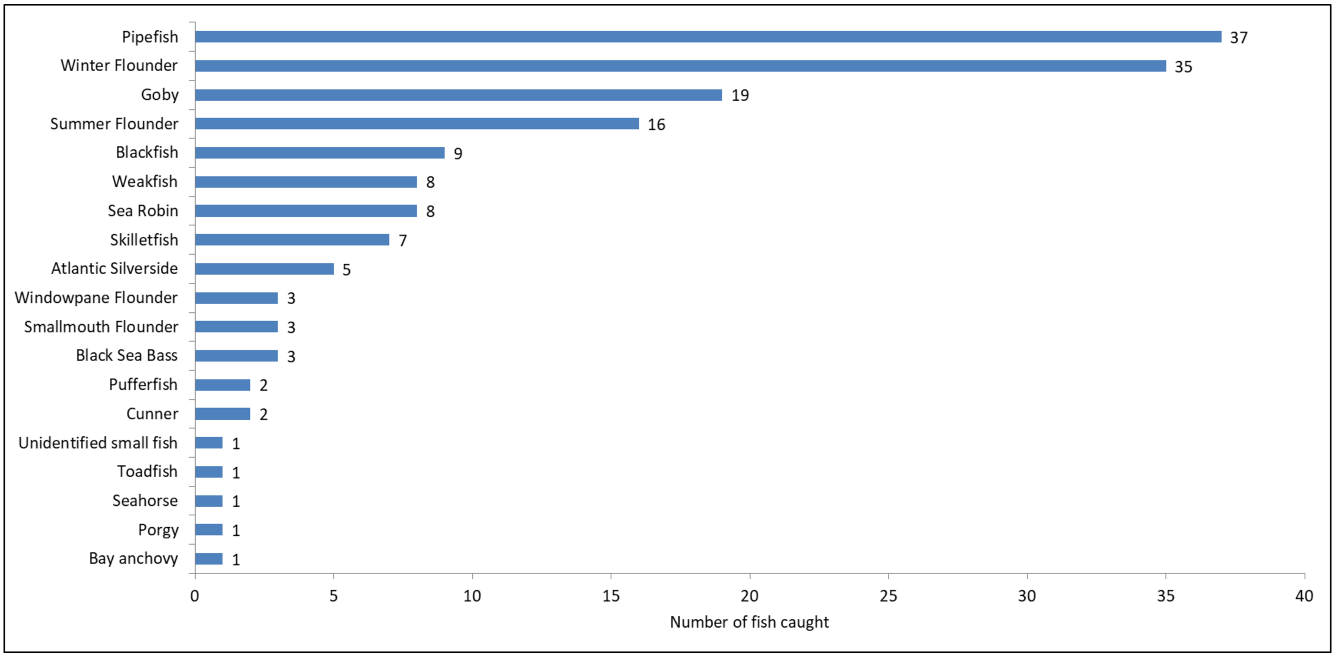


Figure 5.3. Total number of individuals caught for each species in Norwalk Harbor, May through October 2023.

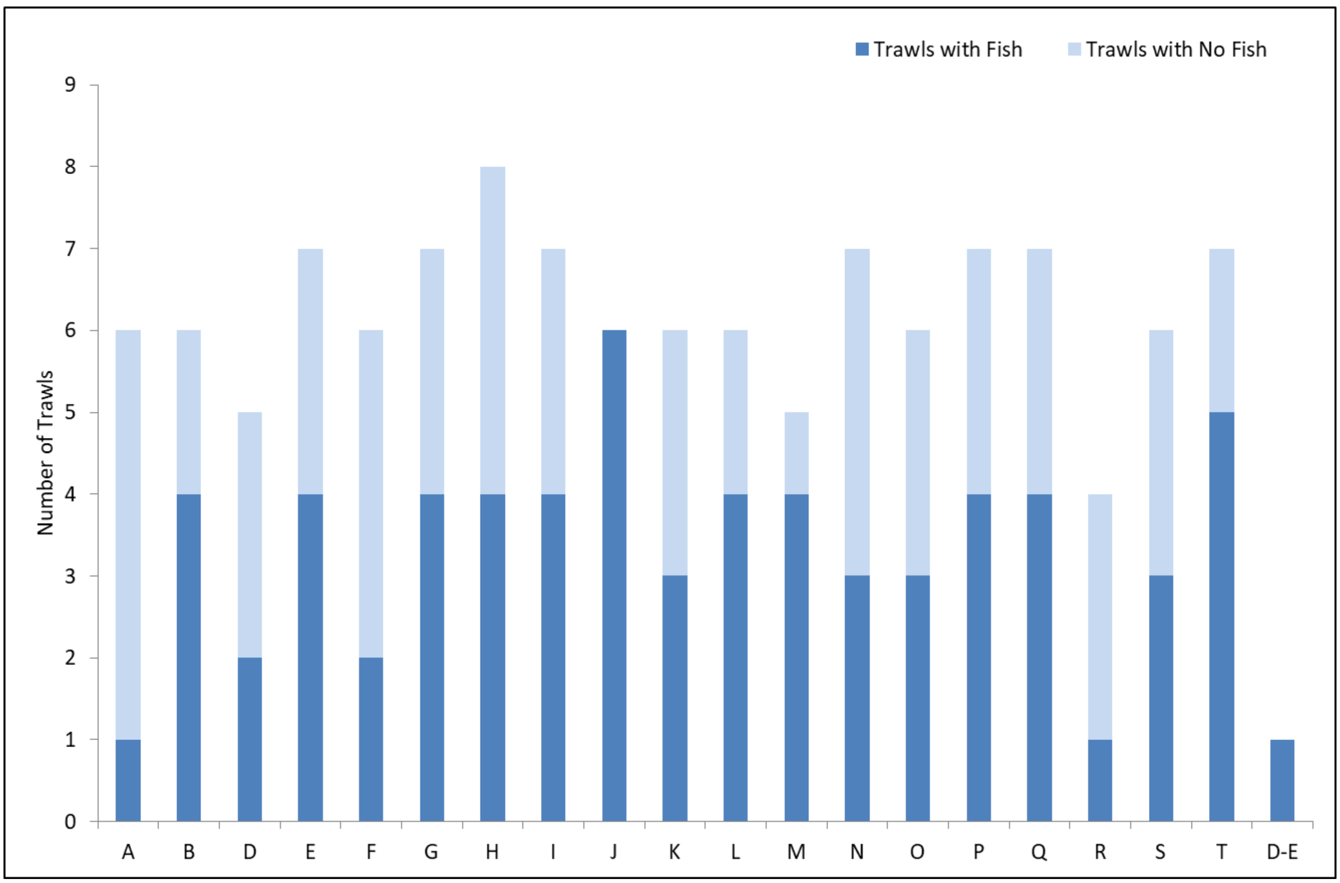


Figure 5.4. Number of trawls with fish or without fish in each "box" in Norwalk Harbor, May through October 2023.

The overall number of fish per trawl in 2023 was 1.35 fish which is 1.01 lower than the fish per trawl in 2022 (Table 5.2). In 2023, 120 trawls were conducted, the highest number in a single year since the study began (Table 5.2). However, the total number of fish caught in 2023 is 105 less than in 2022 (Table 5.2). Potential drivers of the apparent decline in catch over time may include increasing water temperature, low dissolved oxygen values, or predation from other species inhabiting the estuary (with an observed increase in the number of cormorants; personal observation R.B. Harris). Also, in 2023 there were no completely empty nets brought up, a first in this study since its inception. This study is expected to continue in 2024 to provide additional data to this long-term dataset, as well as expand the study into other nearby harbors.

Table 5.2 Trawling stats from 1990 to 2023 in Norwalk Harbor

Year	Total Fish Caught	Total Trawls	Catch Per Unit	Total Empty Nets	Percent Empty Nets	Number of Species
1990	215	47	4.57	12	26%	9
1991	402	66	6.09	17	26%	13
1992	954	60	15.90	8	13%	15
1993	455	81	5.62	14	17%	12
1994	514	30	17.13	6	20%	10
2002	9	6	1.50	1	17%	5
2003	182	49	3.71	12	24%	17
2004	323	61	5.30	5	8%	14
2005	473	47	10.06	4	9%	15
2006	99	68	1.46	35	51%	8
2007	85	22	3.86	7	32%	10
2008	90	48	1.88	19	40%	15
2009	131	65	2.02	18	28%	11
2010	53	67	0.79	37	55%	6
2011	177	97	1.82	31	32%	13
2012	138	74	1.86	23	31%	14
2013	524	85	6.16	24	28%	13
2014	156	78	2.00	29	37%	13
2015	499	75	6.65	16	21%	17
2016	119	82	1.45	40	49%	12
2017	138	76	1.82	30	39%	17
2018	148	75	1.97	34	45%	14
2019	249	71	3.51	22	31%	17
2020	130	59	2.20	23	39%	20
2021	171	68	2.51	23	34%	16
2022	267	113	2.36	41	36%	23
2023	162	120	1.35	0	0%	18

Crustaceans

In 2023, 10,139 individual crustaceans representing 16 species were observed. Certain individual shrimp were too small to confidently identify so they were documented as "Juvenile Shrimp." The catch was dominated by Shore Shrimp, Sand Shrimp, and Mud Crabs, accounting for approximately 79% of the total (Figure 5.5). Individual speciation for mud crabs and spider crabs was not conducted. The "Mud crab" identification represents potentially four species (*Panopeus herbsti, Hexapanopeus angustifrons, Neopanopeus sayi, and Eurypanopeus depresssus)* but was likely dominated by black fingered mud crab (*Panopeus herbsti*). The "Spider crab" identification represents potentially two species (*Libinia emarginata* and *Libinia dubia*) but was likely dominated by the nine-spined spider crab (*Libinia emarginata*). Other notable catches during the monitoring season include Asian shrimp (Palaemon macrodactylus), an invasive species (Carlton, 2022) which has been observed in Long Island Sound as early as 2001 but has not been previously recorded by Harbor Watch, European rockpool shrimp, the first of which Harbor Watch caught in 2022, chameleon shrimp (*Hippolyte zostericola*; previously documented as zostera shrimp in Harbor Health Study: 2022) which is a common shrimp to Long Island Sound but being observed with more frequency in Norwalk Harbor since 2022, and mantis shrimp which were caught approximately 3 times more in 2023 than in 2022. In total, 8 different shrimp species were observed in the 2023 trawling season.

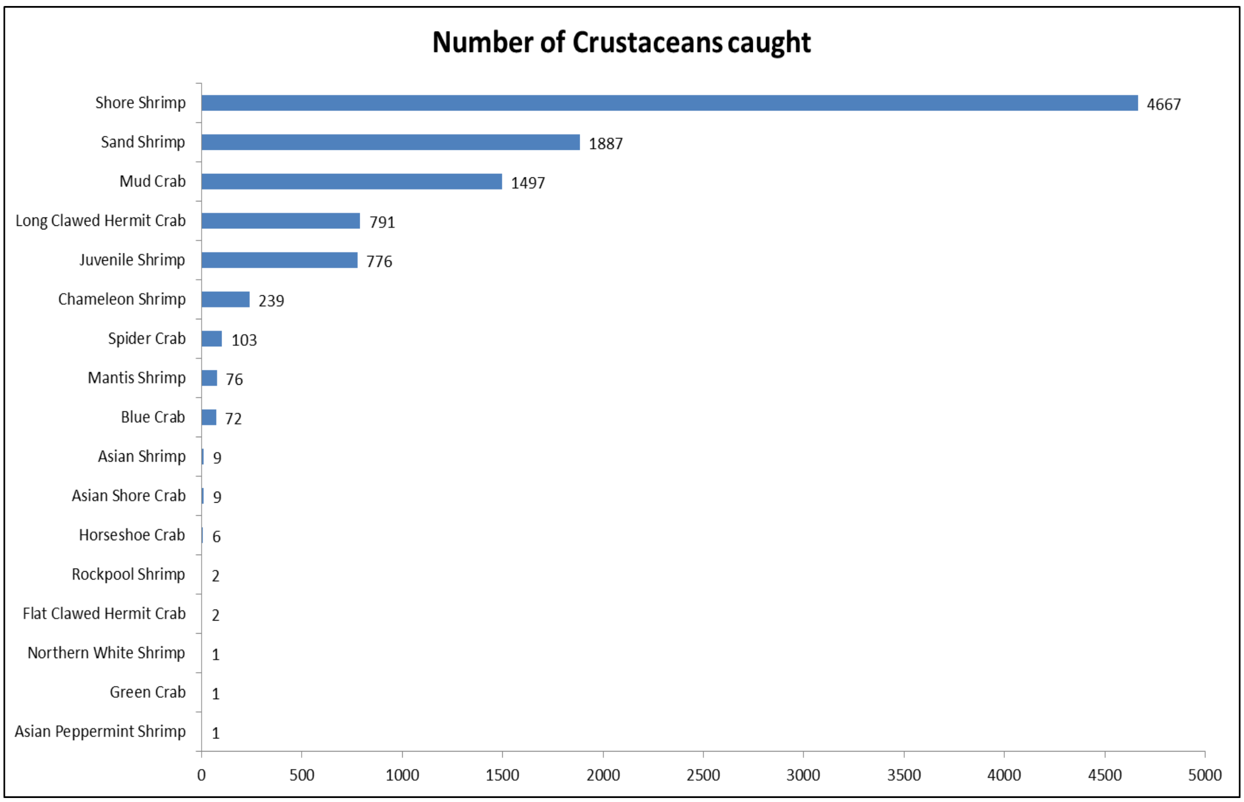


Figure 5.5. Crustaceans caught in Norwalk Harbor from May through October 2023.

6. Water Quality Surveys

Report written by: Marisa Olavarria[1], Nicole C. Spiller[1], and Richard B. Harris[2]
([1]Harbor Watch, Earthplace Inc., Westport, CT 06880; [2]Copps Island Oysters, Norwalk, CT 06855)

Stamford Harbor, Five Mile River Harbor, Norwalk Harbor, Saugatuck Harbor, Bridgeport Harbor (Johnsons Creek and Lewis Gut sections), Housatonic Estuary, and New Haven Harbor (Quinnipiac River section) were studied in 2023. These harbors are used year-round for recreational activities such as boating, swimming, and fishing as well as for commercial activities and play an important role in the Long Island Sound shellfish industry. In 2023, monitoring of these 7 harbors was led by Richard Harris (formerly of Harbor Watch, now on staff at Copps Island Oysters), with assistance from volunteers.

Water quality surveys were conducted to evaluate harbor health and assess their ability to support marine life and in particular shellfish beds. The parameters measured in this study included dissolved oxygen, salinity, water temperature, and water clarity. In 2023, Norwalk Harbor had the greatest percentage of dissolved oxygen observations below 3 mg/L (9%) of the 7 harbors studied (Figure 6.1), indicative of hypoxic conditions that may be harmful to marine life. Norwalk Harbor has a history of extended periods of hypoxia in the upper reaches of the harbor. Hypoxia (defined as values < 3 mg/L) was not observed in Stamford Harbor, Five Mile River Harbor, Housatonic Estuary, or New Haven Harbor during this year's sampling. Saugatuck and Bridgeport Harbors had 1% of observations less than 3 mg/L during the monitoring season. In recent years, conditions have varied across the harbors studied. In 2017, 81% of all sampling events had dissolved oxygen values at the harbor bottom above 3 mg/L (Crosby et al., 2018b). In 2018, conditions overall had improved, and in the following years, 93-97% of the observed bottom dissolved oxygen levels in all harbors monitored were observed to be above 3 mg/L each year (Crosby et al., 2018c, 2019b, 2020, 2021; Spiller et al., 2022). In 2023, 97% of all sampling events had dissolved oxygen values at the harbor bottom above 3 mg/L.

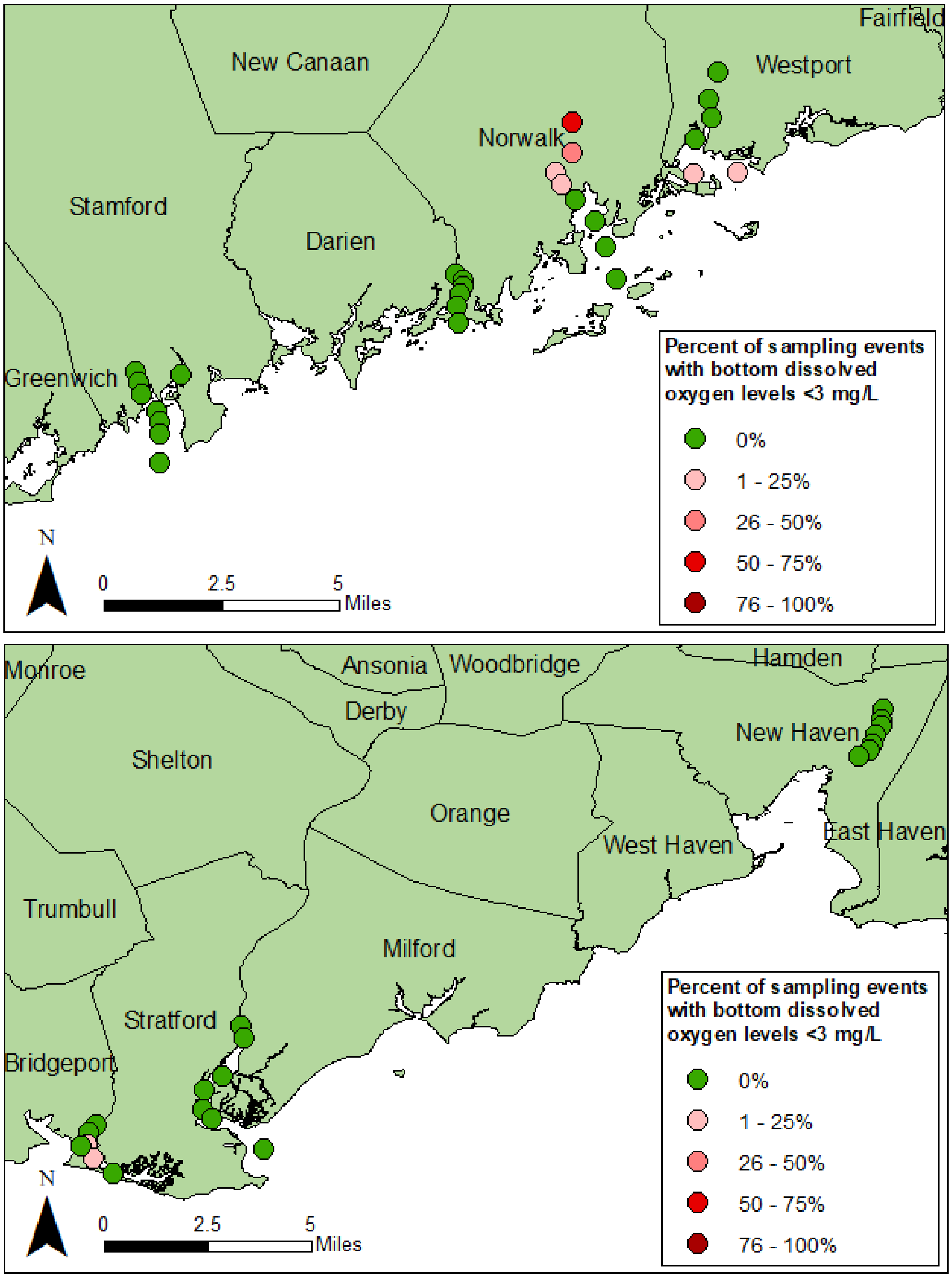


Figure 6.1. Percentage of readings where bottom dissolved oxygen values fell below 3 mg/L in 2023 in the western harbors (top) and the eastern harbors (bottom).

The harbors monitored in this study are estuaries, which are marine embayments with a freshwater source resulting in brackish water. The mixing of these freshwater and saltwater sources in many harbors consists of a “tidal wedge” (Figure 6.2), which is comprised of salt water underlying a freshwater surface layer, which is usually incoming water from a river. The more dense salt water layer oscillates laterally within the harbor in response to the semidiurnal tides. Because of this density-driven stratification within estuaries, the bottom water often becomes depleted of dissolved oxygen when exposed to oxygen demanding (reducing) bottom sediments and poor flushing. As fresh water moves seaward above the tidal wedge, salt water is entrained in the freshwater layer, reducing the stratification. This mixing of fresh and salt water occurs along the length of a harbor, with the salinity of the surface layer increasing as the distance from the freshwater source increases. Mixing of the salt water from the tidal wedge (Figure 6.2) causes a fresh flow of marine water to enter from the mouth of the estuary, bringing nutrients and oxygen with it.

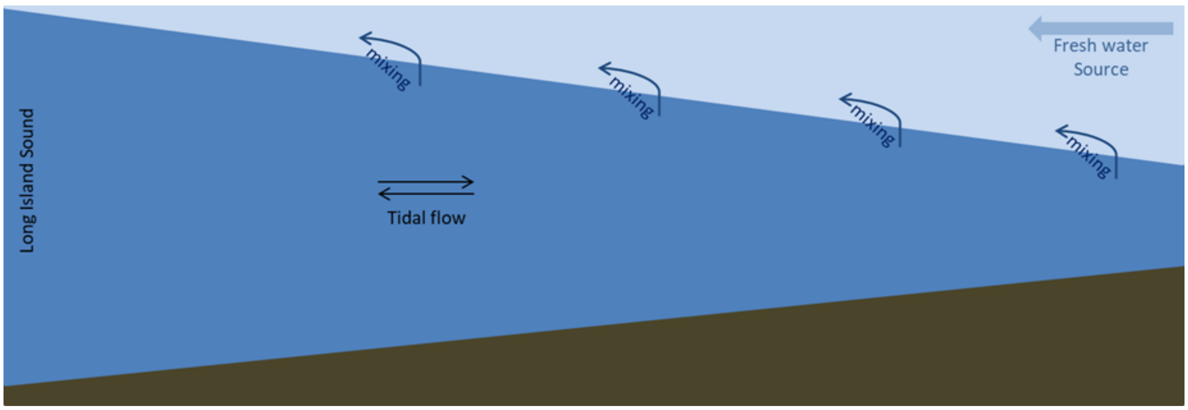


Figure 6.2. Sketch of estuary tidal wedge, water flow, and water column mixing.

Another factor assisting with the flushing of an estuary is the presence of salt marshes. Marshes provide large expanses of low-lying land that serve as a biological filter for the water flowing over and through them during flood tides. Ebb tides return this large volume of marine water to the main harbor channel, where it is then flushed out of the estuary. Unfortunately, all too often these valuable natural resources are filled in for shoreline development and are replaced with man-made bulk-heading. Three harbors monitored in this study, where large marshes are present and contribute to the improvement of local water quality, are New Haven Harbor (Quinnipiac River section), Bridgeport Harbor (Lewis Gut section), and the Housatonic River. In many harbors throughout New England, the majority of historic salt marshes have been reduced or lost (Bromberg and Bertness 2005).

Two natural forces that can affect flushing in a harbor are winds and air temperature. Strong winds, especially from the north, facilitate the movement of the surface layer of water seaward, and decreases in air temperature can drive vertical mixing by increasing the density of the surface waters causing them to sink. As the surface water sinks (downwelling), it causes the (often oxygen-depleted) bottom waters to be forced upward (upwelling). This vertical movement of water can help to increase oxygen concentrations at the bottom of the harbor.

Rainfall can have negative or positive effects on hypoxia in the harbors. Rain adds water to the system, which increases the flow and turbulence of the water on the surface which is one way for rivers and harbors to renew dissolved oxygen in the water column. Rain also increases flow within a river system which can increase vertical mixing and promote cycling within the tidal wedge, in turn increasing dissolved oxygen levels. Conversely, rain can be a conduit to flush nutrients and other pollutants into a waterway via runoff which negatively impacts dissolved oxygen levels. Excess nutrients (eutrophication) can cause plant growth which will initially add oxygen to the system, but as the plants begin to die and decompose the available dissolved oxygen is consumed, causing stressful conditions for many marine species.

Monthly rainfall from May to September in 2022 and 2023 varied greatly (Figure 6.3). In 2022 there was higher rainfall in both May and June. This trend flips from July to September where total rainfall is much higher in 2023 than experienced in 2022. The total rainfall in 2023 from May to September is 11.78 inches greater than in 2022. This difference is reflected in the discharge (cubic feet per second) observed in the rivers that feed the harbors studied (see hydrographs in following sections).

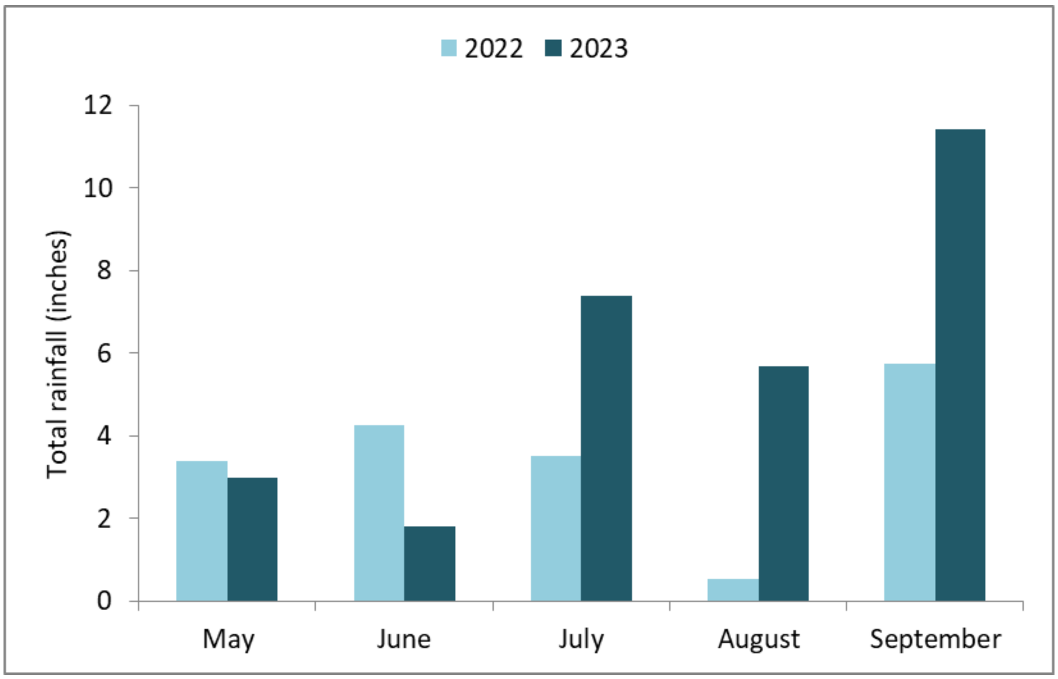


Figure 6.3. Monthly rainfall totals for 2022 and 2023 in Norwalk (Norwalk Health Department, n.d.).

In the following sections, we present a data summary of each of the 7 harbors monitored. Please note that the duration of the sampling season varied slightly among harbors, such that mean values for the studied parameters may not be directly comparable among them. In particular, some harbors' datasets started later in the summer than others or had wider gaps between sampling events and as a result may have been less likely to capture oxygen-rich and/or low temperature conditions. These temporal differences should be kept in mind when interpreting the data and when comparing results with those of prior years.

A. Water Quality Survey Methods

Water Quality Profiling:

Seasonal monitoring was conducted in each of the 7 harbors between April and September by Richard Harris, employees of Copps Island Oysters and East Norwalk Blue, and volunteers. Each harbor had six to eight monitoring stations which were each tested a minimum of four times. Protocols used in all harbor surveys were designed to follow those in Quality Assurance Project Plan (QAPP) Embayment Profile Surveys (previously approved by EPA, but not renewed in 2023 because no federal funds were used for this project). Only one slight deviation from the QAPP was encountered in 2023. Stamford Harbor was only sampled 4 times, and did not meet the minimum 5 times due inability to get the boat to the harbor.

Testing for each harbor was conducted in the early to mid-morning on each monitoring day. A research vessel, staffed with a project leader (usually Richard Harris) and a crew of trained staff or volunteers proceeded to the first station in the estuary to begin testing. The dissolved oxygen meter was calibrated at the first station according to the manufacturer's recommendation (as in the QAPP). The probe was then securely attached to a weighted PVC platform which facilitated vertical descent of the probe into the water column, especially where strong currents existed. The platform was lowered over the side of the research vessel at each station and readings for dissolved oxygen, salinity, and temperature were recorded at the surface. Then the platform was lowered to a half meter below the surface and readings were recorded again. Readings were then recorded at each full meter interval below the surface until the bottom was reached. Ancillary data collection included readings for barometric pressure (first and last station only), wind speed with a Dwyer wind speed gauge, water clarity with a Secchi disk, air temperature with a Fisherbrand™ pocket thermometer, and a visual estimate of wave height.

Monitoring was typically conducted sequentially for all stations, unless the tide cycle or swift currents during sampling dictated otherwise. The calibration was checked on the dissolved oxygen meter at the end of each survey to assure that significant calibration drift (± 2%) did not occur. Harbor surveys were completed within approximately 2 hours on each monitoring day.

B. Water Quality Survey Results and Discussion

1. Stamford Harbor

Stamford Harbor is a large estuary with two freshwater sources discharging to two main channels, the east branch and the west branch. The west branch receives the freshwater discharge of the Rippowam River, whereas the east branch receives approximately 24 million gallons per day in discharge of treated effluent from the Stamford wastewater treatment plant (City of Stamford Website: “The Plant”). With the exception of differences in freshwater input, both east and west branches are similar regarding anthropogenic use of the shoreline. Both channels are largely devoid of natural riparian features, which have long since been replaced by shoreline fill and commercial bulk-heading that has been punctuated with storm drain outfalls. Commercial sand and gravel and industrial facilities are located near the northern ends on both branches (Figure B1.1). Industrial uses requiring barge deliveries and tug boat traffic can be heavy at times in these restricted waterways. Down both branches and below the industrial sections, there is a change in land use. The west branch has marinas on both shorelines while the east branch has marinas on its east bank with Kosciuszko Park on the opposite shore.

Figure B1.1. Industrial development and barge traffic on the east branch of Stamford Harbor.

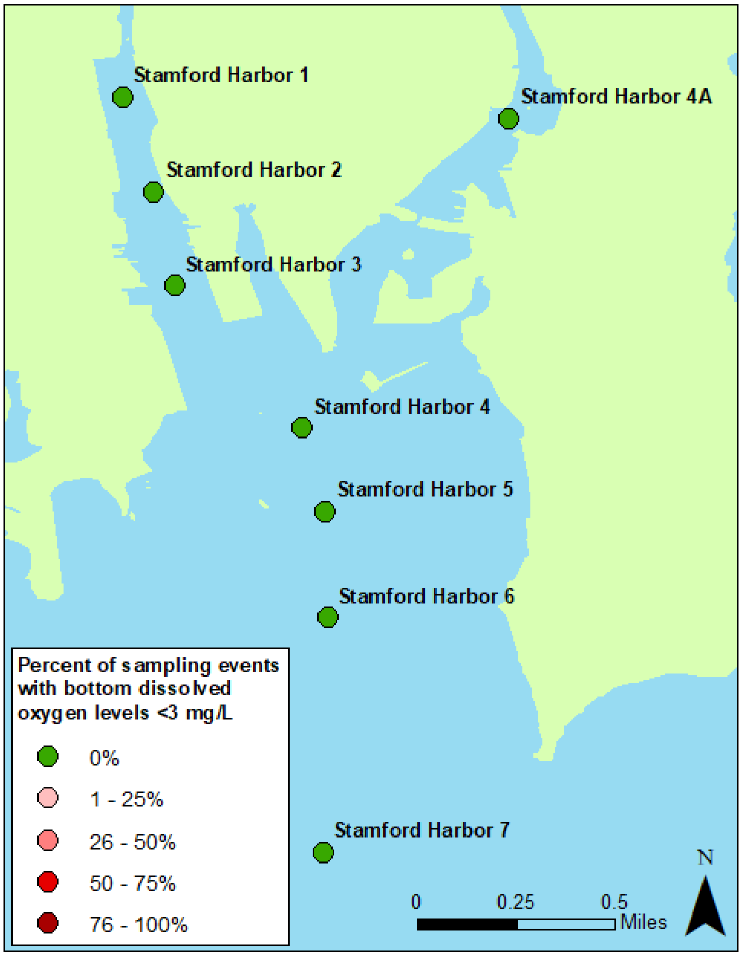


Figure B1.2. Map of Stamford Harbor sampling stations for 2023. Color of dots represents the percent of sampling events with bottom dissolved oxygen levels less than 3 mg/L.

Table B1.1. Coordinates and descriptions for each sampling station in Stamford Harbor

Site Name	Latitude	Longitude	Description
Stamford Harbor 1	41.041283	-73.545000	Off Sand and Gravel Facility
Stamford Harbor 2	41.037817	-73.543833	Stamford Harbor West Branch Channel Buoy #10
Stamford Harbor 3	41.034350	-73.543083	Stamford Harbor West Branch Channel Buoy #7
Stamford Harbor 4A	41.040500	-73.530850	East branch off Woodland Cemetery
Stamford Harbor 4	41.029150	-73.538400	Stamford Harbor West Branch Channel Buoy #1
Stamford Harbor 5	41.026100	-73.537550	Stamford Harbor Channel Buoy #9
Stamford Harbor 6	41.022183	-73.537450	Stamford Harbor Channel Buoy #7
Stamford Harbor 7	41.013600	-73.537650	No Wake Buoy

Dissolved Oxygen
Profiles of the water column were taken at 8 sites along the length of the Harbor (Figure B1.2, Table B1.1). Sampling occurred on 4 days during the monitoring season from late May through early September. Mean dissolved oxygen values in Stamford Harbor ranged from a minimum of 5.39 mg/L on the bottom at Stamford Harbor 1 to a maximum of 7.53 mg/L on the surface at Stamford Harbor 6 (Figure B1.3). Over the course of the monitoring season, there was a seasonal downward trend in both the surface and bottom dissolved oxygen levels (Figure B1.4). There was no data collected for Stamford Harbor 7 on 6/27/23 due to impending storm. Of all of the bottom dissolved oxygen concentrations observed, 13% were less than 5 mg/L, and 0% were less than 3 mg/L (hypoxic).

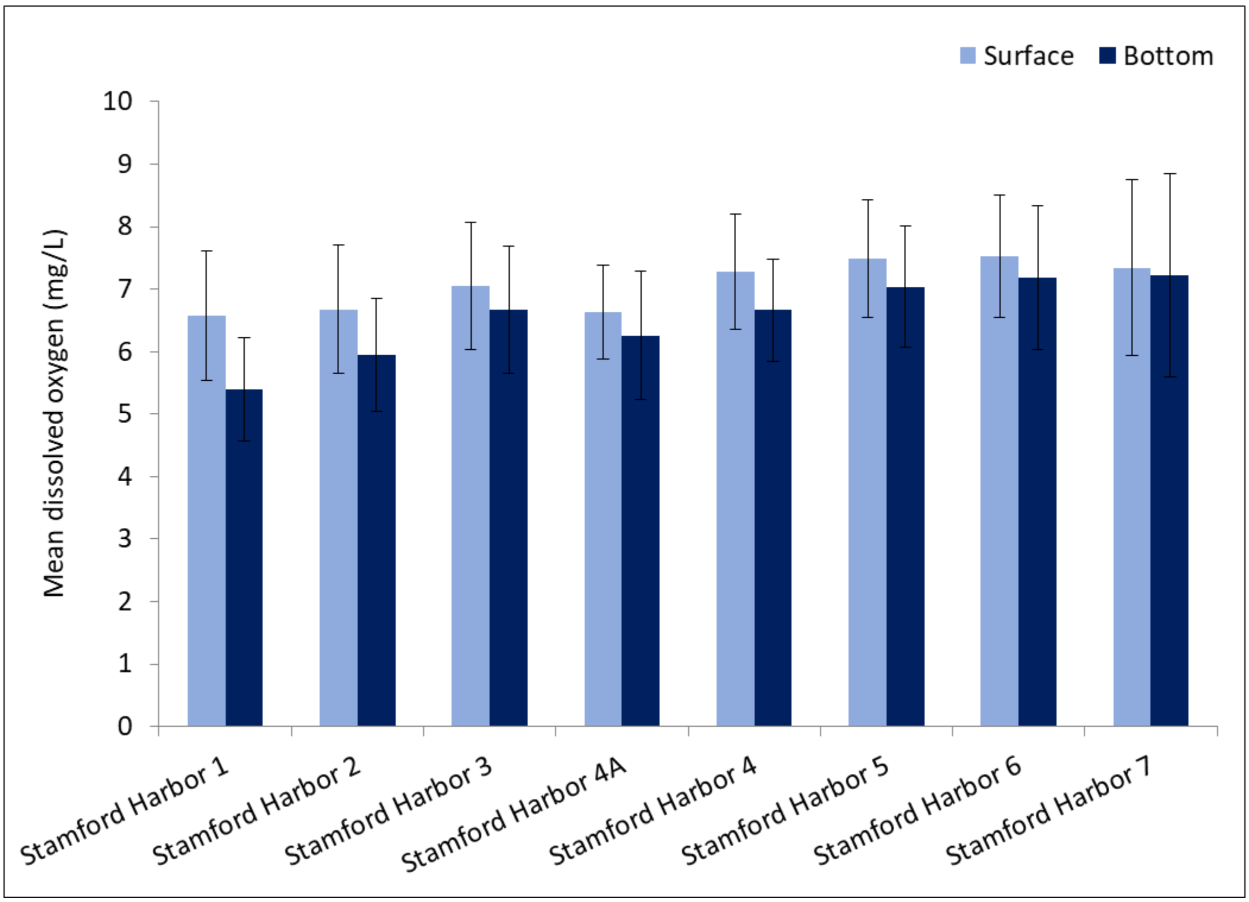


Figure B1.3. Mean dissolved oxygen concentrations at the surface and bottom at each sampling station in Stamford Harbor in 2023. Error bars represent standard error.

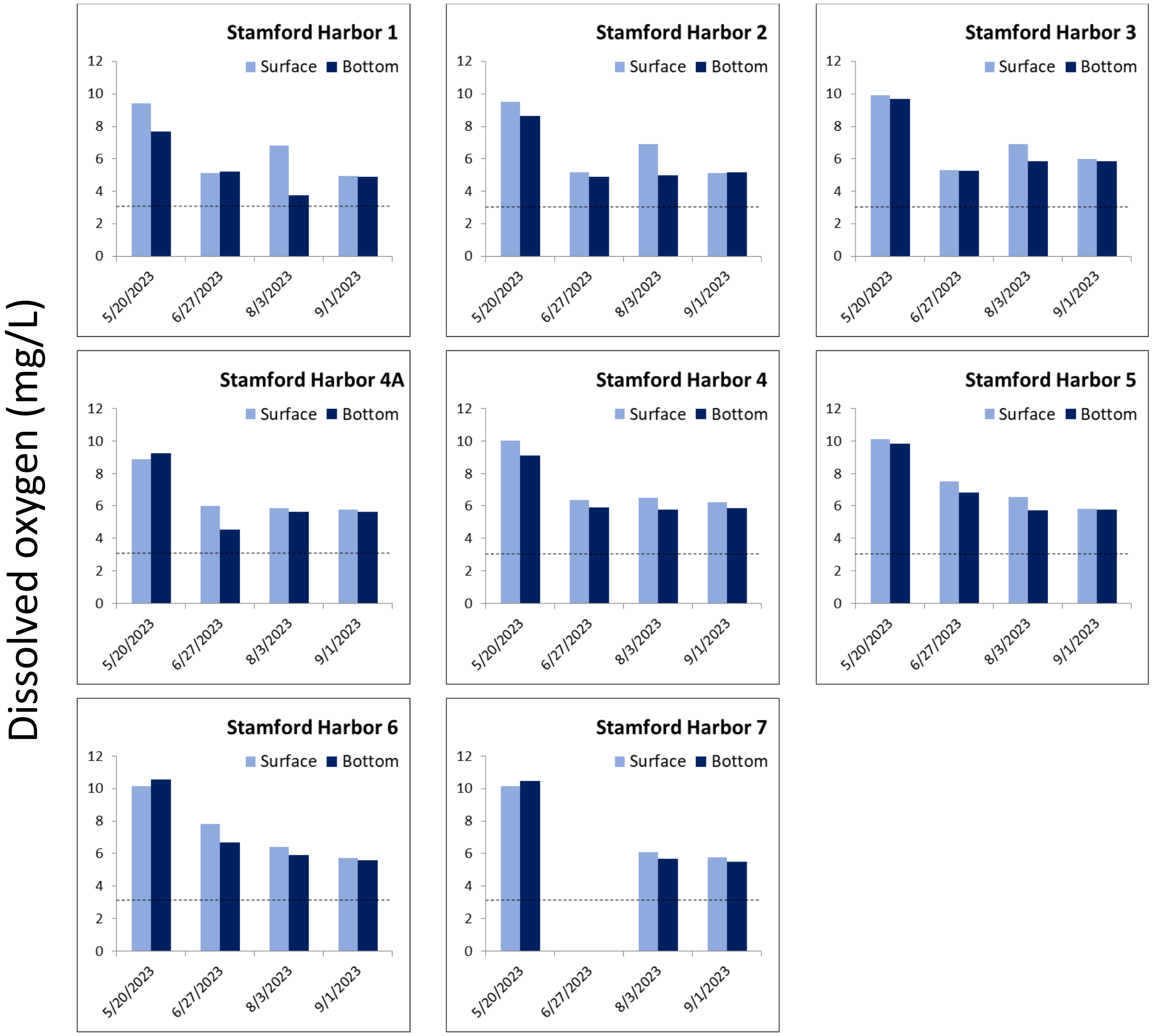


Figure B1.4. Surface and bottom dissolved oxygen values at each Stamford Harbor sampling station on each monitoring date during the 2023 season. The dotted line represents hypoxic conditions (3 mg/L). Please note x-axis is individual sampling dates, not a time scale.

Temperature and Salinity
Mean temperature differences observed between the surface and the bottom were similar throughout the harbor (Figure B1.5). Lower surface salinity at stations Stamford Harbor 1 and Stamford Harbor 4A is likely a result of riverine and stormwater inputs to the upper reaches of the harbor for the west branch, and a constant fresh water flow of treated sewage effluent, estimated at 24 million gallons per day, to the east branch (Figure B1.6).

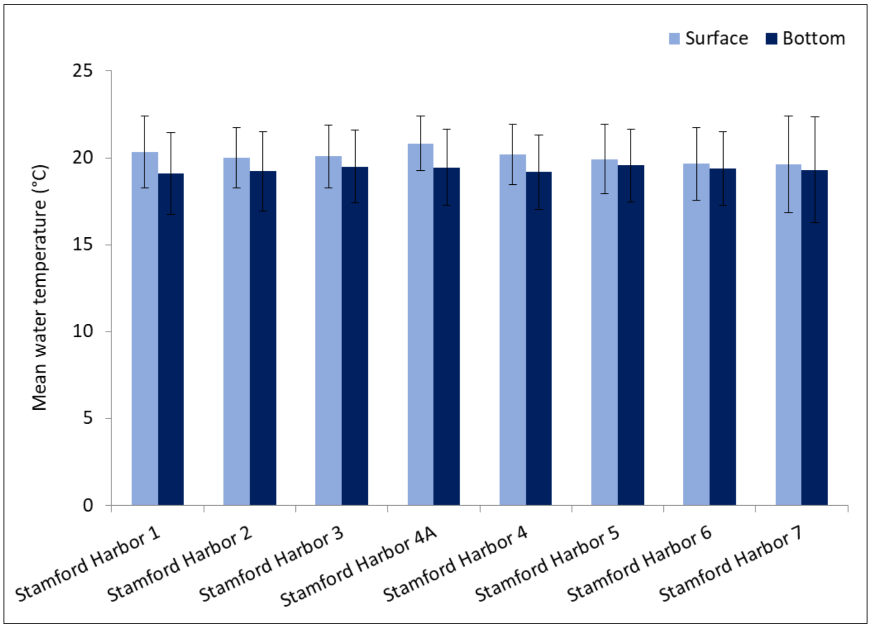


Figure B1.5. Mean water temperature at the surface and bottom at each sampling station in Stamford Harbor in 2023. Error bars represent standard error.

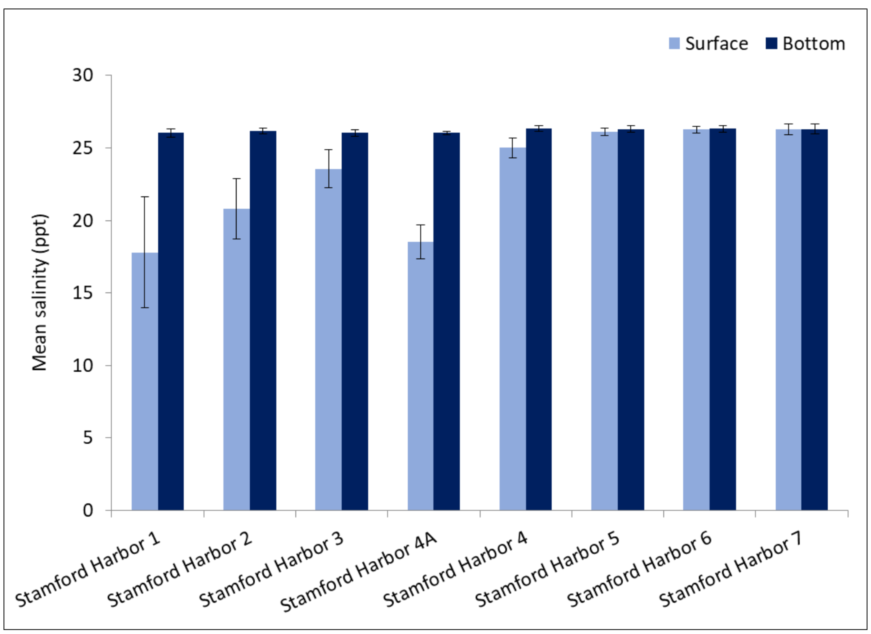


Figure B1.6. Mean salinity at the surface and bottom at each sampling station in Stamford Harbor in 2023. Error bars represent standard error.

Water Clarity

Mean secchi depth readings ranged from a minimum of 1.33m at station Stamford Harbor 2 to a maximum of 1.66m at station Stamford Harbor 7. Mean secchi depth values varied throughout the harbor (Figure B1.7).

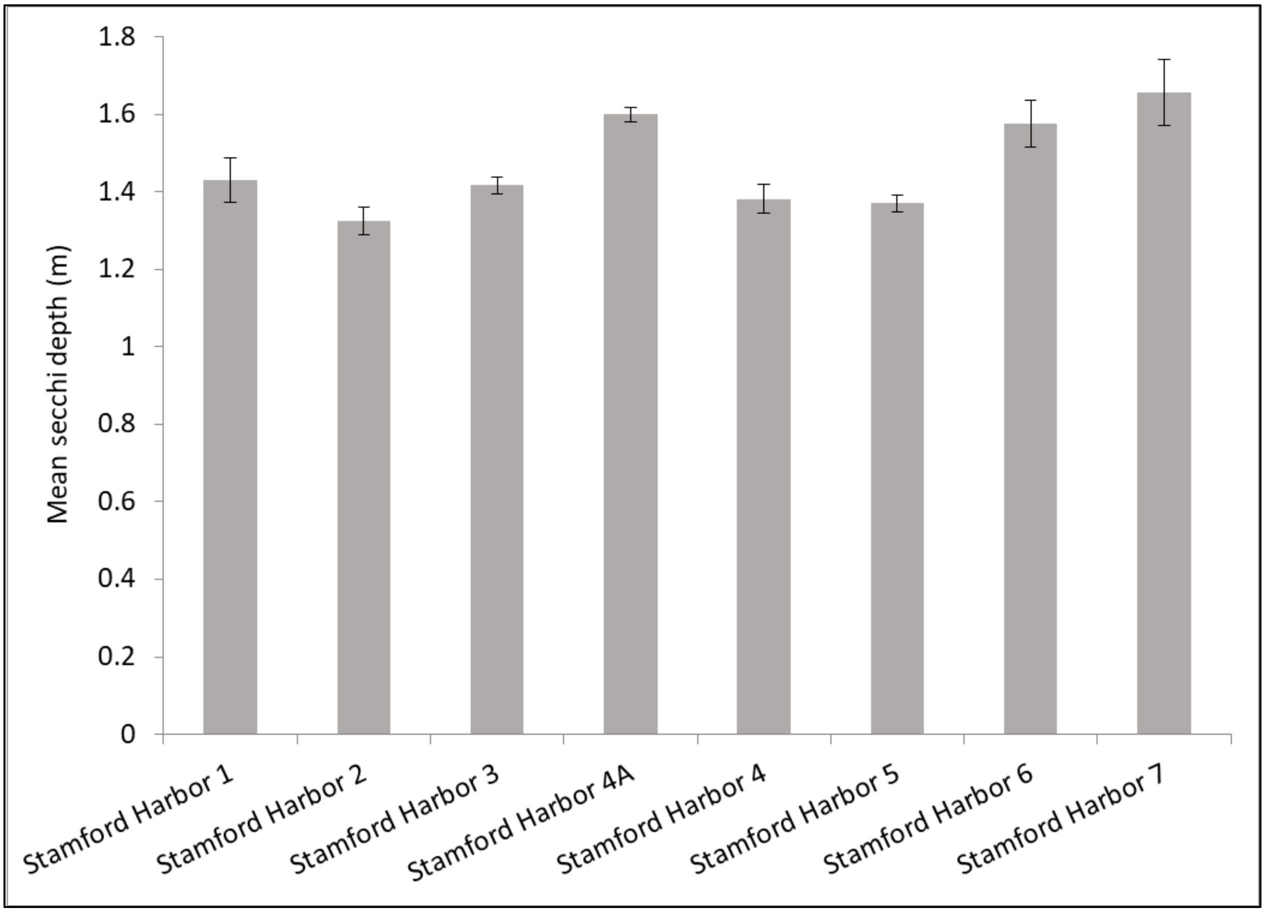
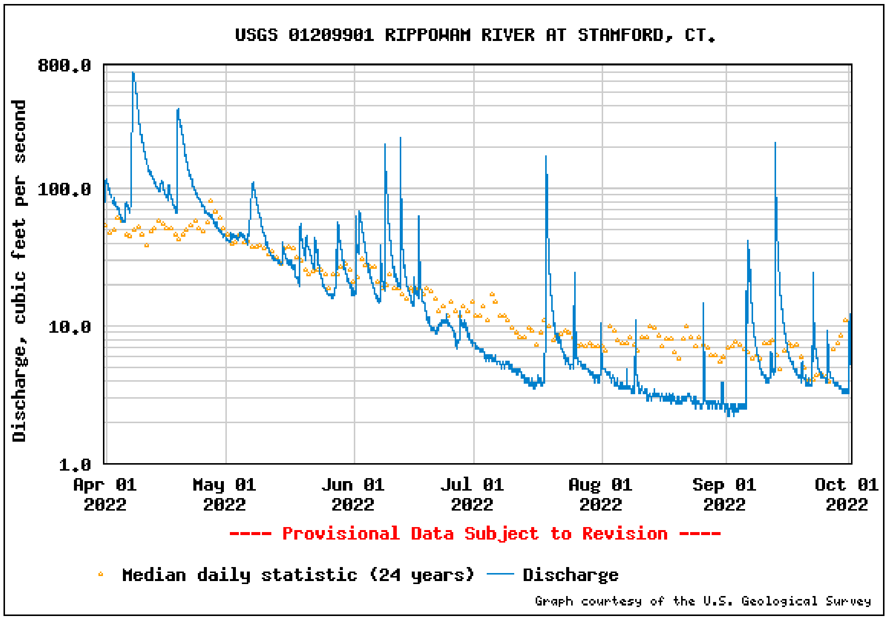


Figure B1.7. Mean secchi depth readings in Stamford Harbor in 2023. Error bars represent standard error.

Rippowam River Discharge

The figures below illustrate discharge in cubic feet per second recorded at the United States Geological Survey (USGS) monitoring station on the Rippowam River in Stamford, CT. Yellow triangles represent the daily median value over the last 24 years, and the blue line represents the recorded discharge for a particular date. In the summer of 2023, discharge was observed to be higher than was observed in 2022.



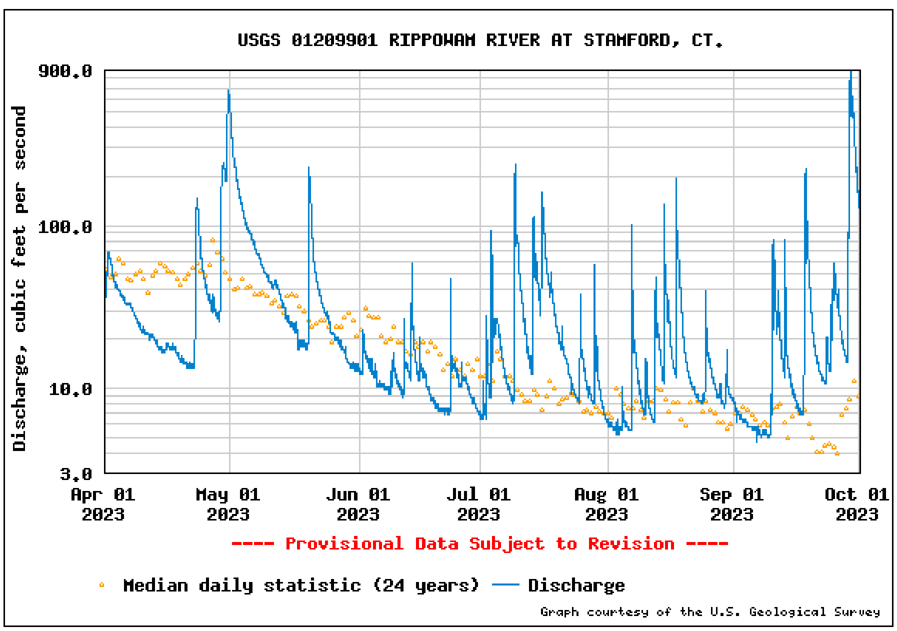


Figure B1.8. USGS flow data in ft^3/s for the period of April 1 through October 1, 2022 (top) and 2023 (bottom) for the Rippowam River near Stamford, CT (Graphs courtesy of the U.S. Geological Survey). Please note the difference in scale on the y-axis.

2. Five Mile River Harbor

Five Mile River Harbor forms the border between the City of Norwalk and the Town of Darien. It is approximately 2 miles long, and is supplied with fresh water from the Five Mile River with headwaters north of New Canaan, Connecticut. An additional source of fresh water to the estuary is Indian Creek, located on the east side of the harbor just north of station Five Mile Harbor 5 (Figure B2.1). Very little undeveloped shoreline and natural ecosystems (such as salt marshes) remain, most of which is located in the Tokeneke cut between stations Five Mile River Harbor 2 and Five Mile River Harbor 1. A flushing basin exists from Five Mile River Harbor 2 to Five Mile River Harbor 4 which may assist with flushing at ebb tide despite the loss of marshes and bulk heading. Land use along the shoreline of the harbor consists primarily of marinas and residential areas on the Norwalk side with large residential areas on the Darien side. The east side of the channel has been dredged by the U.S. Coast Guard for slips and moorings up to station Five Mile River Harbor 5, while the west side of the estuary remains too shallow to accommodate most vessels at low tide. In 2020, site Five Mile River Harbor 6 was added upstream of Five Mile River Harbor 5, with limited access only during high tide.

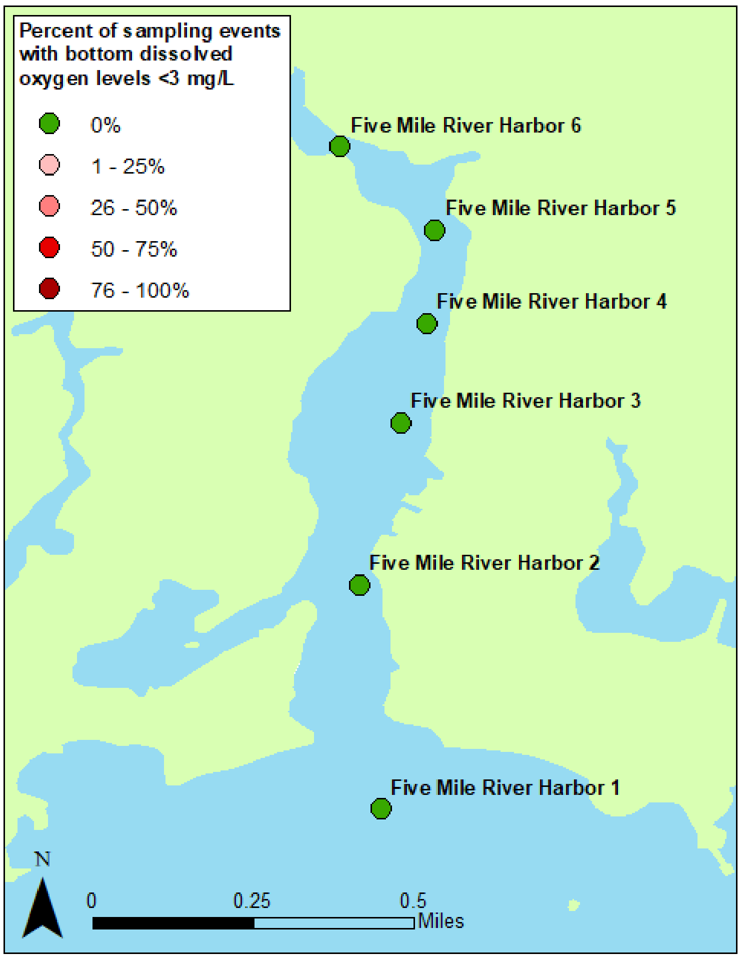


Figure B2.1. Map of Five Mile River Harbor sampling stations. Color of dots represents the percent of sampling events with bottom dissolved oxygen levels less than 3 mg/L in 2023.

Table B2.1. Coordinates and descriptions for each sampling station in Five Mile River Harbor

Site Name	Latitude	Longitude	Description
Five Mile River Harbor 6	41.071213	-73.446686	Dock at 59 5 Mile River Road
Five Mile River Harbor 5	41.069333	-73.444550	Mouth of Indian Creek
Five Mile River Harbor 4	41.067233	-73.444733	DownUnder Kayaking dock
Five Mile River Harbor 3	41.064967	-73.445317	Five Mile River Works
Five Mile River Harbor 2	41.061317	-73.446250	Buoy 6
Five Mile River Harbor 1	41.056250	-73.445767	Buoy 4

Dissolved Oxygen

Profiles of the water column were taken at 6 sites along the length of the harbor (Figure B2.1, Table B2.1) on 9 days during the monitoring season from mid-April through early September. Sampling was not conducted at Five Mile River Harbor 6 on 6/9/2023 and 7/7/2023 due to inaccessibility during low tide. Mean dissolved oxygen values in Five Mile River Harbor ranged from a minimum of 6.13 mg/L on the bottom at Five Mile Harbor 5 to a maximum of 7.81 mg/L at the surface at Five Mile River Harbor 6 (Figure B2.2). Dissolved oxygen concentrations generally decreased from May through early August, after which there was evidence of a slight recovery in late August and early September (Figure B2.3). Of all of the bottom dissolved oxygen observations, 35% were less than 5 mg/L, and no observations fell below 3 mg/L.

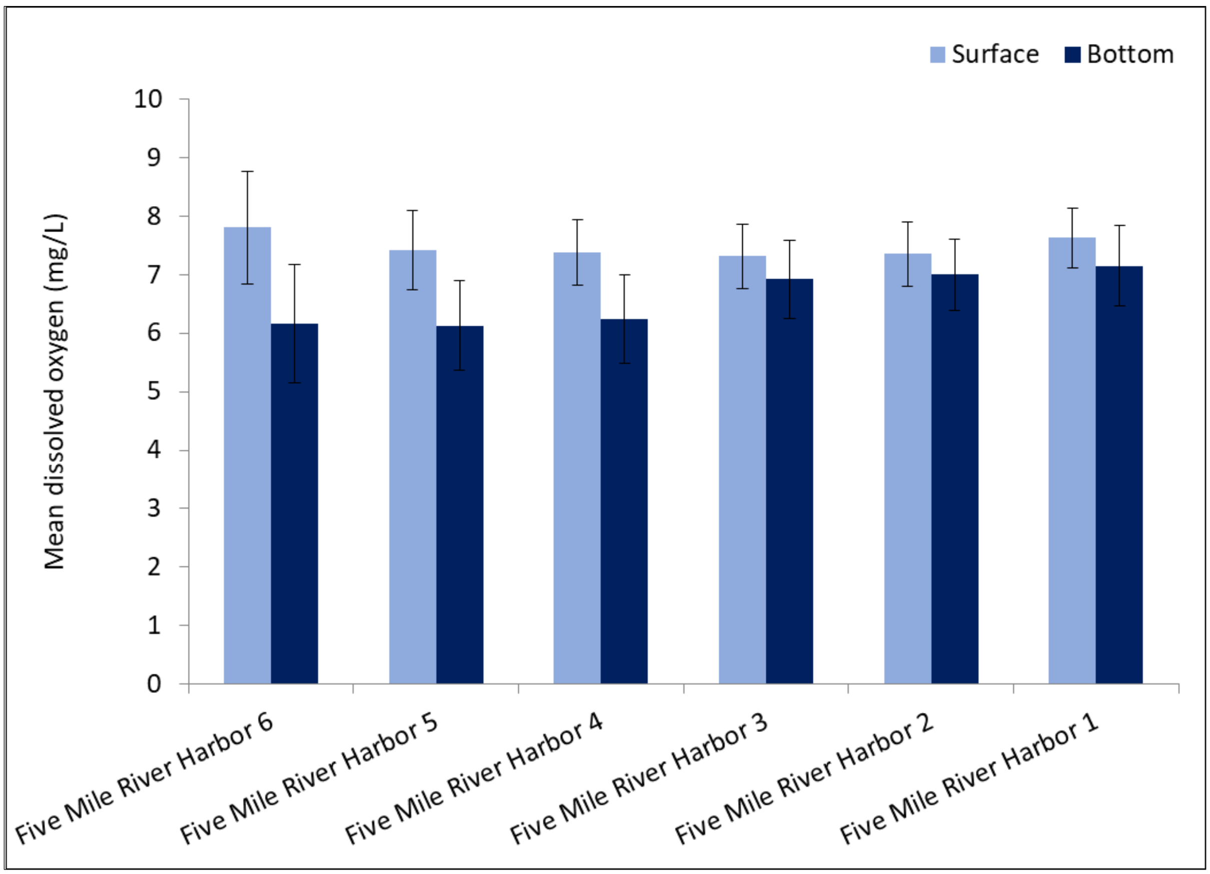


Figure B2.2. Mean dissolved oxygen concentrations at the surface and bottom at each sampling station in Five Mile River Harbor in 2023. Error bars represent standard error.

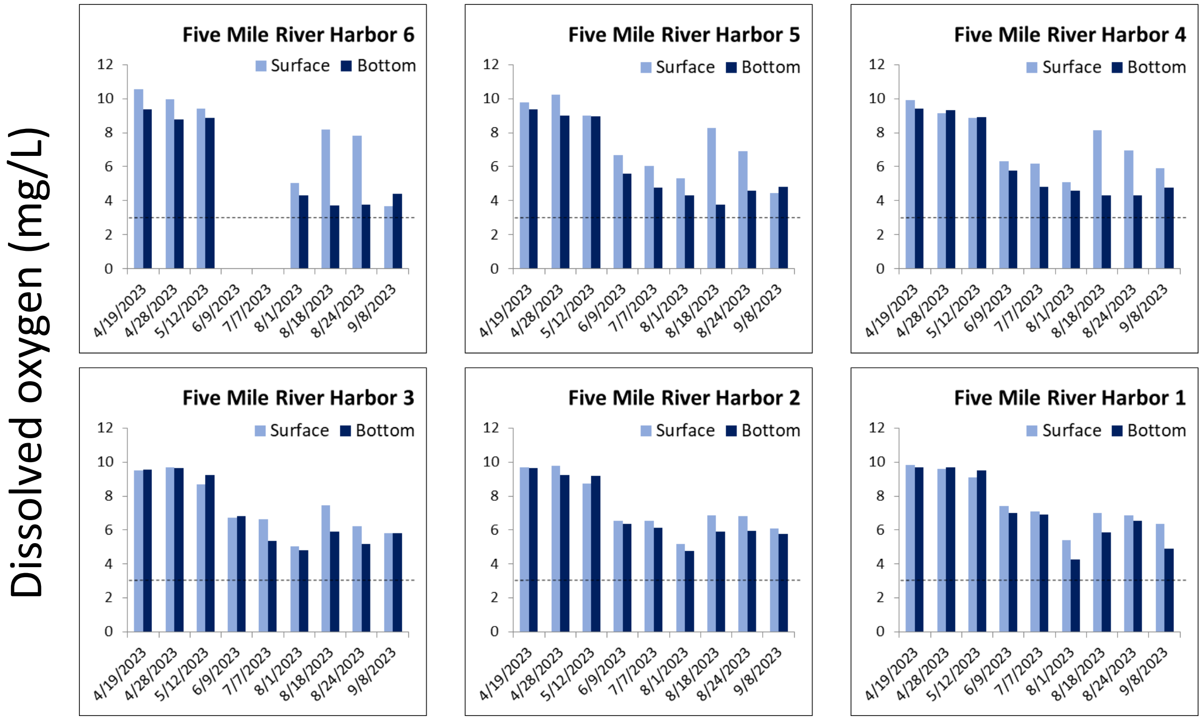


Figure B2.3. Surface and bottom dissolved oxygen values at each Five Mile River Harbor sampling station on each monitoring date during the 2023 season. The dotted line represents hypoxic conditions (3 mg/L). Station Five Mile River Harbor 6 was not sampled on 6/9/2023 and 7/7/2023 due to inaccessibility. Please note x-axis is individual sampling dates, not a time scale.

Temperature and Salinity

Mean surface and bottom water temperature in Five Mile River Harbor were similar throughout the harbor (Figure B2.4). Lower salinity observed at the surface in the landward end of the estuary reflects the impact of Five Mile River input from the north and Indian Creek input upstream of Five Mile Harbor 5, where the harbor is less well mixed (Figure B2.1, Figure B2.5).

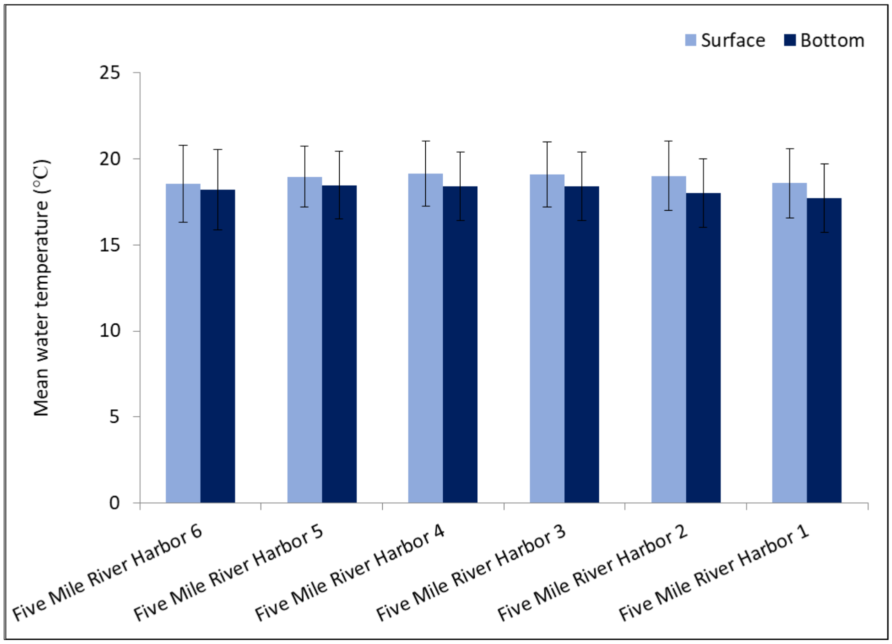


Figure B2.4. Mean water temperature at the surface and bottom at each sampling station in Five Mile River Harbor in 2023. Error bars represent standard error.

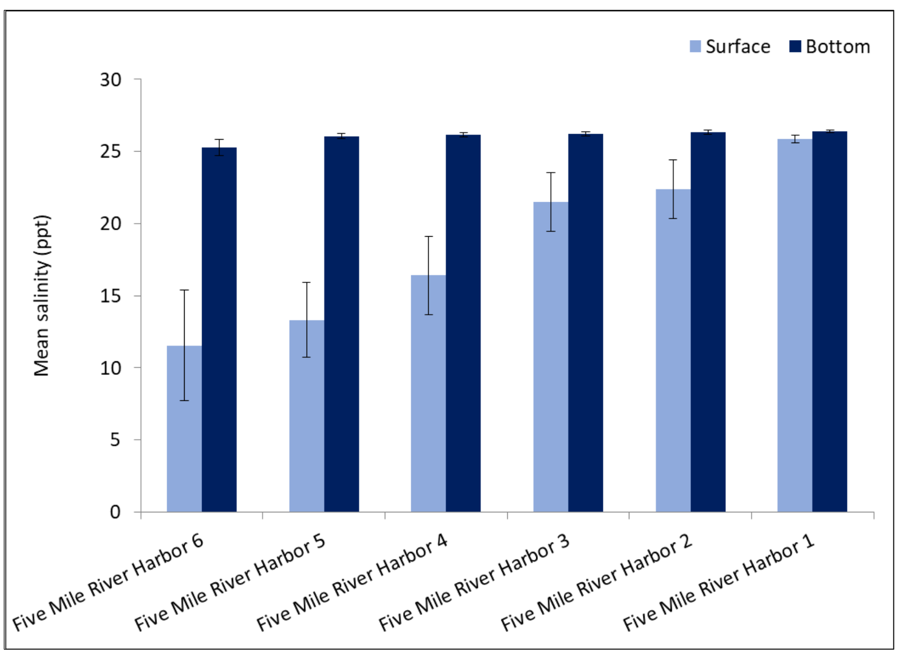


Figure B2.5. Mean salinity at the surface and bottom at each sampling station in Five Mile River Harbor in 2023. Error bars represent standard error.

Water Clarity
Mean secchi depth readings ranged from a minimum of 1.09m at station Five Mile River Harbor 6 to a maximum of 1.47m at station Five Mile River Harbor 1. Mean secchi depth readings slightly increase from station Five Mile River Harbor 6 to Five Mile River Harbor 1 (Figure B2.6).

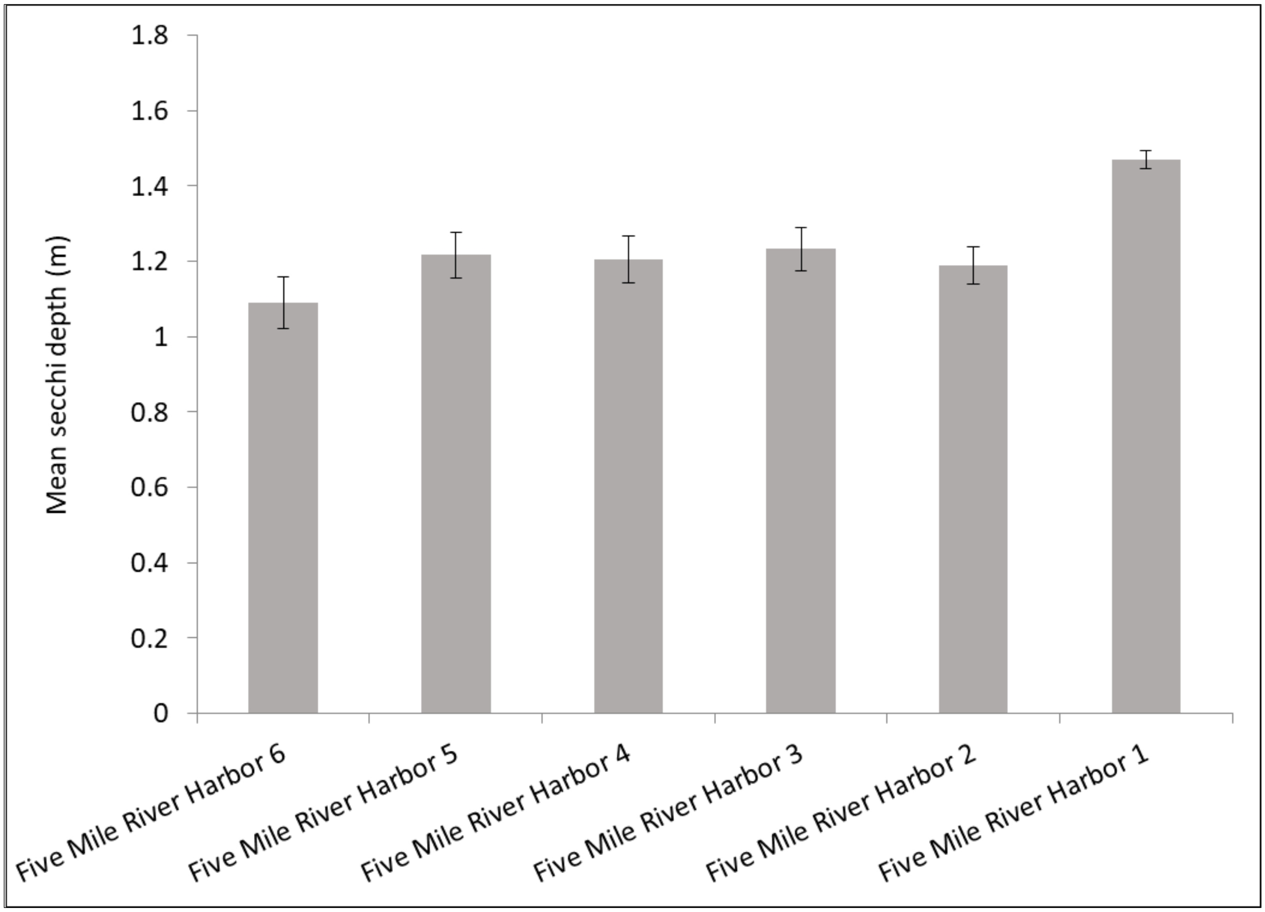
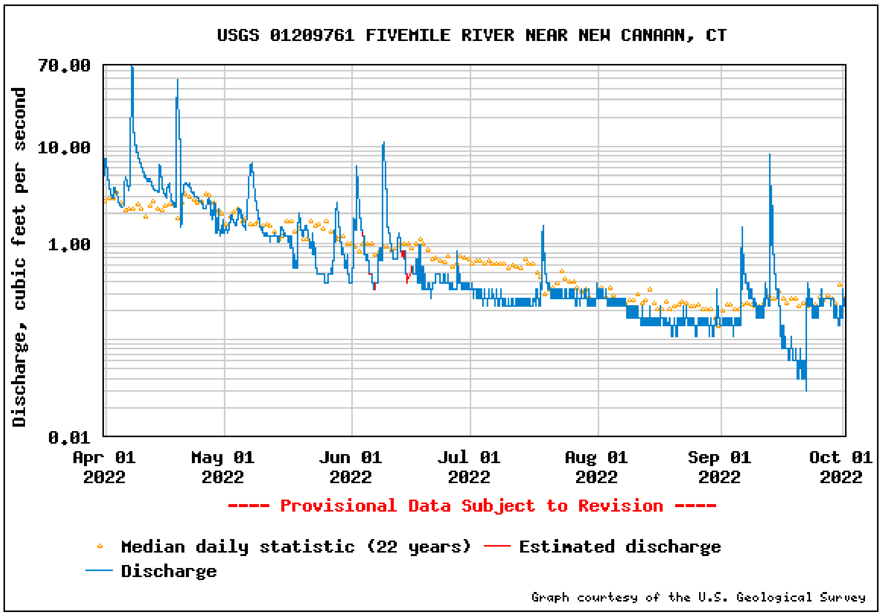


Figure B2.6. Mean secchi depth readings in Five Mile River Harbor in 2023. Error bars represent standard error.

Five Mile River Discharge

The figures below illustrate discharge rates (cubic feet per second) recorded at the United States Geological Survey monitoring station on the Five Mile River in New Canaan, CT. Yellow triangles represent the daily median value over the last 22 years, and the blue line represents the recorded discharge for a particular date. In 2023, frequent rain events increased discharge often from July through October while discharge was observed to be lower in 2022, and often below the median.



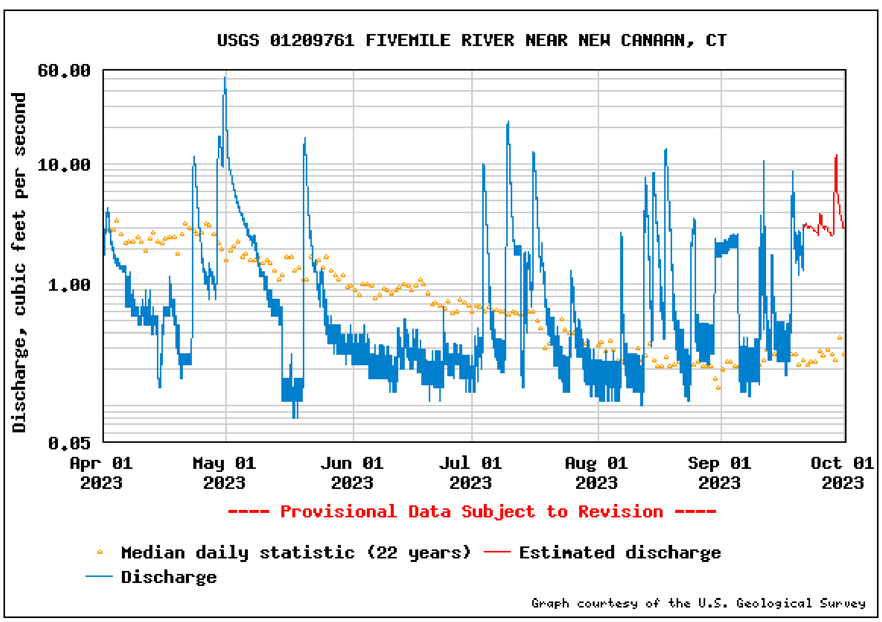


Figure B2.7. USGS flow data in ft^3/s for the period of April 1 through October 1, 2022 (top) and 2023 (bottom), respectively for the Five Mile River in New Canaan, CT (Graph courtesy of the U.S. Geological Survey). Please note the difference in scale on the y-axis.

3. Norwalk Harbor

Norwalk Harbor, located in Norwalk, CT, is fed with fresh water from the Norwalk River. Of the harbors monitored in this report, the Norwalk Harbor is the only one which does not have a tidal basin which could aid in flushing at ebb tide. The harbor once had extensive wetlands on both shorelines (Figure B3.1) which have now been filled in or removed and replaced with hardened shoreline to accommodate the many industrial and commercial businesses located along the shores. Land use around the edges of the harbor includes landfills, marinas, and housing developments ranging from high density apartments to single-family homes. This report will discuss the inner harbor, which includes the length of the estuary from Wall Street to the Norwalk Islands (Figure B3.2).

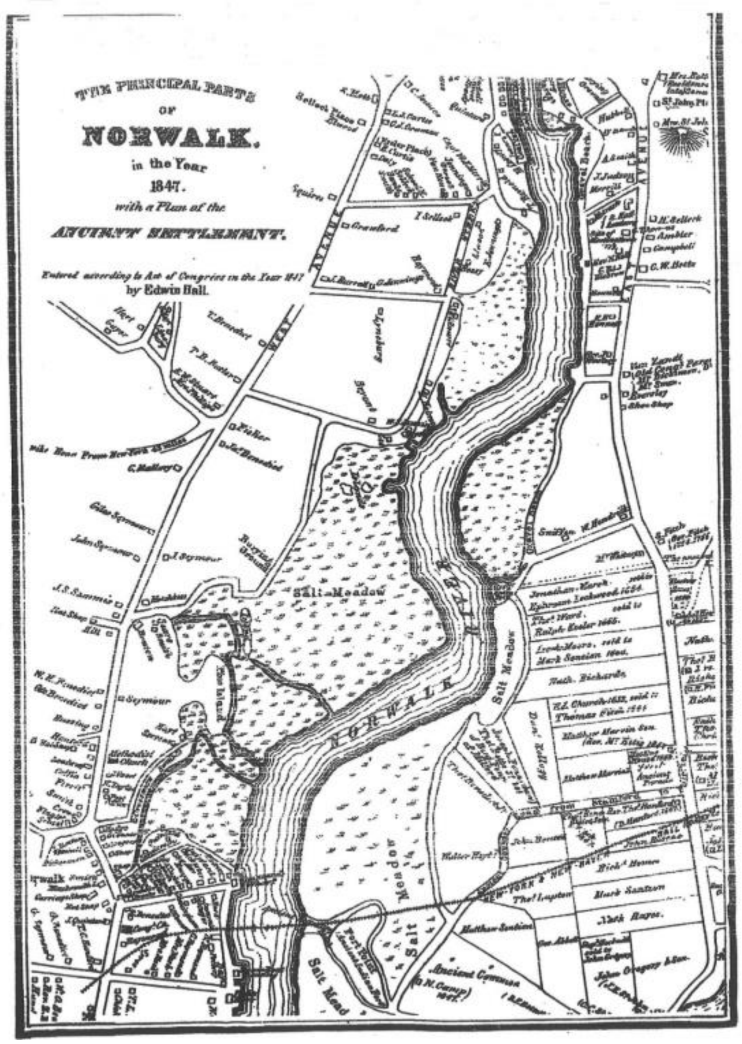


Figure B3.1. Norwalk Harbor estuary in 1847. Extensive wetlands once dominated both shorelines. Image credit: Norwalk Historical Society.

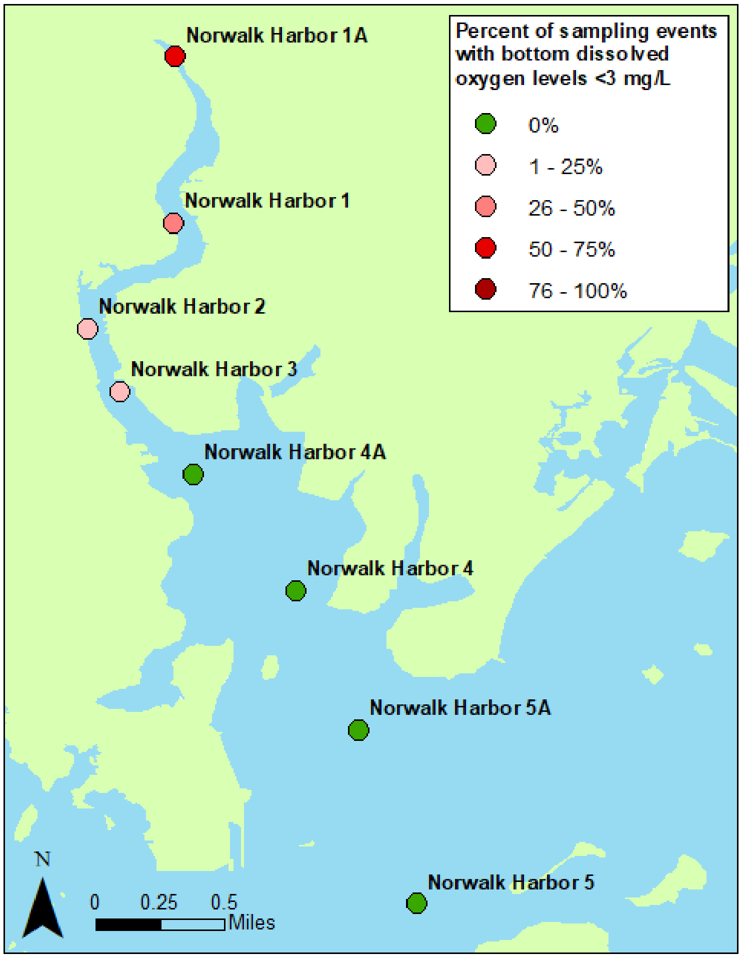


Figure B3.2. Map of Norwalk Harbor sampling stations in the inner harbor for 2023. Color of dots represents the percent of sampling events with bottom dissolved oxygen levels less than 3 mg/L.

Table B3.1. Coordinates and descriptions for each sampling station in Norwalk Harbor

Site Name	Latitude	Longitude	Description
Norwalk Harbor 1A	41.117389	-73.411056	Wall Street
Norwalk Harbor 1	41.108000	-73.411167	I-95 Bridge
Norwalk Harbor 2	41.102056	-73.416000	Maritime Aquarium dock
Norwalk Harbor 3	41.098472	-73.414194	Public boat launch
Norwalk Harbor 4A	41.093861	-73.410028	Ischoda Yacht Club moorings
Norwalk Harbor 4	41.087278	-73.404250	Buoy 19
Norwalk Harbor 5A	41.079402	-73.400727	Buoy 15
Norwalk Harbor 5	41.069611	-73.397472	Oyster stakes off Chimon Island

Dissolved Oxygen

Profiles were taken in the inner harbor at 8 sampling stations. Sampling occurred 12 times between April and September 2023. Stations Norwalk Harbor 5A and Norwalk Harbor 5 were only sampled 11 and 8 times, respectively, throughout the monitoring season due to rough seas. Mean dissolved oxygen concentrations ranged from a minimum of 3.11 mg/L on the bottom at station Norwalk Harbor 1A to a maximum of 8.71 mg/L at the surface at station Norwalk Harbor 1A (Figure B3.3). Station Norwalk Harbor 1A had the widest range between surface and bottom mean dissolved oxygen concentrations in Norwalk Harbor. Of all of the bottom dissolved oxygen observations, 32% were less than 5 mg/L, and 18% were less than 3 mg/L.

Wide ranges in dissolved oxygen concentrations at the surface and bottom were observed in most of the upstream sampling locations (Figure B3.3, Figure B3.4). At the sampling locations further seaward, the differences in dissolved oxygen concentrations were smaller, presumably from the larger width of the harbor and increased mixing reducing stratification. The upper 3 stations, Norwalk Harbor 1A, Norwalk Harbor 1, and Norwalk Harbor 2, likely had a highly stratified water column throughout the season based on limited mixing time with the flow of fresh water entering the harbor from the Norwalk River (Figure B3.3, Figure B3.9). Station Norwalk Harbor 1A was the most impaired water in the harbor for dissolved oxygen, consistent with past years.

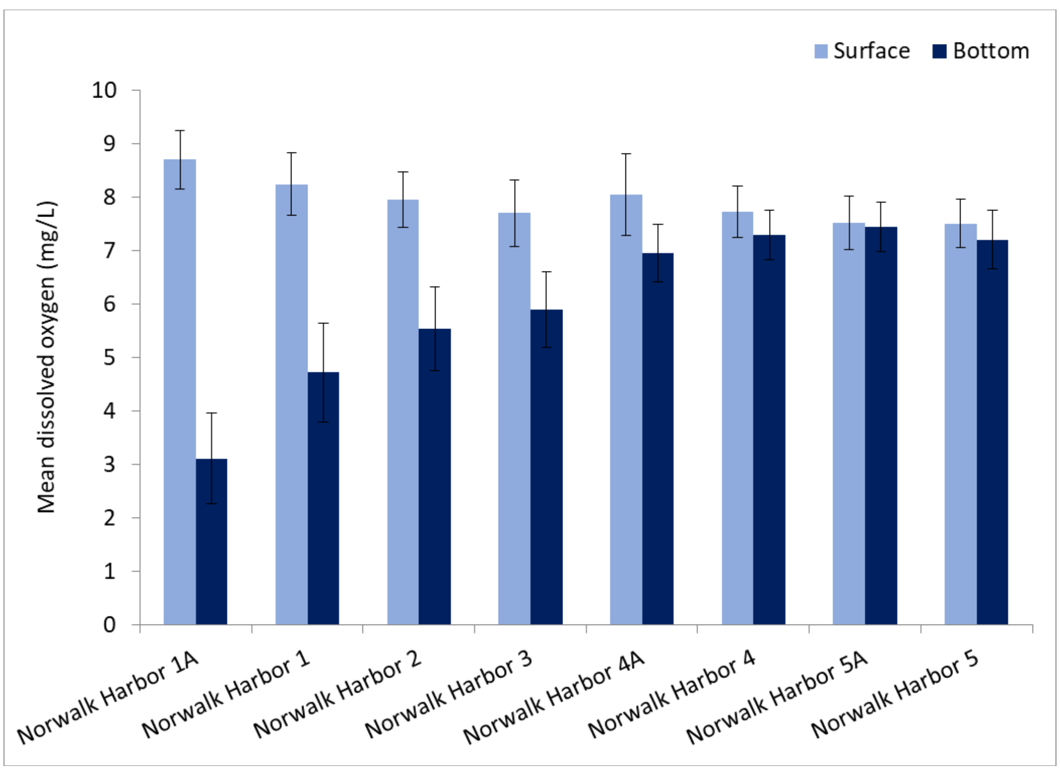


Figure B3.3. Mean dissolved oxygen concentrations at the surface and bottom at each sampling station in Norwalk Harbor during 2023. Error bars represent standard error.

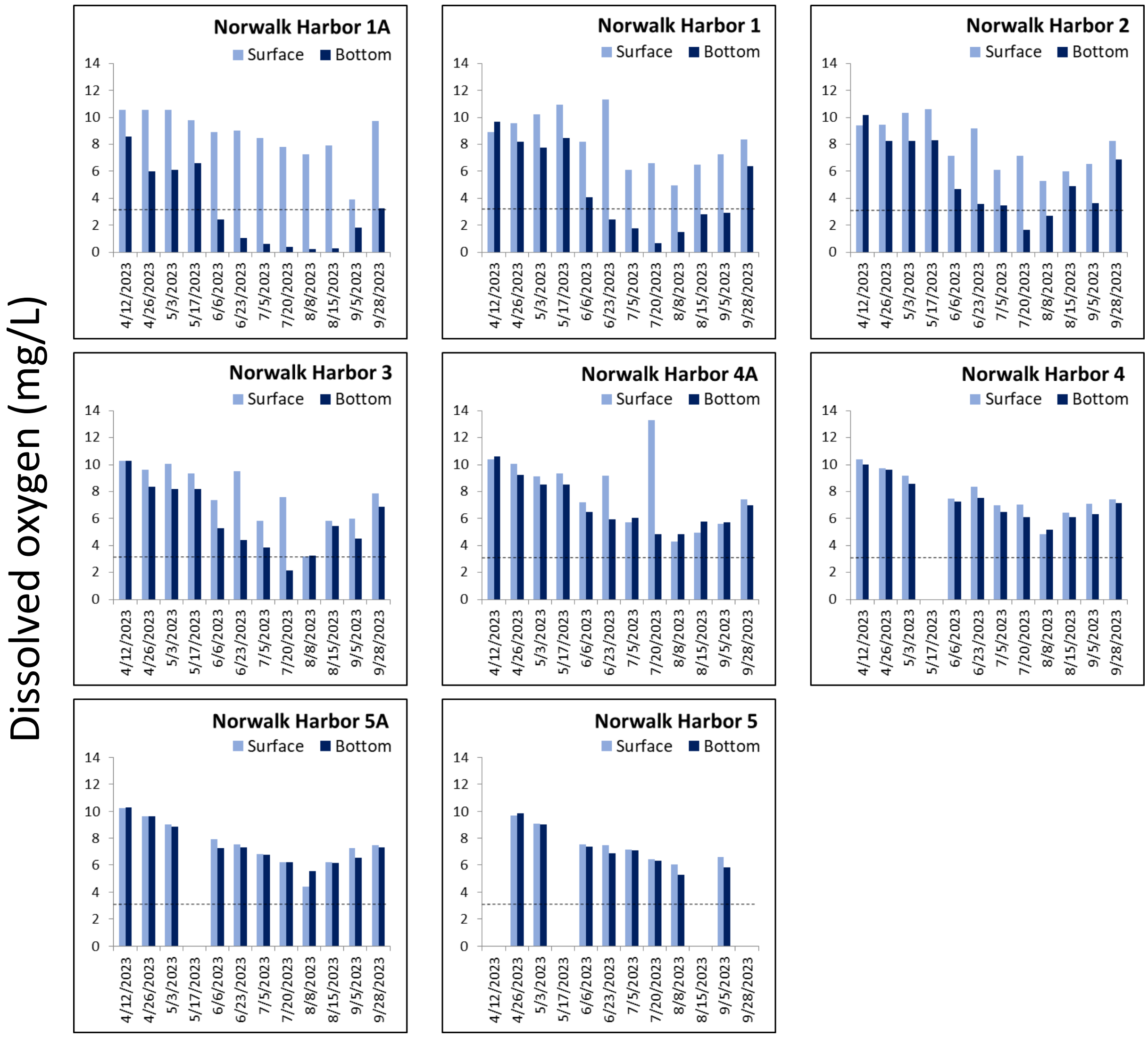


Figure B3.4. Surface and bottom dissolved oxygen values at each Norwalk Harbor sampling station on each monitoring date during the 2023 season. The dotted line represents hypoxic conditions (3 mg/L). Please note x-axis is individual sampling dates, not a time scale.

Temperature and Salinity
Mean water temperature was fairly consistent across all Norwalk Harbor stations (Figure B3.5). Mean bottom temperatures were observed to be higher than surface temperatures at Norwalk Harbor 1A and Norwalk Harbor 1. Salinity was lower at the surface than the bottom at all stations, with the largest difference observed at the inner harbor stations, reflecting the impact of the riverine inputs from the north where the harbor is less well mixed (Figure B3.6). This salinity stratification was the most pronounced at station Norwalk Harbor 1A, where the fresh water river discharge meets the toe of the tidal wedge.

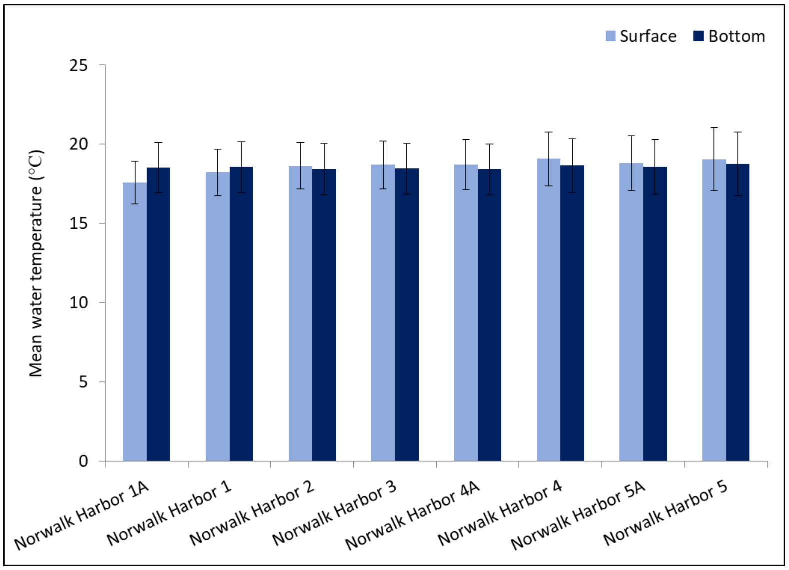


Figure B3.5. Mean water temperature at the surface and bottom at each sampling station in Norwalk Harbor in 2023. Error bars represent standard error.

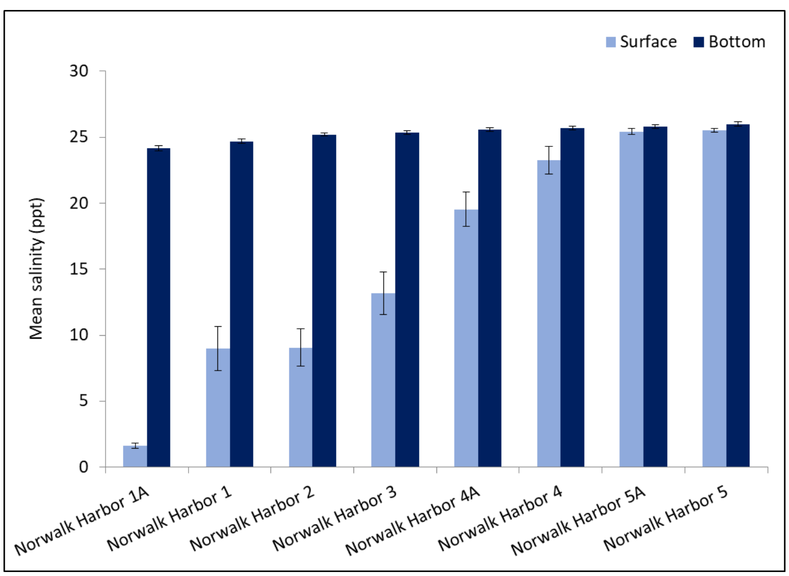


Figure B3.6. Mean salinity at the surface and bottom at each sampling station in Norwalk Harbor in 2023. Error bars represent standard error.

Water Clarity

Mean secchi depth readings ranged from a minimum of 1.15m at station Norwalk Harbor 3 to a maximum of 1.82m at station Norwalk Harbor 5. Mean secchi readings decrease from station Norwalk Harbor 1A to Norwalk Harbor 3, after which they increase up to Norwalk Harbor 5 (Figure 2.C.7). This may have been a result of sediment and debris deposition during rainfall events in 2023 from large stormwater outfalls which line the harbor in this area. Also, the waters between Norwalk Harbor 2 and Norwalk Harbor 3 often appeared to be plankton rich, which may have impacted water clarity (personal observation, R. Harris).

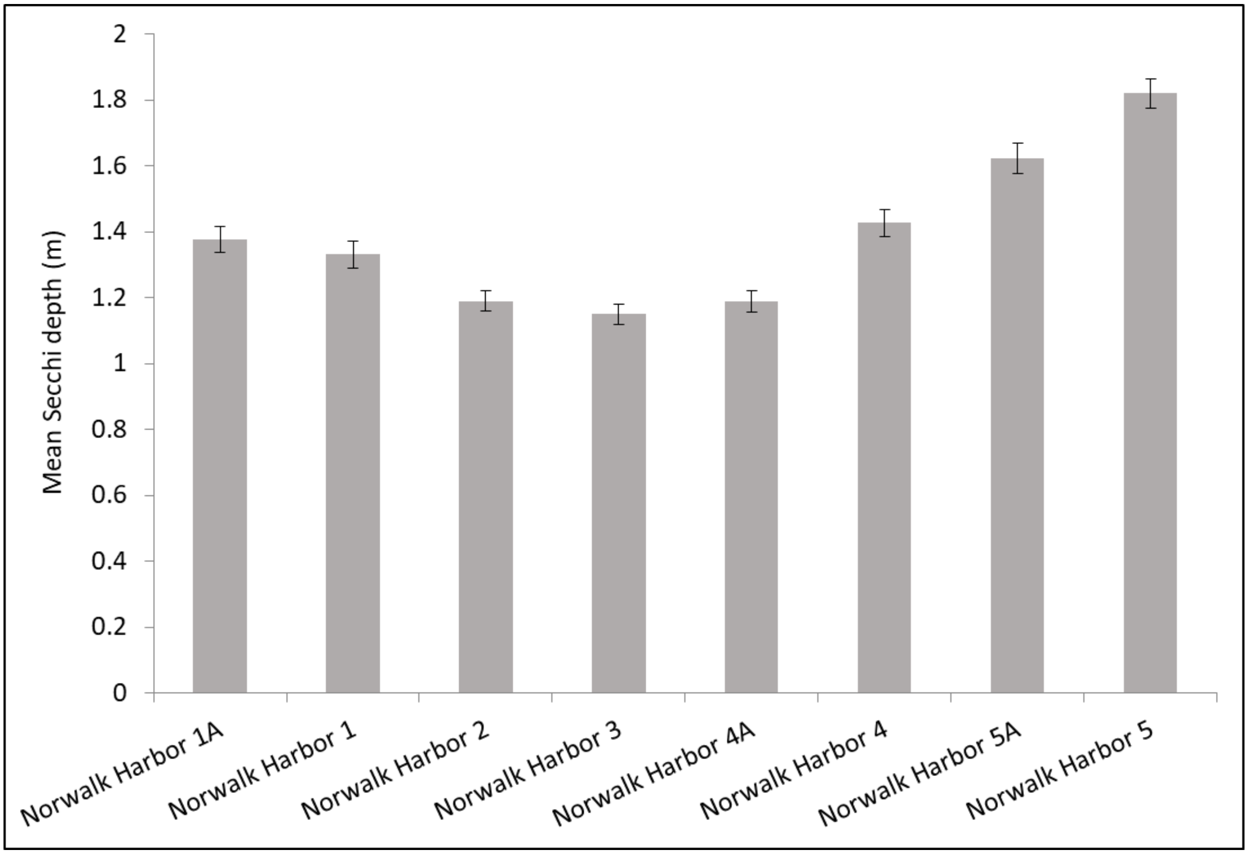
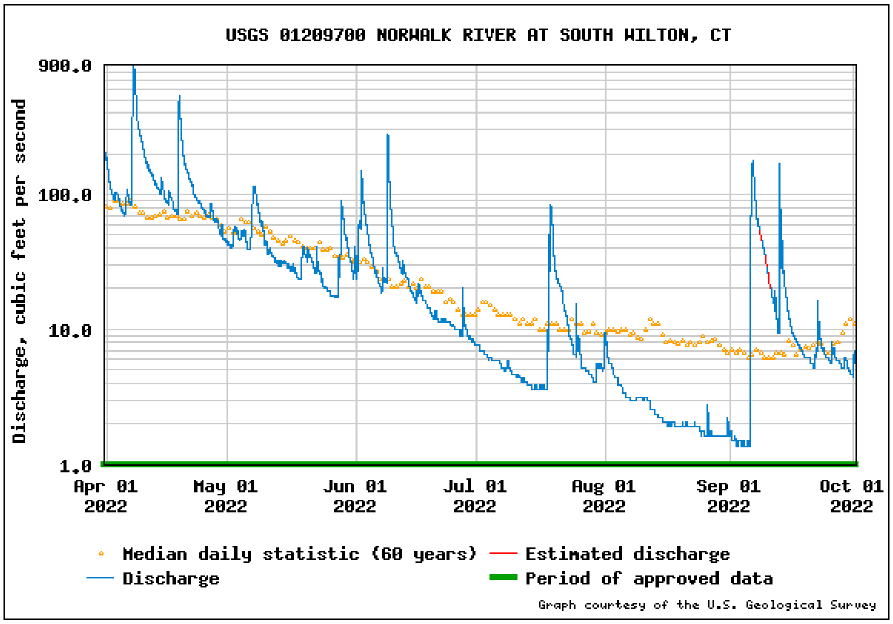


Figure B3.7. Mean secchi depth readings in Norwalk Harbor in 2022. Error bars represent standard error.

Norwalk River Discharge

The figures below illustrate discharge (cubic feet per second) recorded at the United States Geological Survey monitoring station on the Norwalk River in South Wilton, CT. Yellow triangles represent the daily median value over the last 60 years, and the blue line represents the recorded discharge for a particular date. Discharge in 2023 was higher than in 2022, particularly from July through Octobers (Figure 2.C.8).



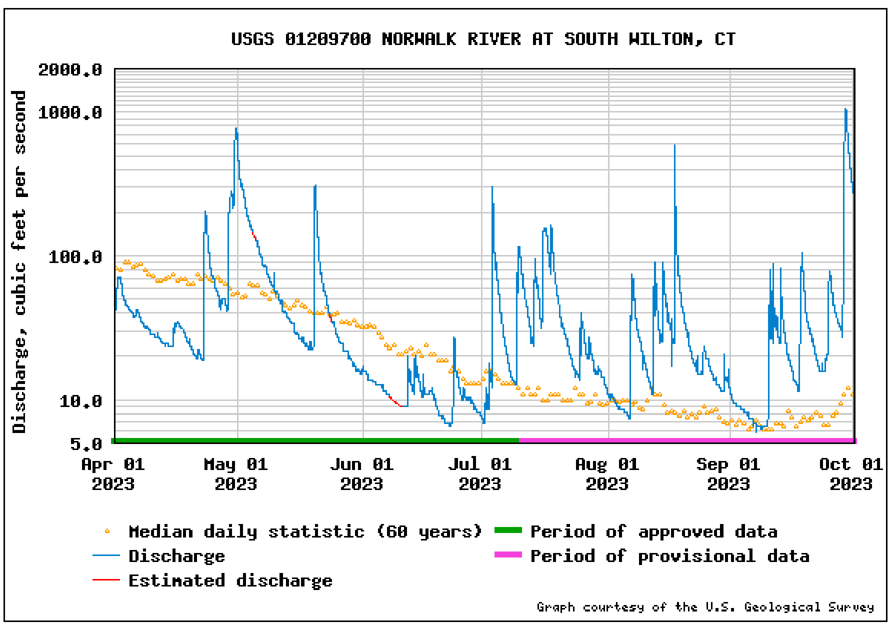


Figure B3.8. USGS flow data in ft^3/s for the period of April 1 through October 1, 2022 (top) and 2023 (bottom), respectively for the Norwalk River in South Wilton, CT (Graph courtesy of the U.S. Geological Survey). Please note the difference in scale on the y-axis.

4. Saugatuck Harbor

Situated at the mouth of the Saugatuck River, Saugatuck Harbor is approximately three miles long and relatively narrow with the exception of two basins. The first of these is a large basin located just to the north of station Saugatuck Harbor 6 (Figure B4.1, Figure B4.2). The second smaller basin is located just to the north of station Saugatuck Harbor 4 (Figure B4.2). The combined effect of these basins on ebb tide provides a strong flushing current for the estuary. The estuary then broadens into a wide but shallow harbor just to the south of station Saugatuck Harbor 3 (Figure B3.2). The land area on both sides of the upper estuary and the main harbor is mostly developed. The commercial area of the Town of Westport borders the northeastern side of the harbor above the Route 1 bridge. From this point moving southward the east bank of the harbor is residential up to the Longshore Country Club area and the Compo Boat Basin Marina. The west bank of the harbor is developed with a mixture of commercial businesses including a rowing club and a few small marinas. The Saugatuck Shores area on the western bank of Saugatuck Harbor is developed with single-family homes and two yacht clubs. Some salt marshes are present along the harbor margins south of the Canal Street bridge and just to the north of the I-95 bridge. Much of the shoreline has been filled for development but several large strip marshes are also still present along the western bank as the harbor opens into a larger basin near the mouth (Figure B4.2).

Figure B4.1. Looking upstream at the first basin from Saugatuck Harbor 6.

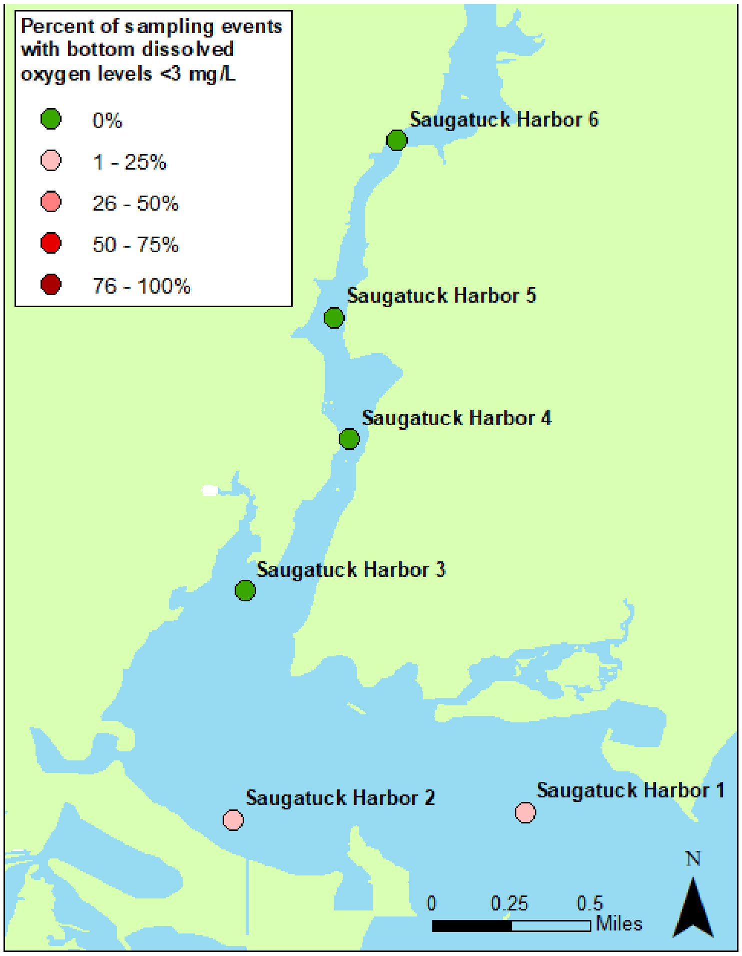


Figure B4.2. Map of Saugatuck Harbor sampling stations in 2023. Color of dots represents the percent of sampling events with bottom dissolved oxygen levels less than 3 mg/L.

Table B4.1. Coordinates and descriptions for each sampling station in Saugatuck Harbor

Site Name	Latitude	Longitude	Description
Saugatuck Harbor 6	41.132683	-73.366383	Sunoco (in the channel)
Saugatuck Harbor 5	41.124617	-73.369233	VFW marina (in the channel)
Saugatuck Harbor 4	41.119067	-73.368517	Metro North Railroad bridge
Saugatuck Harbor 3	41.112167	-73.373317	Buoy 27
Saugatuck Harbor 2	41.101733	-73.373833	Buoy 18
Saugatuck Harbor 1	41.102050	-73.360533	Buoy 9

Dissolved Oxygen

Profiles were taken at 6 stations on 8 sampling days from May through September 2023. Station Saugatuck Harbor 6 was the only site sampled 5 times due to tidal restrictions. Mean dissolved oxygen values ranged from a minimum of 5.06 mg/L at the bottom of station Saugatuck Harbor 6 to a maximum of 7.41 mg/L at the surface of station Saugatuck Harbor 4 (Figure B4.3). Dissolved oxygen concentrations demonstrated a downward trend at all sites throughout the monitoring season, recovering slightly in September (Figure B4.4). Of all of the bottom dissolved oxygen observations, 33% fell below 5 mg/L, and 4% fell below 3 mg/L.

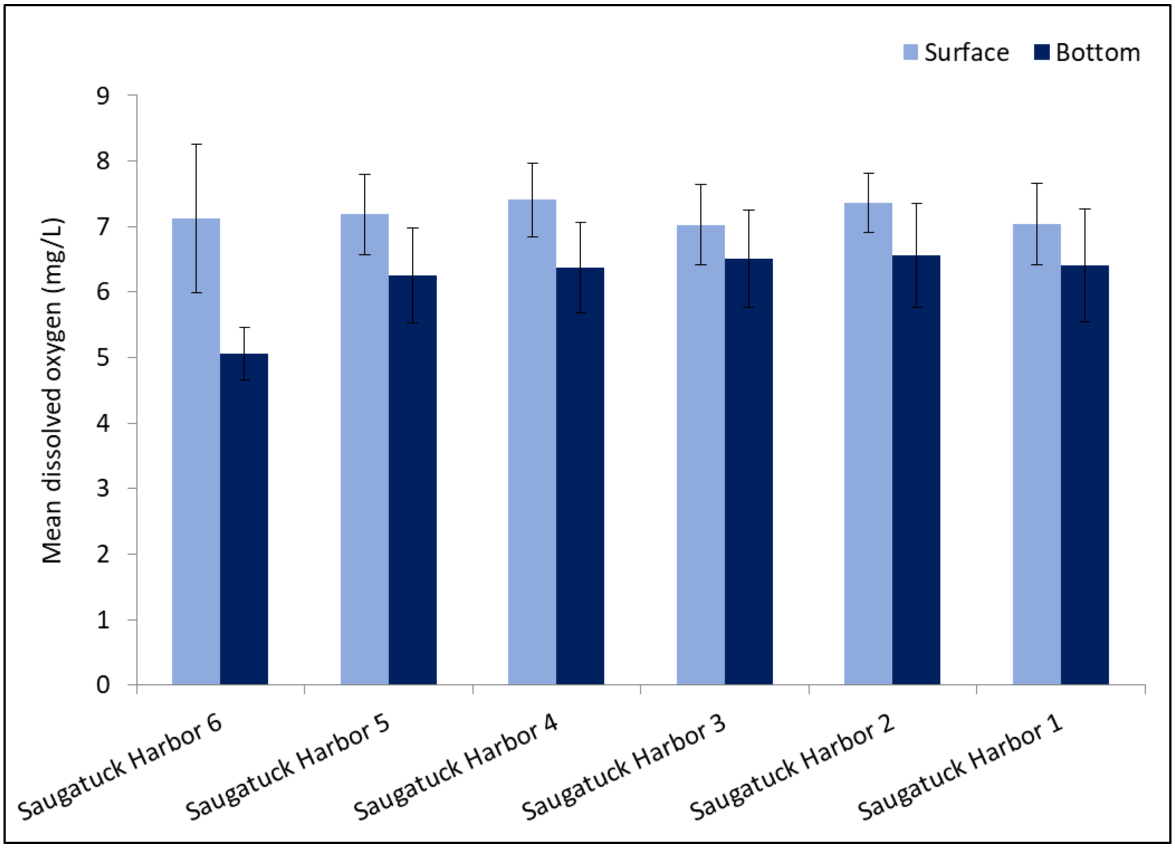


Figure B4.3. Mean dissolved oxygen concentrations at the surface and bottom at each sampling station in Saugatuck Harbor in 2023. Error bars represent standard error.

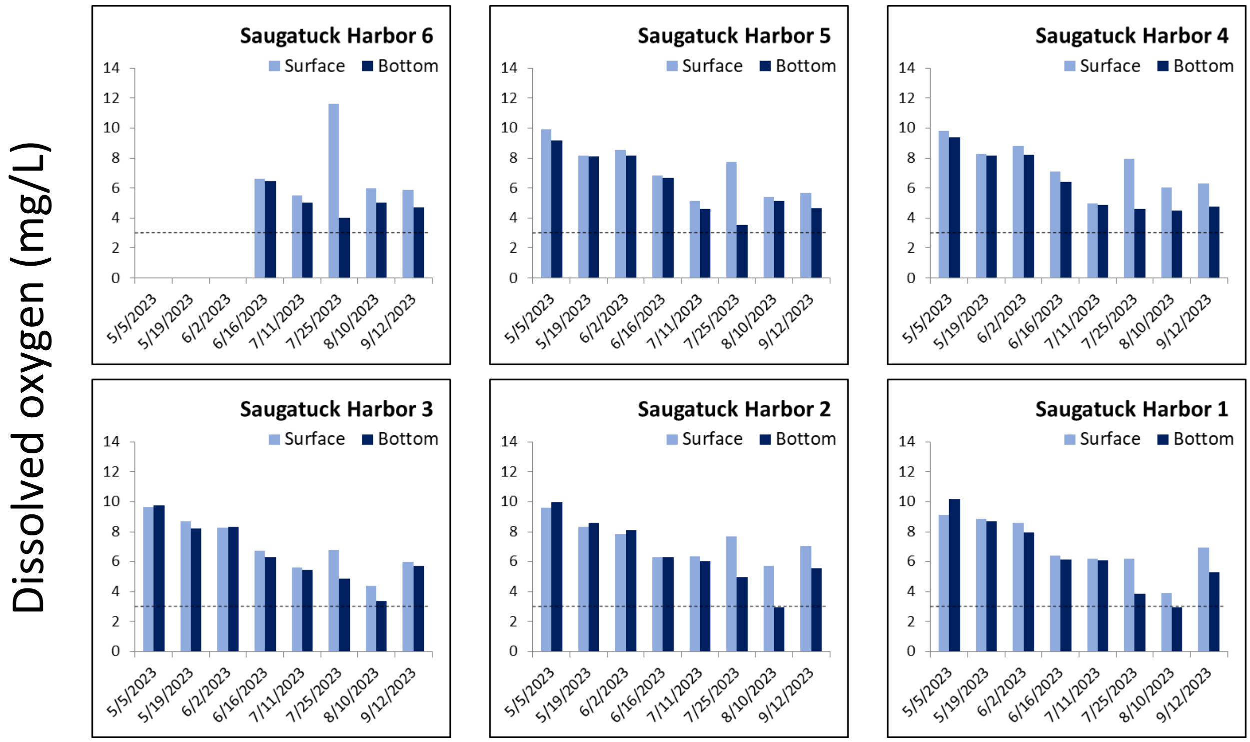


Figure B4.4. Surface and bottom dissolved oxygen values at each Saugatuck Harbor sampling station on each monitoring date during the 2023 season. The dotted line represents hypoxic conditions (3 mg/L). Please note x-axis is individual sampling dates, not a time scale.

Temperature and Salinity

Mean water temperatures were similar at both the surface and the bottom of all sites throughout the harbor, with a slight downward trend from the inner most station to the outermost station (Figure B4.5). Salinity was lower at the surface than the bottom at all stations and that difference was most pronounced in the inner harbor stations, reflecting the impact of the increased riverine inputs from the north where the harbor is less well mixed (Figure B4.5, Figure B4.6).

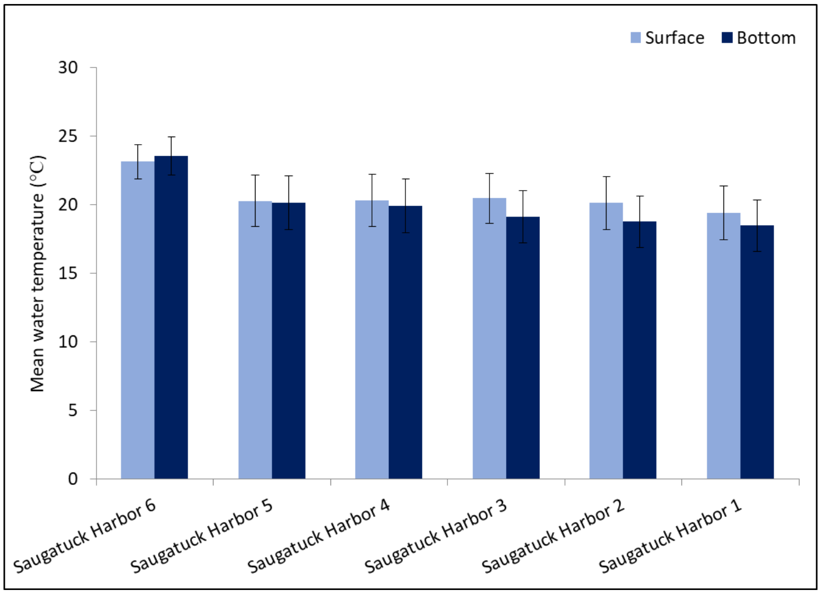


Figure B4.5. Mean water temperature at the surface and bottom at each sampling station in Saugatuck Harbor in 2023. Error bars represent standard error.

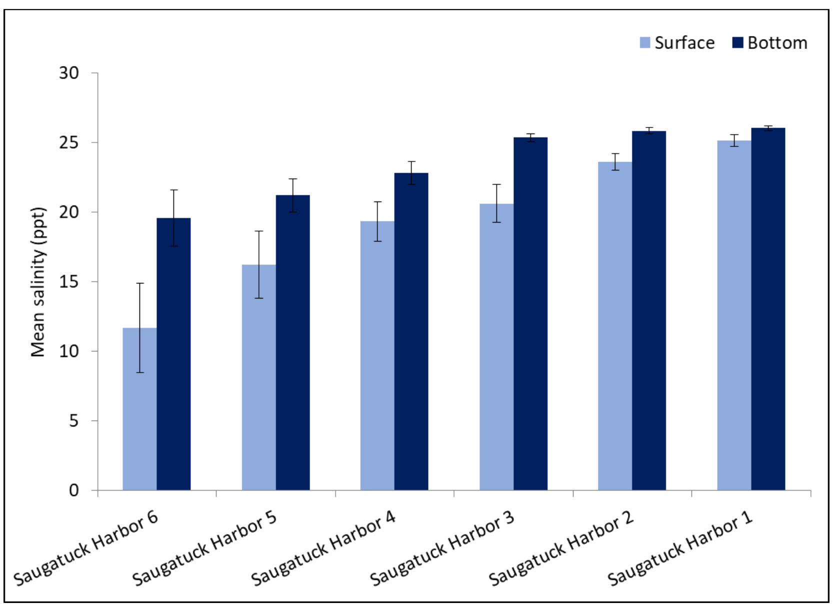


Figure B4.6. Mean salinity at the surface and bottom at each sampling station in Saugatuck Harbor in 2023. Error bars represent standard error.

Water Clarity
Mean secchi depth readings ranged from a minimum of 0.83m at station Saugatuck Harbor 6 to a maximum of 2.04m at station Saugatuck Harbor 1. Mean secchi readings steadily increased from the inner harbor stations to the outer harbor stations (Figure B4.7).

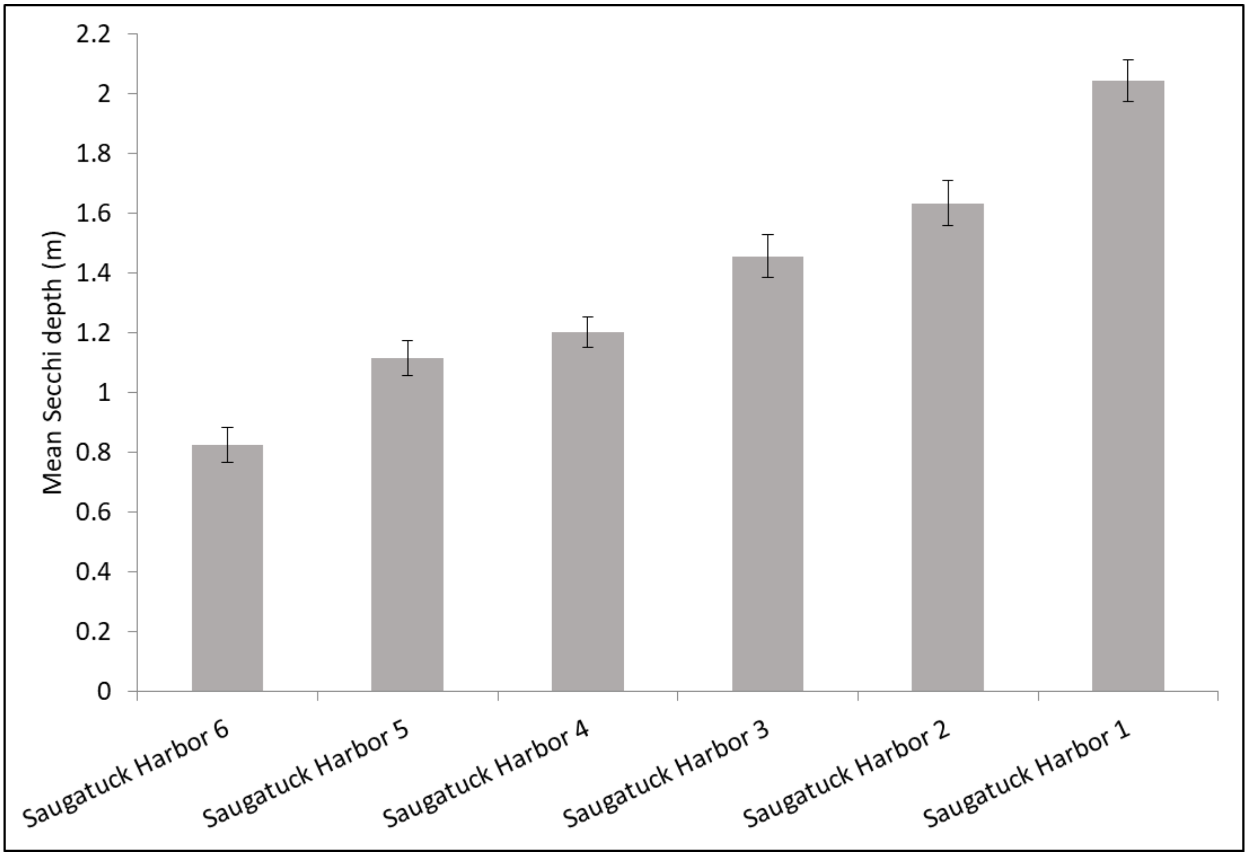
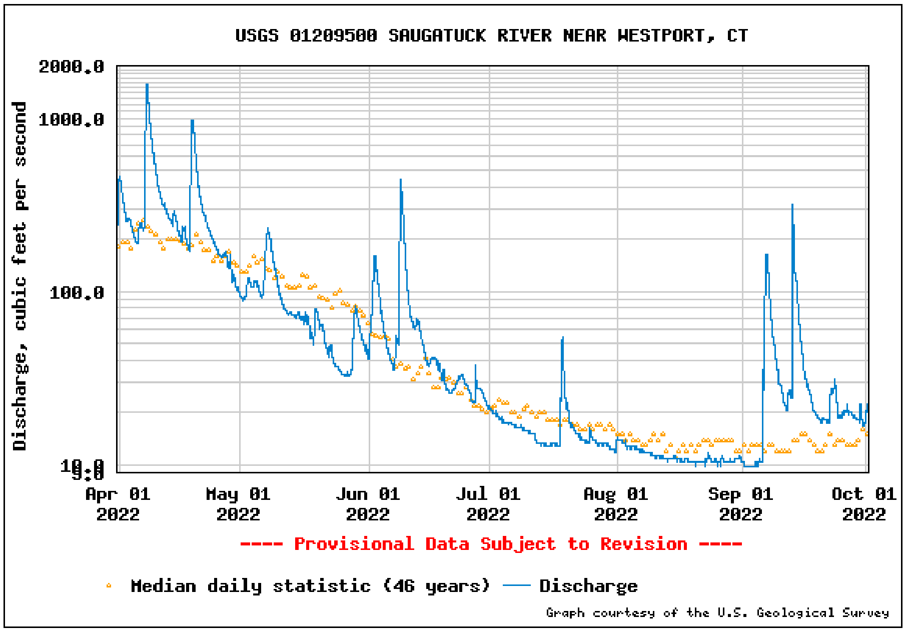


Figure B4.7. Mean secchi depth readings in Saugatuck Harbor in 2023. Error bars represent standard error.

Saugatuck River Discharge

The figures below illustrate discharge in cubic feet per second recorded at the United States Geological Survey monitoring station on the Saugatuck River near Westport, CT. Yellow triangles represent the daily median value over the last 46 years, and the blue line represents the recorded discharge for a particular date. Rainfall events in 2023 were more frequent than those experienced in 2022, especially toward the end of the monitoring season, resulting in more discharge.



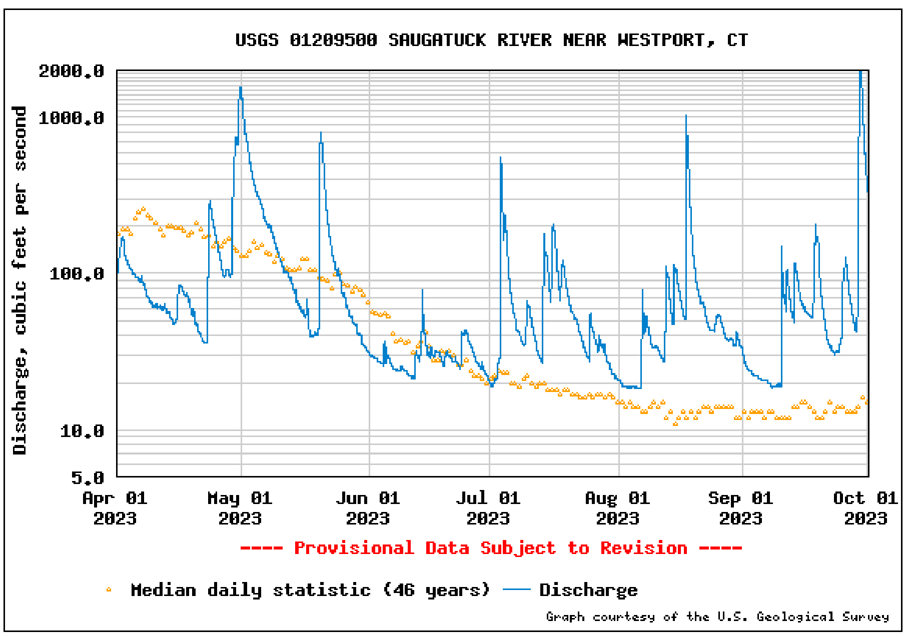


Figure B4.8. USGS flow data in ft^3/s for the period of April 1 through October 1 for the 2022 (top) and 2023 (bottom) respectively for the Saugatuck River near Westport, CT (Graphs courtesy of the U.S. Geological Survey).

5. Bridgeport Harbor (Johnsons Creek and Lewis Gut sections)

Johnsons Creek is a short quarter mile channel that starts at the discharge area of Bruce Brook and extends to the south-western end of Lewis Gut (Figure B5.1). Johnsons Creek flows southwest past a series of petroleum storage tanks and 2 marinas on both banks down to the remains of the swing bridge at the entrance to Bridgeport Harbor (Figure B5.1, Figure B5.2, Figure B5.3). Johnsons Creek waters mix with those of Lewis Gut during tidal cycles. The 2 water bodies present a significant contrast in terms of development and shoreline habitat features. On the one hand, Lewis Gut possesses features that support an environmentally sound embayment and is surrounded by a natural shoreline. As an added benefit, the bordering extensive wetlands serve to improve water quality. On the other hand, Johnsons Creek is commercially developed with a highly developed shoreline and receives the discharge from a tributary (Bruce Brook) with a known history of impairment (Figure B5.3; Spiller et al., 2023).

Lewis Gut extends 2 miles to the east behind a barrier beach known as Pleasure Beach on its western end and Long Beach on its eastern end. The barrier beach and the waters of Lewis Gut have been spared the impact of man-made development over time because a fire destroyed the only bridge that connected the barrier beach to the mainland. A noteworthy environmental feature of Lewis Gut is the extensive *Spartina alterniflora*-dominated salt marsh which flanks the northern edge and eastern end of Lewis Gut. While supported by more natural features along its immediate shoreline than Johnsons Creek, Lewis Gut is still part of a highly developed watershed (Figure B5.3).

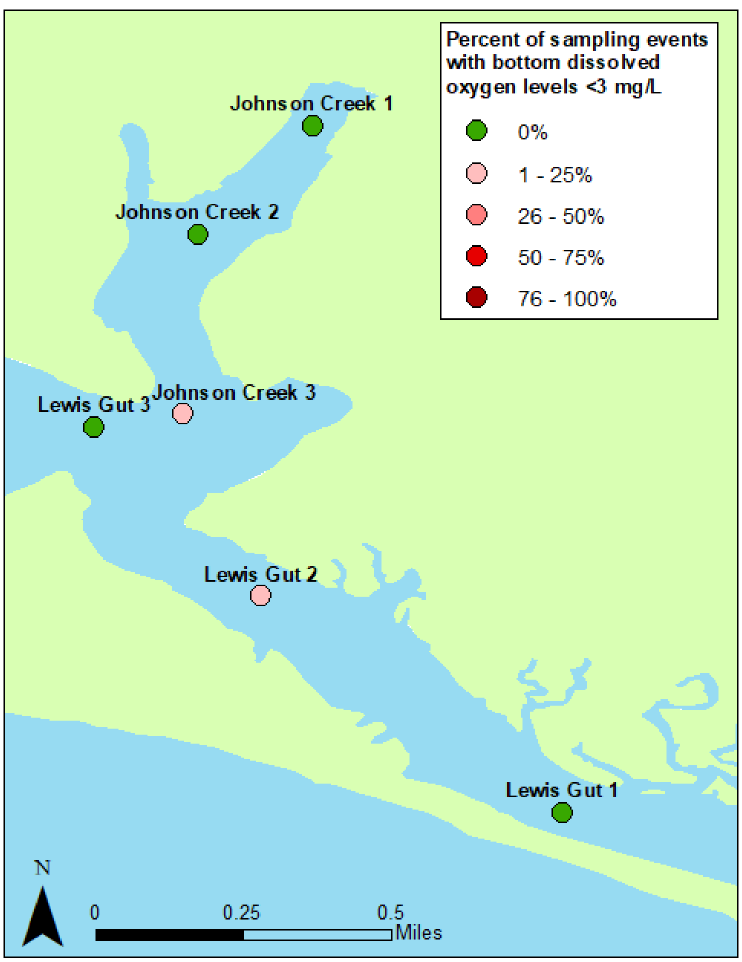


Figure B5.1. Map of Johnsons Creek and Lewis Gut sampling stations in 2023. Color of dots represents the percent of sampling events with bottom dissolved oxygen levels less than 3 mg/L.

Table B5.1. Coordinates and descriptions for each sampling station in Johnsons Creek and Lewis Gut

Site Name	Latitude	Longitude	Description
Johnsons Creek 1	41.172900	-73.160583	Off of East End Yacht Club
Johnsons Creek 2	41.170250	-73.163367	Mid-channel off PC Metals
Johnsons Creek 3	41.165833	-73.163750	Nun Buoy #4
Lewis Gut 3	41.165517	-73.165917	Swing Bridge east side
Lewis Gut 2	41.161383	-73.161867	Lewis Gut
Lewis Gut 1	41.156083	-73.154467	Lewis Gut east end

Figure B5.2. Looking down Johnsons Creek, which has many commercial land uses on its borders. The swing bridge in the background (now removed) is where Johnsons Creek meets Lewis Gut.

Figure B5.3. An aerial view of a highly industrialized Johnsons Creek in contrast to the more natural immediate setting around Lewis Gut (photo source: Google Maps).

Dissolved Oxygen

Dissolved oxygen data were collected at 6 sites on 6 sampling dates from May through September. Mean dissolved oxygen ranged from a minimum of 5.82 mg/L at the bottom of station Johnsons Creek 2 and a maximum of 7.50 mg/L at the surface of station Lewis Gut 2 (Figure B5.4). The dissolved oxygen concentrations varied throughout the monitoring season for each site (Figure B5.5). Of all of the bottom dissolved oxygen observations, 19% were below 5 mg/L, and 6% were below 3 mg/L.

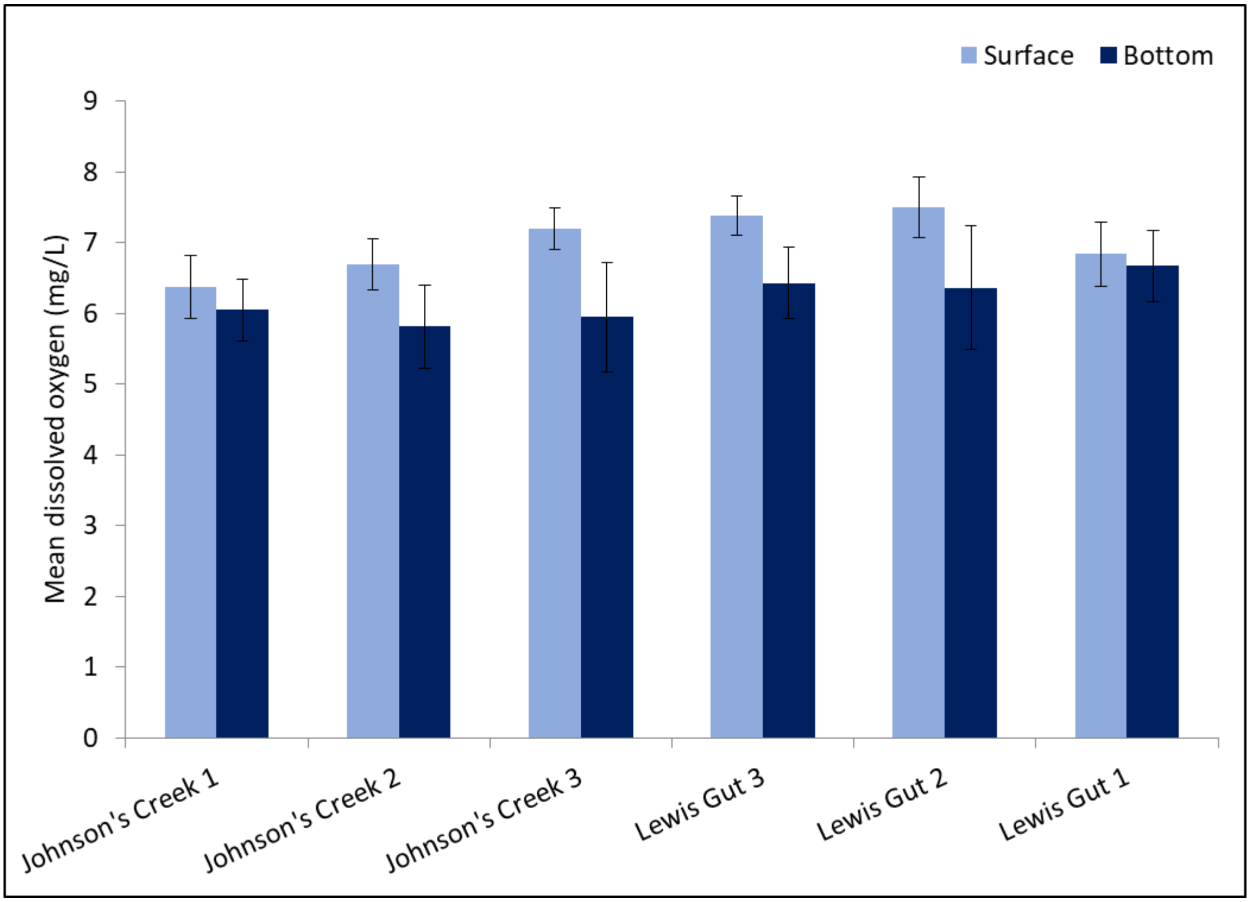


Figure B5.4. Mean dissolved oxygen concentrations at the surface and bottom at each sampling station in Johnsons Creek and Lewis Gut in 2023. Error bars represent standard error.

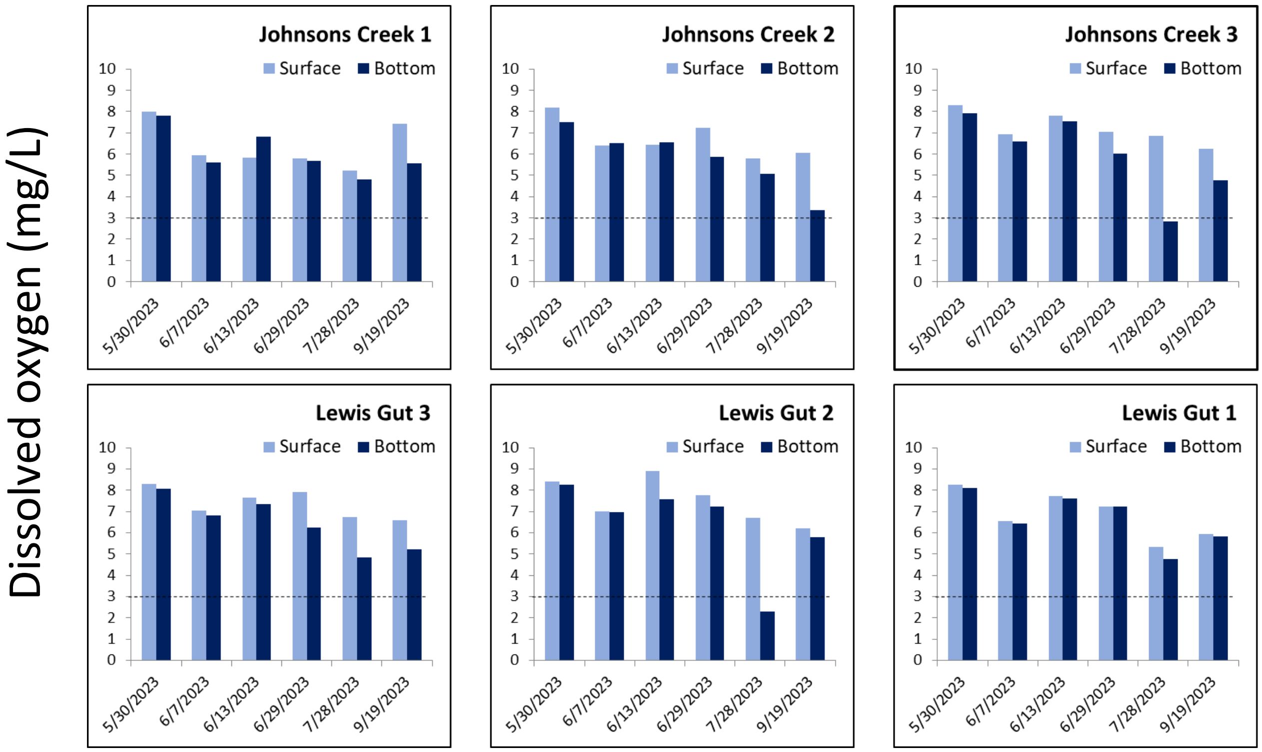


Figure B5.5. Surface and bottom dissolved oxygen values at each Johnsons Creek and Lewis Gut sampling station on each monitoring date during the 2023 season. The dotted line represents hypoxic conditions (3 mg/L). Please note x-axis is individual sampling dates, not a time scale.

Temperature and Salinity

Mean water temperature in Johnsons Creek and Lewis Gut were relatively consistent across all sites (Figure B5.6). Salinity was lower at the surface than the bottom in the Johnsons Creek stations, where the harbor is influenced by Bruce Brook and is less well mixed. There was no notable salinity gradient in Lewis Gut (Figure B5.7).

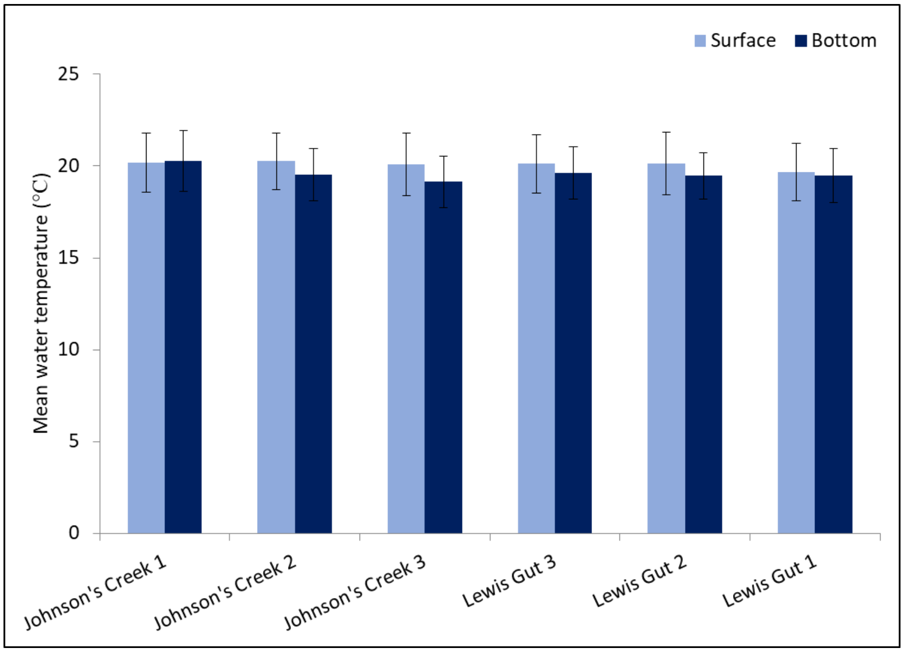


Figure B5.6. Mean water temperature at the surface and bottom at each sampling station in Johnsons Creek and Lewis Gut in 2023. Error bars represent standard error.

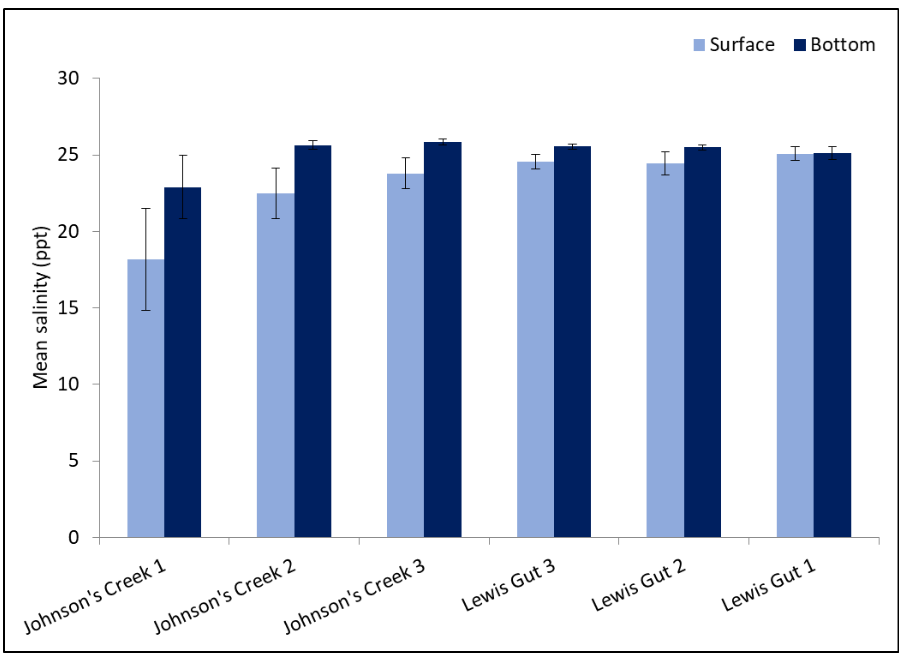


Figure B5.7. Mean salinity at the surface and bottom at each sampling station in Johnsons Creek and Lewis Gut in 2023. Error bars represent standard error.

Water Clarity

Mean secchi depth readings ranged from a minimum of 1.11m at station Johnsons Creek 1 to a maximum of 1.39m at station Lewis Gut 2. Mean secchi readings varied in both sections of the harbor with the higher readings being observed near the mouth where both embayments converge into Bridgeport Harbor (Figure B5.8).

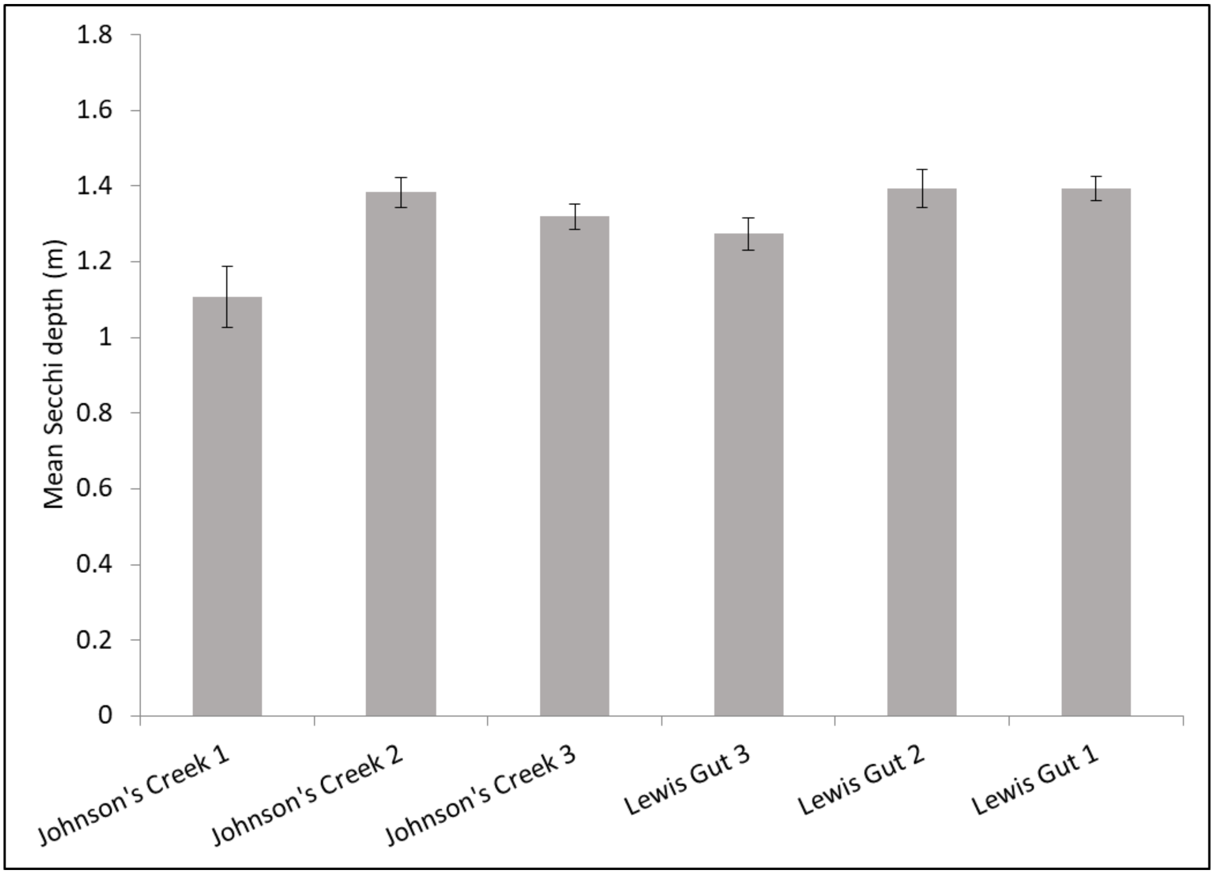


Figure B5.8. Mean secchi depth readings in the Johnsons Creek and Lewis Gut in 2023. Error bars represent standard error.

6. Housatonic Estuary

Developmental pressures on the east and west shorelines of the Housatonic River estuary offer a contrast in land use. The fully-developed west bank from the mouth of the estuary north to the I-95 Bridge contains two small parks, an abandoned engine plant, an Air and Space Center, Sikorsky Memorial Airport, a waste water treatment plant and three marinas (R. Harris, personal observations; Figure B6.1). The east bank's land use is different; the Charles E. Wheeler Wildlife Management Area includes a 625 acre tidal marsh at the mouth of the estuary and is protected from wave action by a barrier beach. Land use heading north is largely residential before reaching the I-95 Bridge, with a power plant to the north of the bridge (Figure B6.1). Flushing of the harbor is promoted by the wetlands as well as strong freshwater river currents. Flood tides are very strong and turbulent in this harbor due to the configuration of the outer harbor and the large crescent shape of the surrounding shoreline (Figure B6.2). Ebb tides can also be strong due to the wide basin in the river which can promote flushing. As a result of these dynamic currents, the water column is well mixed throughout the harbor, as was observed at all 7 stations for dissolved oxygen, water temperature, and salinity (see figures on following pages). The prevailing currents were so strong during the monitoring season, sampling could only be conducted during slack tides. The estuary is fished by many different shellfish companies for seed oysters and many boats can be seen on its waters when the seed oyster season is open.

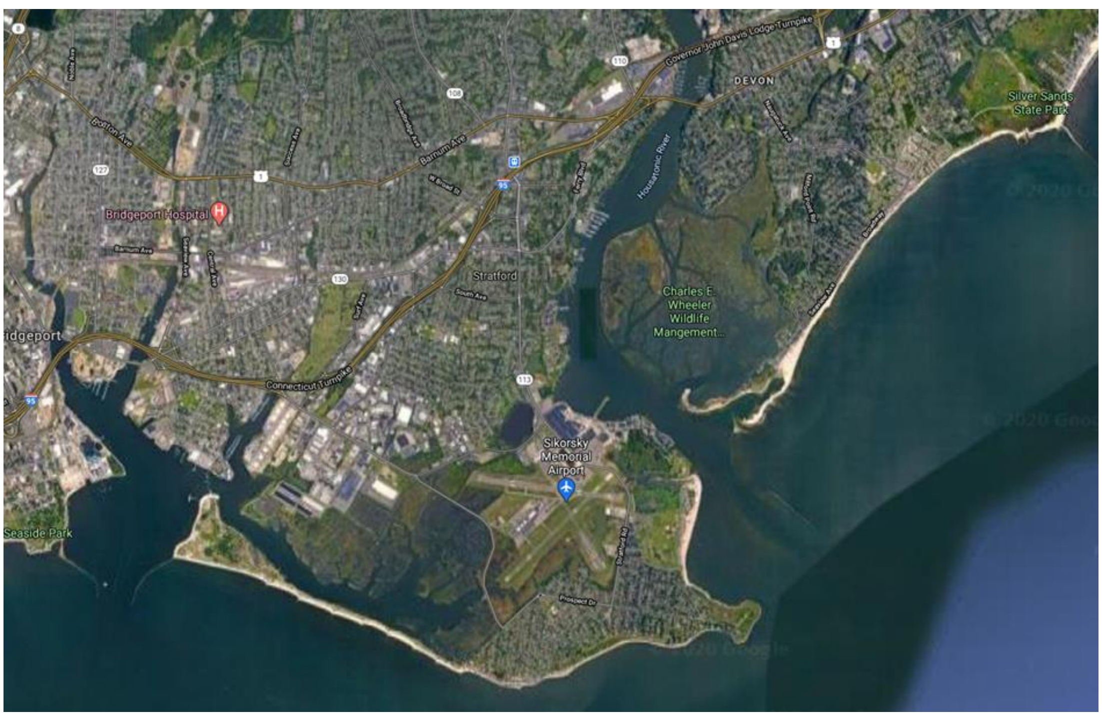


Figure B6.1. Aerial image of the Housatonic River and surrounding development and wildlife management area (photo source: Google Maps).

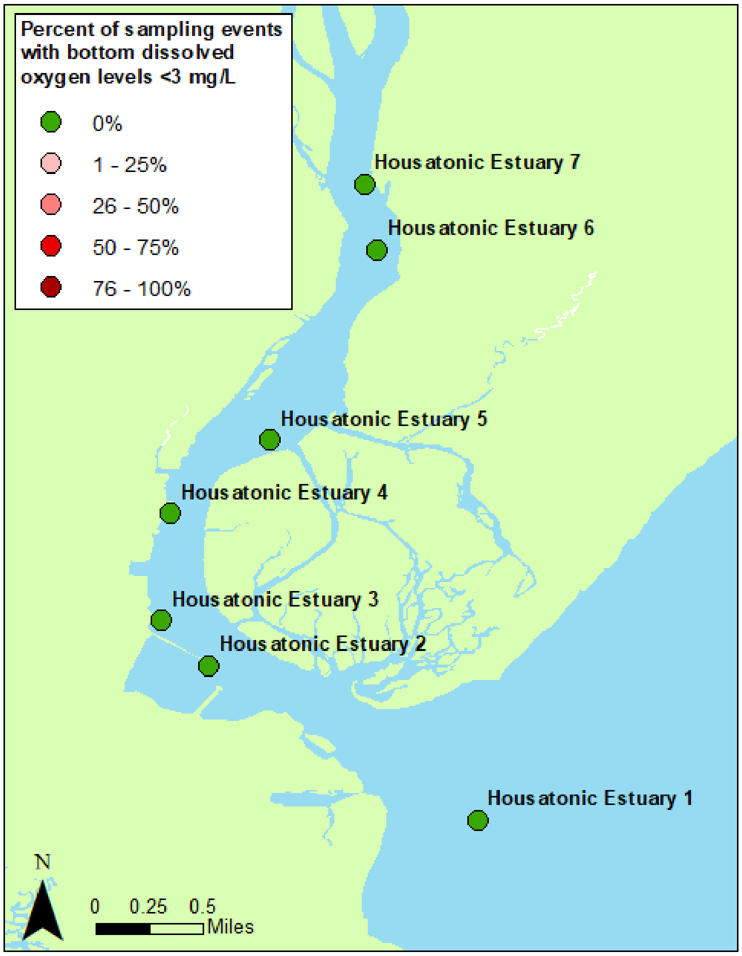


Figure B6.2. Map of Housatonic River sampling stations in 2023. Color of dots represents the percent of sampling events with bottom dissolved oxygen levels less than 3 mg/L.

Table B6.1. Coordinates and descriptions for each sampling station in Housatonic River

Site Name	Latitude	Longitude	Description
Housatonic Estuary 7	41.20755	-73.109833	Nun buoy #28
Housatonic Estuary 6	41.203067	-73.10895	Nun buoy #24
Housatonic Estuary 5	41.190217	-73.11615	Can buoy #21
Housatonic Estuary 4	41.18525	-73.122917	Pilings
Housatonic Estuary 3	41.178033	-73.12355	Nun buoy #14
Housatonic Estuary 2	41.174983	-73.120333	Engine Plant Point
Housatonic Estuary 1	41.164533	-73.102183	Nun buoy #4

Dissolved Oxygen

Seven stations were monitored in Housatonic Estuary on 6 days from May through September. Mean dissolved oxygen concentrations ranged from a minimum of 7.36 mg/L at the bottom of station Housatonic Estuary 3 to a maximum of 8.74 mg/L at the surface of station Housatonic River 7 (Figure B6.3). Dissolved oxygen concentrations trended downward throughout the course of the monitoring season, increasing slightly in late August into mid-September (Figure B6.4). Of all of the dissolved oxygen observations, 2% were below 5 mg/L, and no observations measured below 3mg/L.

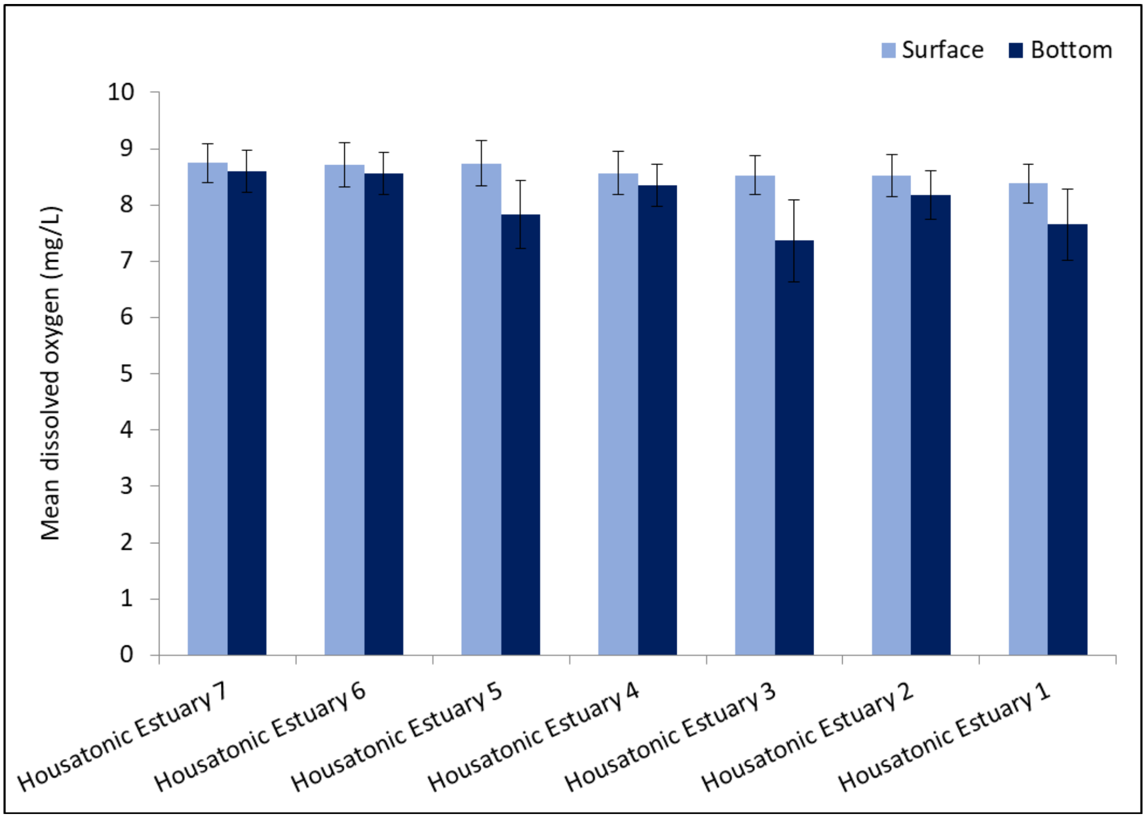


Figure B6.3. Mean dissolved oxygen concentrations at the surface and bottom at each sampling station in the Housatonic River in 2023. Error bars represent standard error.

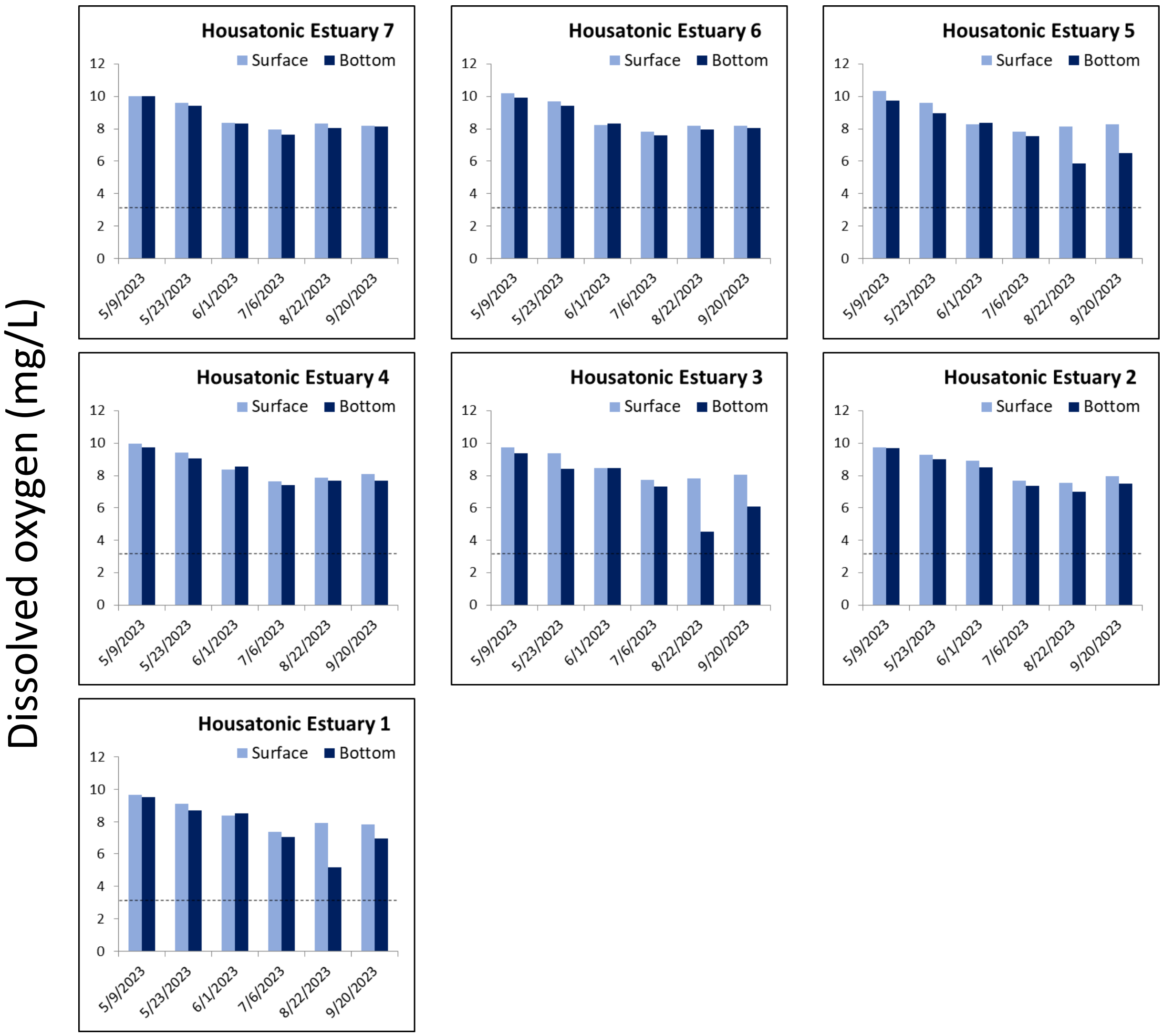


Figure B6.4. Surface and bottom dissolved oxygen values at each Housatonic River sampling station on each monitoring date during the 2023 season. The dotted line represents hypoxic conditions (3 mg/L). Please note x-axis is individual sampling dates, not a time scale.

Temperature and Salinity

Mean water temperature in the Housatonic Estuary was similar throughout the water column in 2023 (Figure B6.5). Mean salinity was lower at the surface than the bottom at all stations likely due to the influence of rainfall event runoff within the watershed and fresh water from the Housatonic River (Figure B6.6). On 4 days, salinity levels throughout the water column at each site in the estuary were <15 ppt. On 7/6/23, 80% of all water column salinity readings were <1 ppt. Prolonged low salinity concentrations can have negative impacts on marine species, particularly the larval stages of fish and crustaceans as was observed in 2021 and 2023 in the harbor (R. Harris, P. Fraboni, and J. Bloom, personal observations).

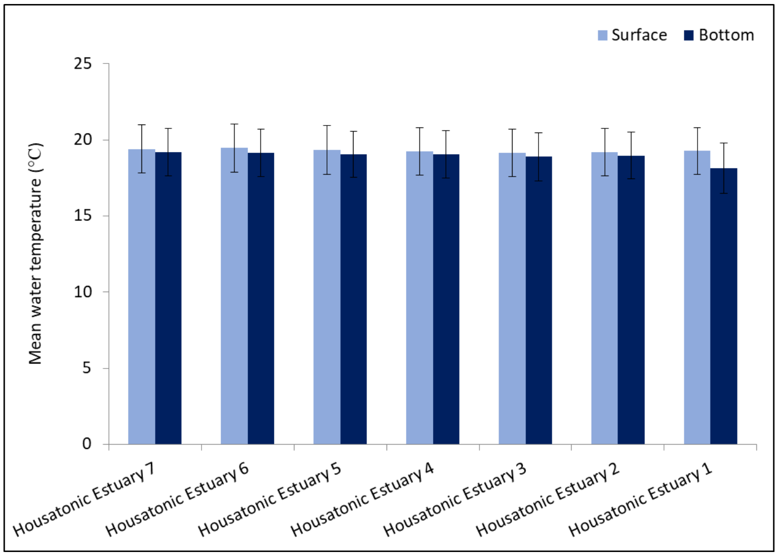


Figure B6.5. Mean water temperature at the surface and bottom at each sampling station in the Housatonic Estuary in 2023. Error bars represent standard error.

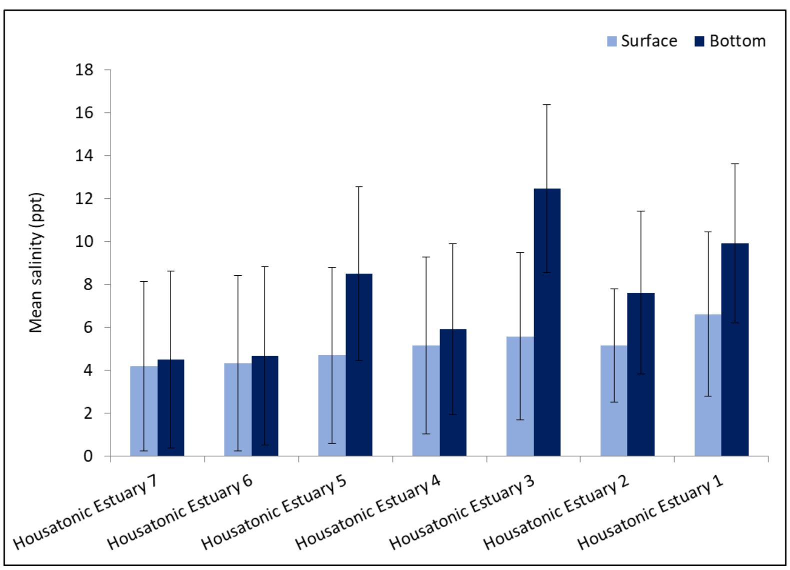


Figure B6.6. Mean salinity at the surface and bottom at each sampling station in the Housatonic Estuary in 2023. Error bars represent standard error.

Water Clarity
Mean secchi depth readings ranged from a minimum of 1.42m at station Housatonic Estuary 2 to a maximum of 1.56m at station Housatonic Estuary 7. Mean secchi readings fluctuated along the length of the estuary (Figure B6.7).

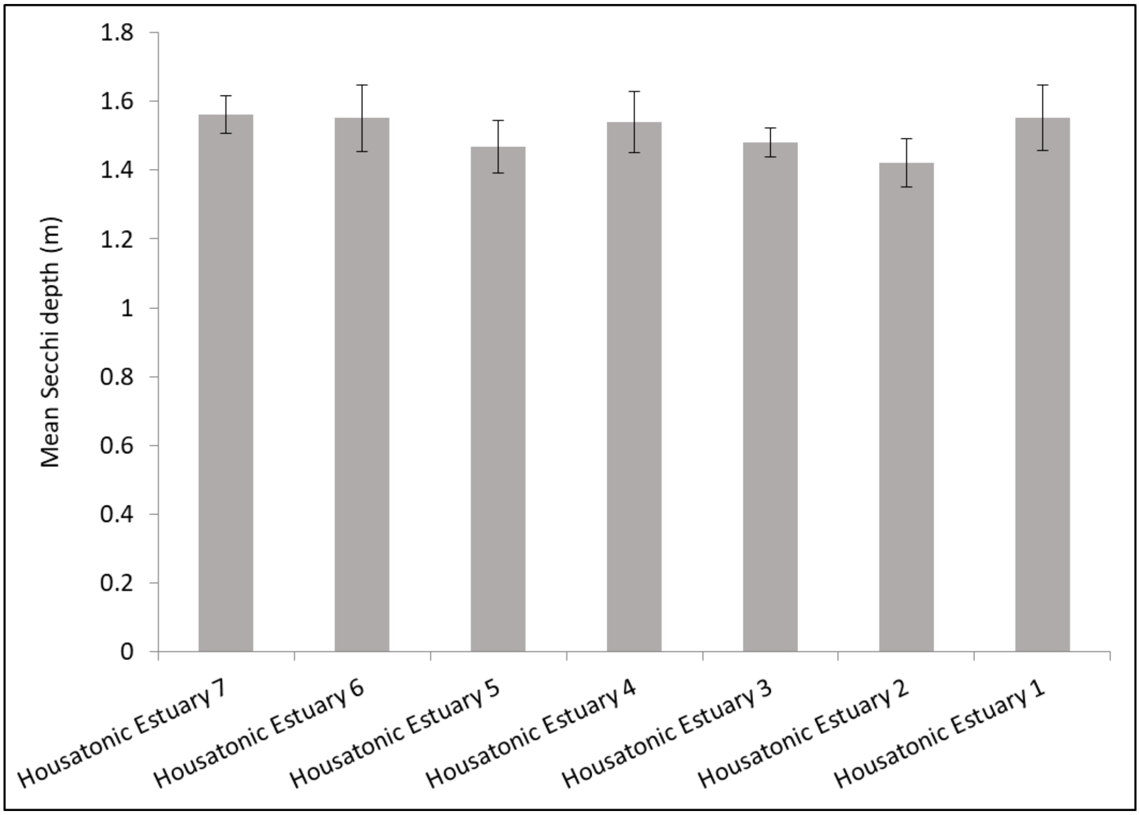
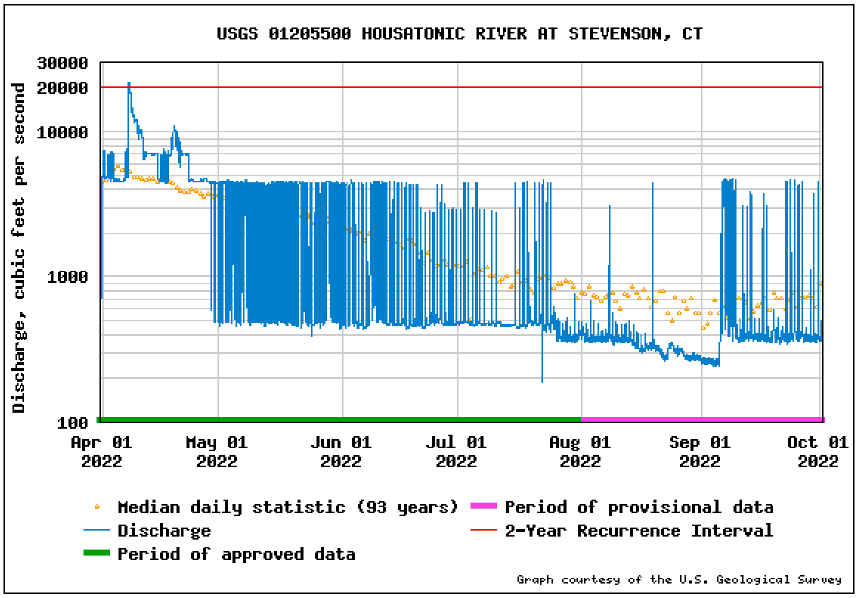


Figure B6.7. Mean secchi depth readings in the Housatonic Estuary in 2023. Error bars represent standard error.

Housatonic River Discharge

The figures below illustrate discharge in cubic feet per second recorded at the United States Geological Survey monitoring station on the Housatonic River in Stevenson, CT. Yellow triangles represent the daily median value over the last 93 years, and the blue line represents the recorded discharge for a particular date. Flow in the Housatonic River is regulated by dams which is why the graphs below have many vertical lines. Discharge in 2023 was higher than in 2022, specifically between late July through early October due to frequent rain events in 2023 (Figure B6.8).



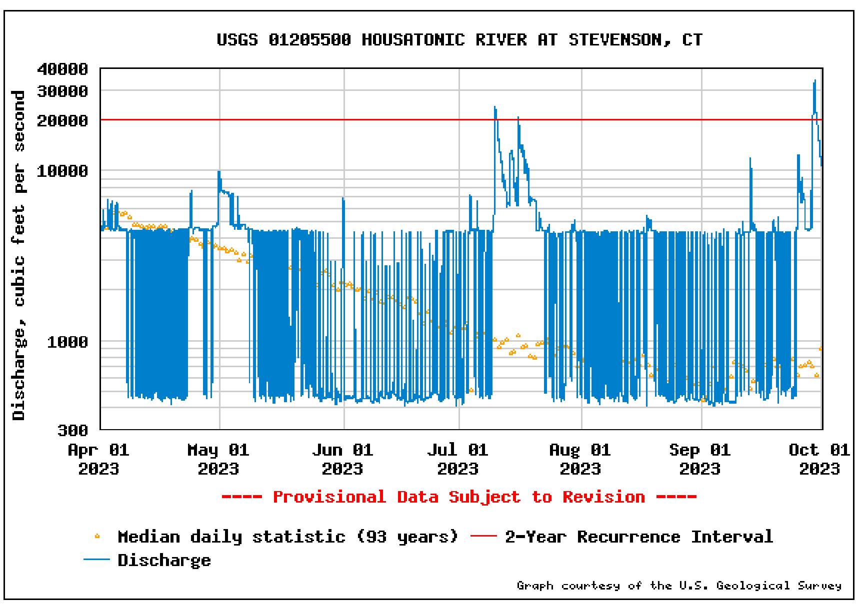


Figure B6.8. USGS flow data in ft^3/s for the period of April 1 through October 1, 2022 (top) and 2023 (bottom), respectively for the Housatonic River in Stevenson, CT (Graphs courtesy of the U.S. Geological Survey). Please note the difference in scale on the y-axis.

7. New Haven Harbor (Quinnipiac River section)

New Haven Harbor is an important estuary for the shellfish industry because it is a spawning ground for oysters. The Quinnipiac River supplies the fresh water flow at the northern end of the estuary, meeting the harbor near the I-91 bridge. The southern end of the estuary widens to a broad but shallow embayment south of the Ferry Street Bridge. The constricted area at the lower end of the basin (station Housatonic River 4) provides excellent tidal flushing for the whole basin on ebb tide. The upper portion of the estuary between the Ferry Street bridge and the I-91 bridge was studied for this water quality survey. Approximately 1.5 miles long by 0.25 miles wide, this portion of the estuary is a semi-enclosed basin. A protected wetland, the 35-acre Quinnipiac Meadows - Eugene B. Fargeorge Preserve, is located on the eastern shoreline along the upper portion of the estuary (Figure B7.1). The lower portion on the eastern shore, south of the Grand Avenue Bridge, is occupied by Copps Island Oysters harvesting facility and a barge refurbishing company. The land use on the western shore includes a marina and residential areas. The area south of the Grand Avenue Bridge is navigable by large vessels while the area north of the bridge becomes very shallow at low tide and is navigable only by small boats. Due to these shallow waters and prevailing fast currents, monitoring could only occur during slack high tides.

Figure B7.1. View of the large flushing basin in New Haven Harbor with extensive wetlands on the eastern shore.

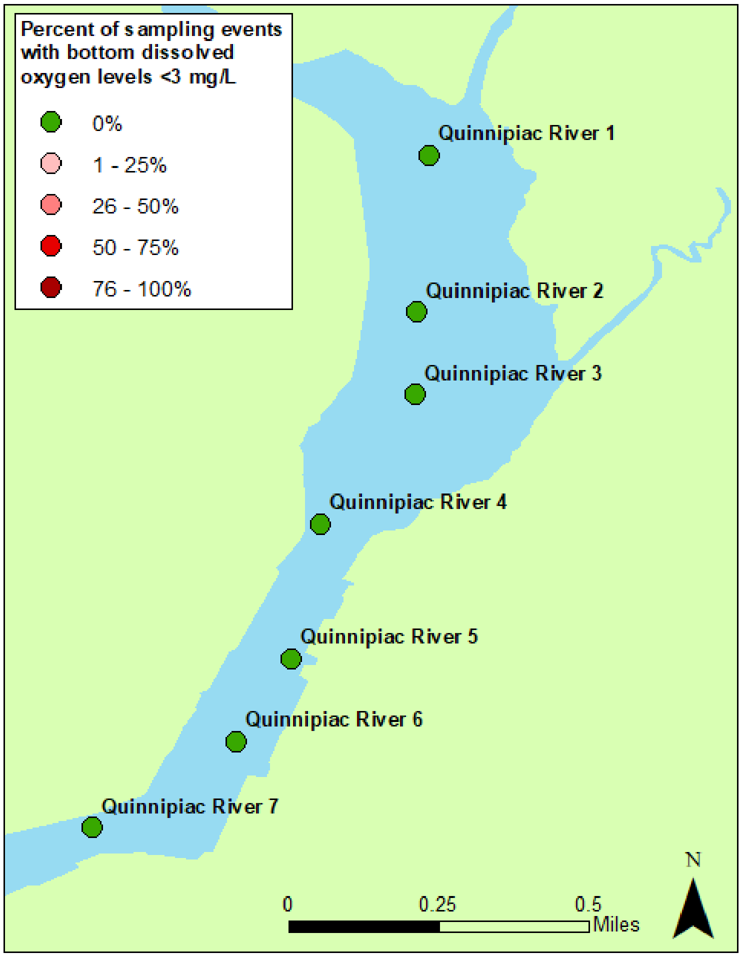


Figure B7.2. Map of Quinnipiac River sampling stations in 2023. Color of dots represents the percent of sampling events with bottom dissolved oxygen levels less than 3 mg/L.

Table B7.1. Coordinates and descriptions for each sampling station in Quinnipiac River

Site Name	Latitude	Longitude	Description
Quinnipiac River 1	41.318350	-72.885483	Mid-channel just north of Quinnipiac Meadows
Quinnipiac River 2	41.314550	-72.885783	Off of the Anastasio's Boathouse Cafe
Quinnipiac River 3	41.312550	-72.885800	Mid-channel south of Waucoma Yacht Club
Quinnipiac River 4	41.309409	-72.888093	Upstream from the Grand Ave Bridge
Quinnipiac River 5	41.306167	-72.888817	South end of the shell pile on Quinnipiac Ave
Quinnipiac River 6	41.304167	-72.890133	Four pilings
Quinnipiac River 7	41.302067	-72.893617	Ferry Street Bridge

Dissolved Oxygen

Seven stations were monitored in the Quinnipiac River on 6 days, from May through September. Mean dissolved oxygen concentrations ranged from a minimum of 6.40 mg/L on the bottom at station Quinnipiac River 2 to a maximum of 6.97 mg/L at the surface at station Quinnipiac River 7 (Figure B7.3). Dissolved oxygen values followed expected seasonal trends with concentrations dropping from early June through August and then slightly rising through September. Of all of the bottom dissolved oxygen observations, 5% fell below 5 mg/L while no bottom dissolved oxygen values fell below 3 mg/L.

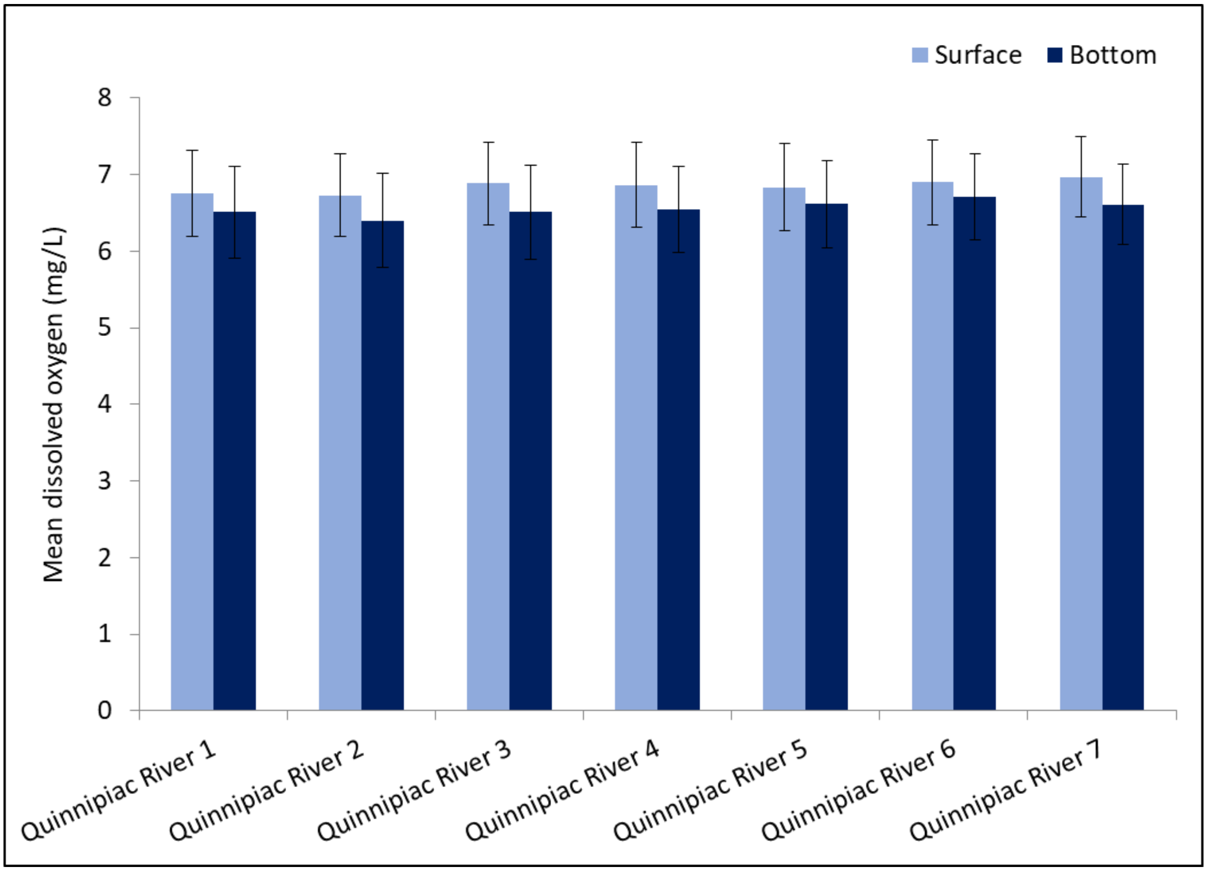


Figure B7.3. Mean dissolved oxygen concentrations at the surface and bottom at each sampling station in the Quinnipiac River in 2023. Error bars represent standard error.

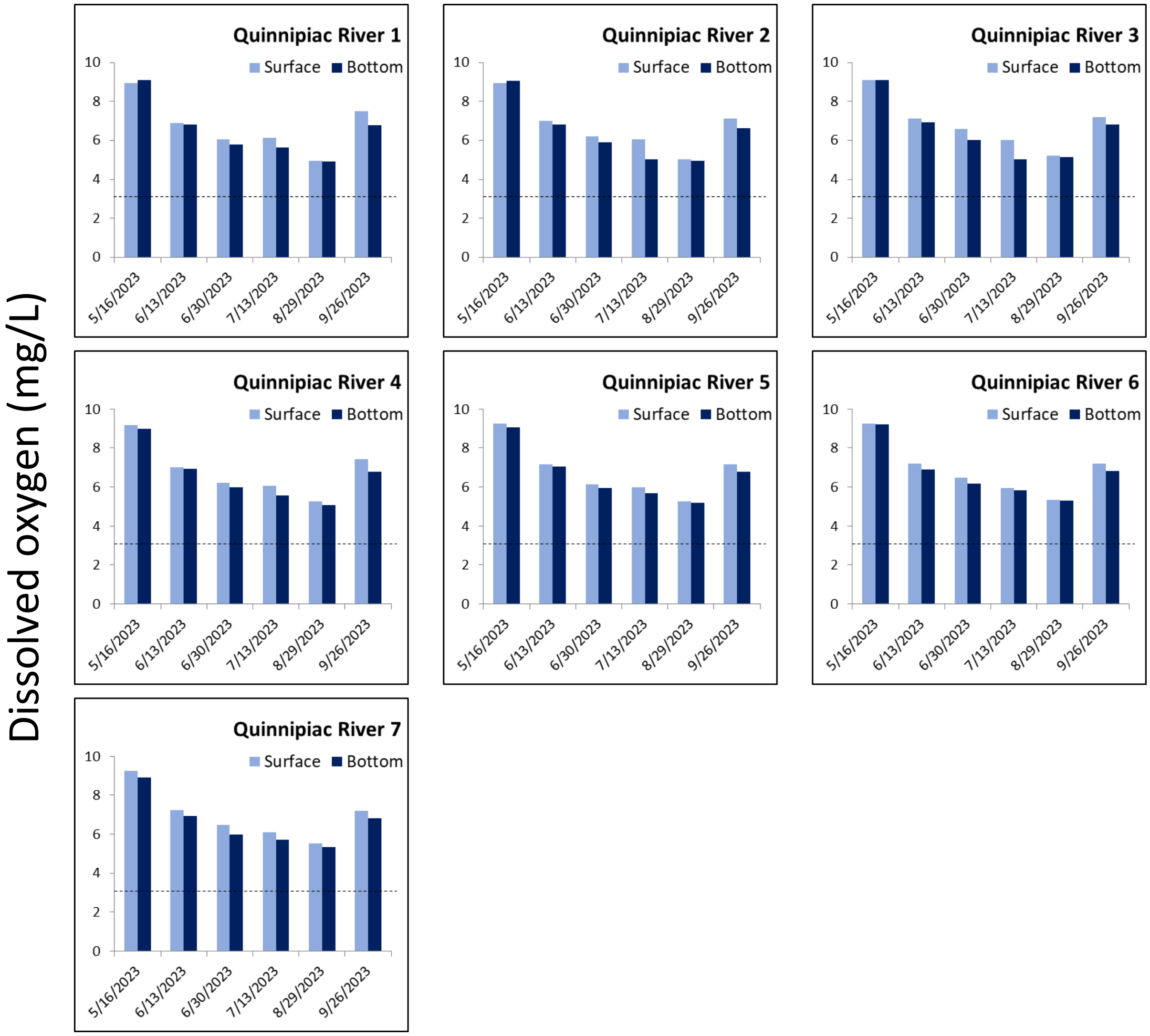


Figure B7.4. Surface and bottom dissolved oxygen values at each Quinnipiac River sampling station on each monitoring date during the 2023 season. The dotted line represents hypoxic conditions (3 mg/L). Please note x-axis is individual sampling dates, not a time scale.

Temperature and Salinity

Mean water temperature in the Quinnipiac River was observed to be similar throughout the water column in 2023 (Figure B7.5). Salinity was slightly lower at the surface than the bottom at all stations due to fresh surface water input from the Quinnipiac River (Figure B7.6).

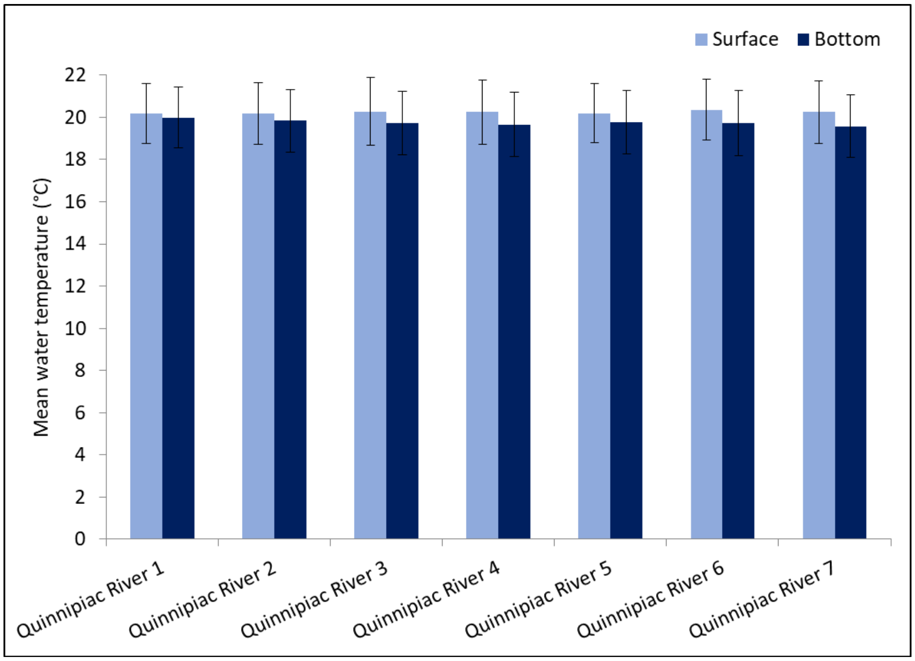


Figure B7.5. Mean water temperature at the surface and bottom at each sampling station in the Quinnipiac River in 2023. Error bars represent standard error.

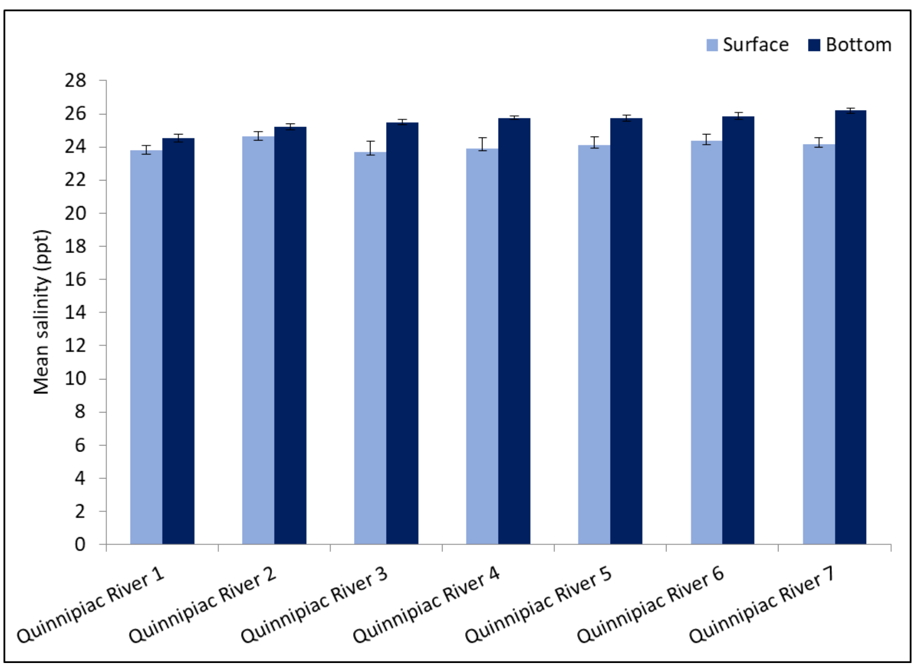


Figure B7.6. Mean salinity at the surface and bottom at each sampling station in the Quinnipiac River in 2023. Error bars represent standard error.

Water Clarity
Mean secchi depth readings ranged from a minimum of 1.45m at station Quinnipiac River 4 to a maximum of 1.6m at station Quinnipiac River 1. Mean secchi readings drop slightly after station Quinnipiac River 1 and then remain consistent down the harbor (Figure B7.7).

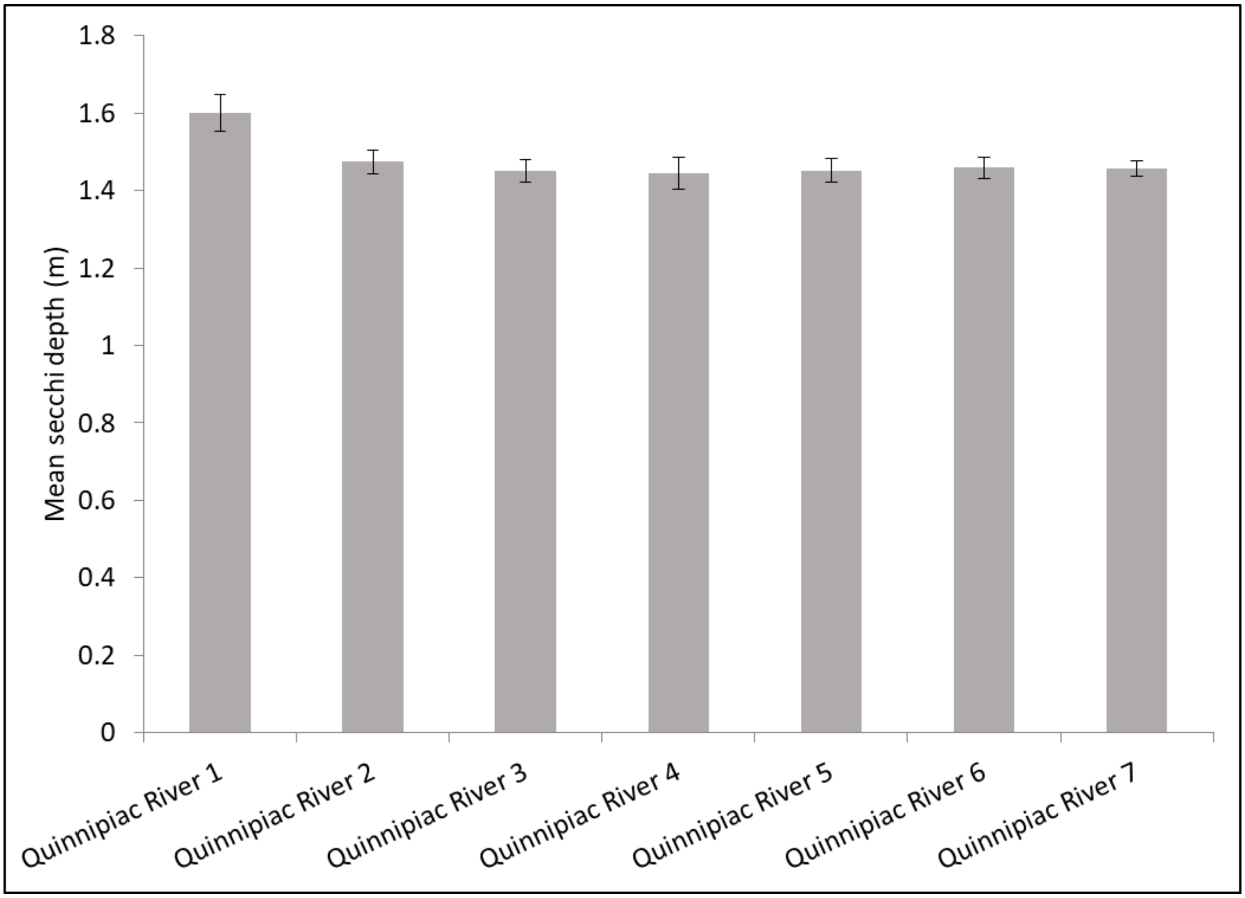
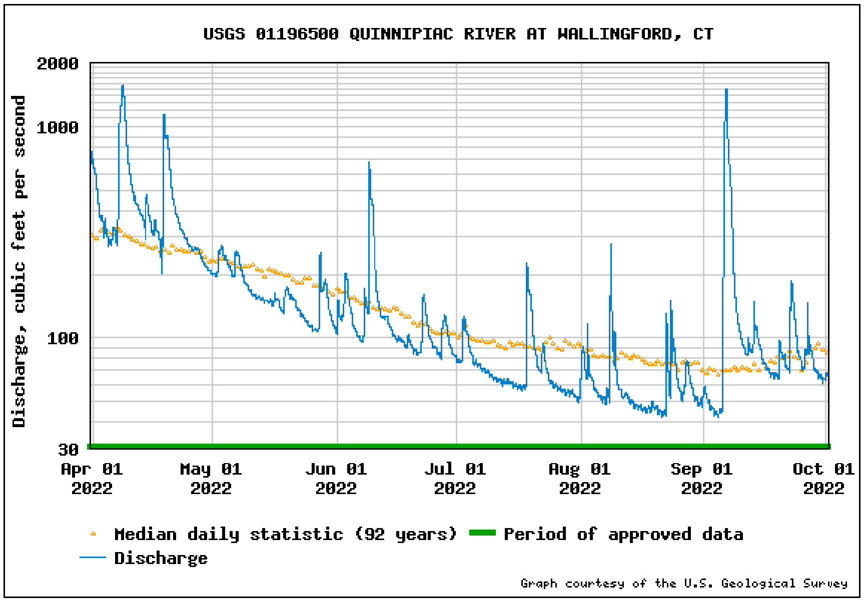


Figure 2.G.7. Mean secchi depth readings in the Quinnipiac River in 2023. Error bars represent standard error.

Quinnipiac River Discharge
The figures below illustrate discharge in cubic feet per second recorded at the United States Geological Survey monitoring station on the Quinnipiac River in Wallingford, CT. Yellow triangles represent the daily median value over the last 92 years, and the blue line represents the recorded discharge for a particular date. During 2023, the watershed experienced numerous precipitation events specifically from July through September which caused discharge to be much higher than what was observed in 2022 as well as against the median daily statistic.



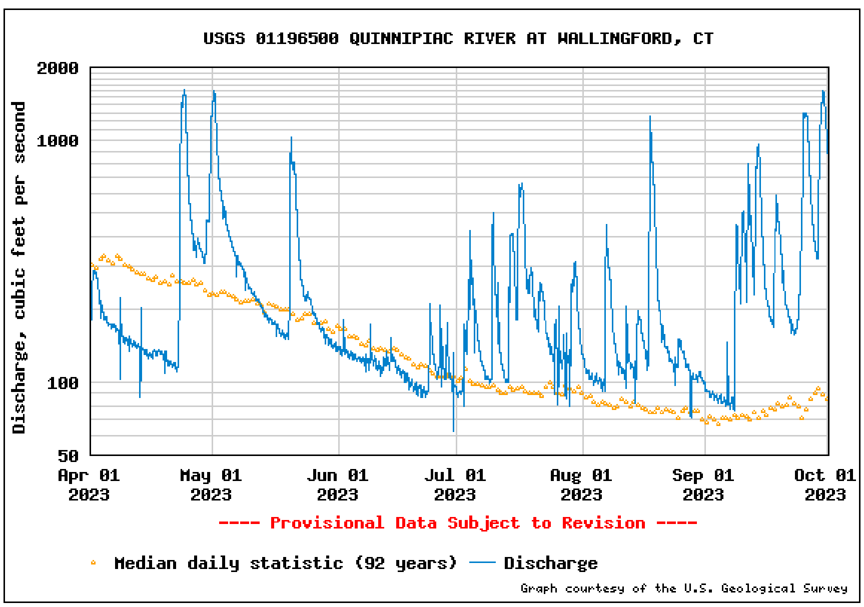


Figure B7.8. USGS flow data in ft^3/s for the period of April 1 through October 1, 2022 (top) and 2023 (bottom), respectively for the Quinnipiac River in Wallingford, CT (Graphs courtesy of the U.S. Geological Survey). Please note the difference in scale on the y-axis.

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8. QAPP Deviation Summary

Quality Assurance Project Plan (QAPP) Report (11/14/23)

This report includes any deviations from the approved QAPP (QA Tracking #23075). These deviations are listed by the section of the QAPP where the deviation occurred. Any notes from this report that would result in a process change will be updated in future QAPP submissions.

Project Name: 1m Beam Trawl Survey in Norwalk Harbor

Monitoring Organization: Harbor Watch, a program of Earthplace, Inc.
10 Woodside Lane, Westport, CT 06880

Approved for: Monitoring Season 2023

1.6 Project/Task Description

- Approximate depth was not recorded at deployment but instead was recorded at either the retrieval when depth sensor or was estimated based on experience from captain.

2.1 Sampling Design

- Box A and B were never accessible at high tide, prior to 2022 these sites could be trawled at any point in the tide cycle.
- Bow C was not trawled due to pipe crossing/construction.
- There was a time where it was necessary to trawl from box D into box E, this is designated as its own ID, box D-E and this was only done once.
- Each box was trawled an average of 6 times, and R was trawled the least at 4 times, due to tidal access.
- Mid-way through the season (August 22) we had to change boats due and navigational equipment, as a result we no longer have the boxes layered onto our navigational equipment and the trawls were more estimates compared to the precision from earlier in the season.

2.5 Quality Control Requirements

- There were only 2 species identifications discrepancies on second trawl species QC ID, which were discussed as a team and re-identified.
- There were 9 unidentified species this season, images of each organism were sent to an expert for final identification.