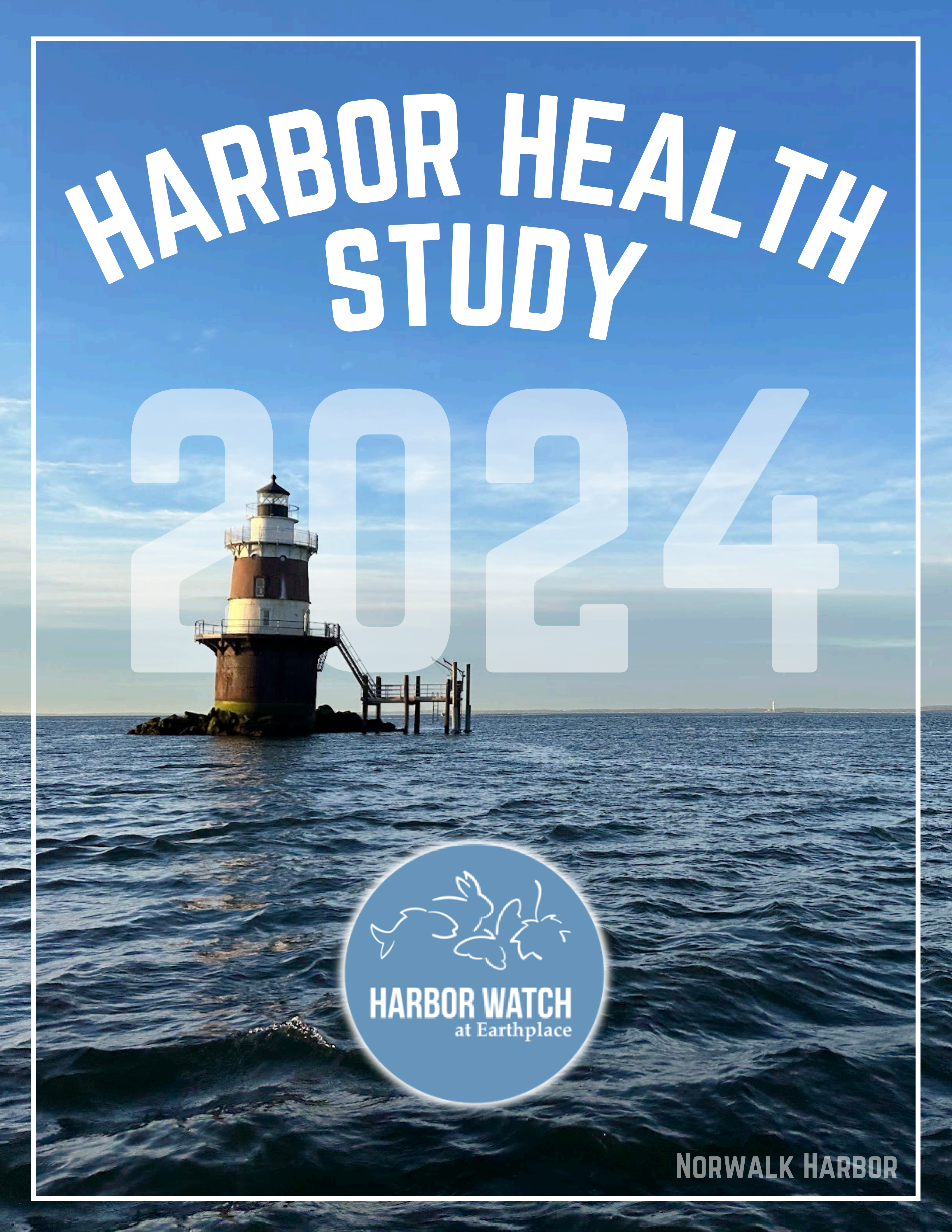
HARBOR HEALTH STUDY

2024



HARBOR WATCH
at Earthplace

NORWALK HARBOR

Contents

Harbor Health Study: 2024

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 and invertebrates in Norwalk and Saugatuck Harbors and water quality in Five Mile River Harbor, Wilson Cove, Norwalk Harbor, Saugatuck Harbor, Housatonic Estuary, and Quinnipiac Estuary.

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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 blend science, conservation, and education into pathways for learning about nature and the environment with access for all.

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 Afroz Ali, Alexander Berkley, Owen Boberski, Ryan Burns, Danielle Buttermore, Mairead Coyne, Gabriela de Brito, Olivia DeLawder, Tristan Ebrahimi, Max Eikinas, Benjamin Haisley, Hannah Hsu, Talia Lalli, R McClenning, Andrew Moore, Juliette Moore, Alicia Mozian, Arushi Patel, Kevin Piotrowicz, Rachel Precious, Joe Racz, Nandan Raman, Cosmo Randazzo, Tiffany Rivera, Hazel Rossi, Logan Santisi, Grayson Schottmuller, Amanda Stowe, Theodore Strobach, Zack Sullivan, Andre Sun, David Tomaszewski, Beatrice Tucker, Lindsay Weismann, Bill Wright, and Annabelle Zheng for all of their help with the work presented in this report.

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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 2024 on the fish and invertebrate communities in the Norwalk and Saugatuck Harbors in Connecticut, led by Harbor Watch, as well as the monitoring of water quality conditions in 6 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 and the Saugatuck 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 as many as 7 harbors annually for dissolved oxygen conditions and a study of the Norwalk and Saugatuck Harbors for species diversity and abundance.

From May through September 2024, water quality data were collected in 6 harbors (Five Mile River, Wilson Cove, Norwalk, Saugatuck, Housatonic Estuary, and the Quinnipiac Estuary). From February through October 2024, an embayment biological study was conducted in 2 harbors (Norwalk and Saugatuck). All 6 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 a 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 and Saugatuck Harbor Embayment Biological Study

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

The Saugatuck and Norwalk Harbors are both active harbors with different usage. Saugatuck Harbor is most populated during the warmer months and is known for its beaches, marinas, and recreational boating activities. The harbor hasn't been dredged in decades, making navigation difficult at low tide and disconnecting the upper portion of the river from the mouth. Despite this, the harbor is used extensively by sailors and boaters throughout the year. Norwalk Harbor is used year-round both commercially and recreationally. The harbor is most recognized for its renowned shellfishing industry, which has risen to national prominence since its start in 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. As part of the Stewart B. McKinney National Wildlife Refuge, these islands serve a valuable and important environmental function for the harbor (Steadman et al., 2016).
In 2024, Harbor Watch conducted trawls in the Saugatuck Harbor for the first time in a decade. Historically, Harbor Watch trawled the Saugatuck Harbor every year from 1990-1995 and then sporadically from 2002-2014. From the 1990s to today, there has been a large change in the fish diversity and abundance in the Saugatuck Harbor (Figure 5.1).

Harbor Watch also continued its study of the benthic community in the Norwalk Harbor, which started in 1990. With a dedicated network of volunteers, including the Wilton High School Marine Biology Club, Harbor Watch has been quantifying the abundance and species composition of fish and invertebrates in the harbor, focusing on demersal species. Sampling was conducted from 1990 through 1994, and then again from 2002 to today. Throughout this time, there has been a notable increase in development along the length of the Norwalk River Estuary. As a result of shoreline hardening, there has been a reduction in riparian buffers and 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 bird 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 5.2). 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. Also, 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.

Long data sets, like that of the Norwalk and Saugatuck Harbors, are important because 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 a nursery, 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). This trend has also been evident in the Saugatuck Harbor.

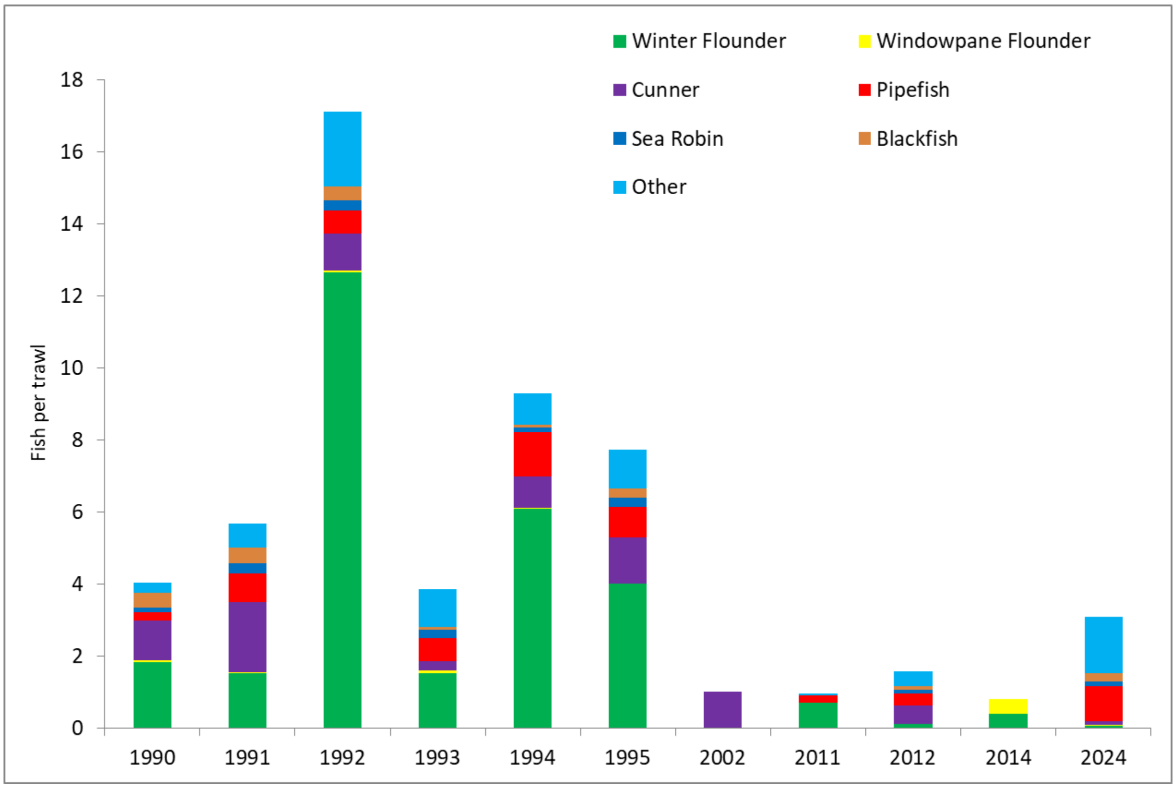


Figure 5.1. Number of fish caught per trawl (total number of individuals divided by the total number of trawls) of select species of interest from 1990 to 2024 in Saugatuck Harbor.

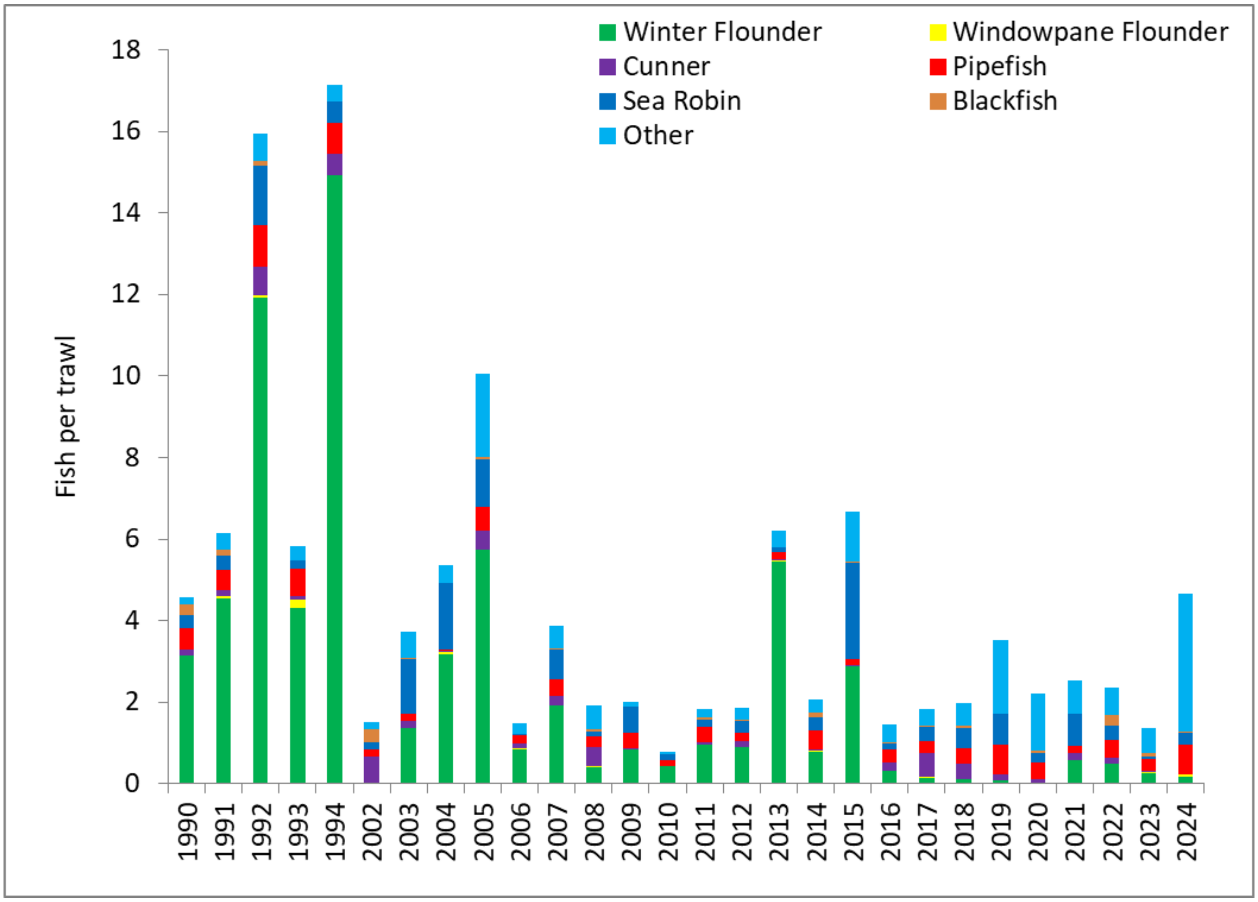


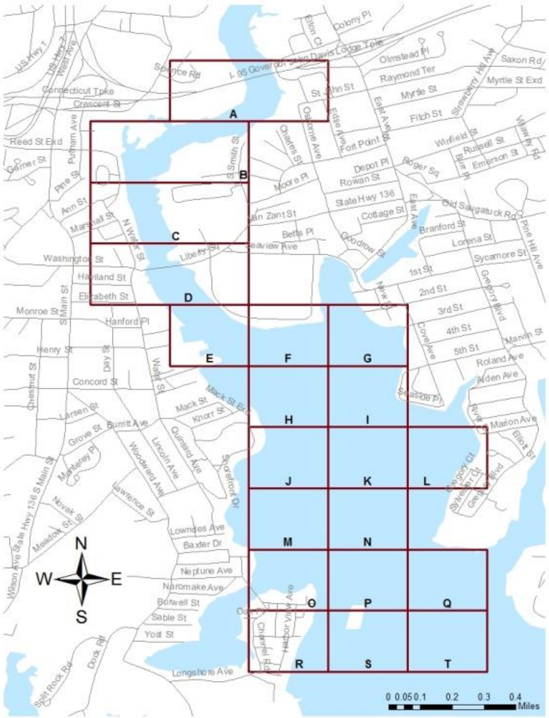
Figure 5.2. Number of fish caught per trawl (total number of individuals divided by total number of trawls) of select species of interest from 1990 to 2024 in Norwalk Harbor.

5.A. Embayment Biological Study Methods

Protocols used in trawling events in Norwalk Harbor 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. The ability to trawl in Saugatuck Harbor was realized after QAPP approval, but methods followed those in the approved QAPP.

In late 2023, Harbor Watch had a new custom research vessel built; a 24' Seamule equipped with an electric pot hauler for trawl retrieval. To ensure that the vessel was functioning as needed and to allow staff time to become accustomed to the vessel, 11 trawls were conducted in Norwalk Harbor before the typical start of the season. These trawls occurred on 2 days in February and 1 day in April. The data collected during these trawls are included in the analysis, but the main trawling season was conducted from May to October. 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, established by CT DEEP in 1990, boxed off both harbors into $300m^2$ sampling areas. Norwalk Harbor has a total of 20 boxes and Saugatuck Harbor has 24 boxes (Figure 5.A.1 (a, b)). During each trawling session, typically a minimum of 3 of the sampling area "boxes" were selected to trawl. An attempt was made to sample from each of the upper harbor (Norwalk Harbor: boxes A-F, Saugatuck Harbor: boxes A-E), middle harbor (Norwalk Harbor: boxes G-N, Saugatuck Harbor: boxes F-M, P-R), and outer harbor (Norwalk Harbor: boxes O-T, Saugatuck Harbor: boxes N, O, S-X) on each sampling day. When the research vessel was positioned within the selected box using a Garmin 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 the 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 years that this study has been conducted, 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, 5.2).

(a) 

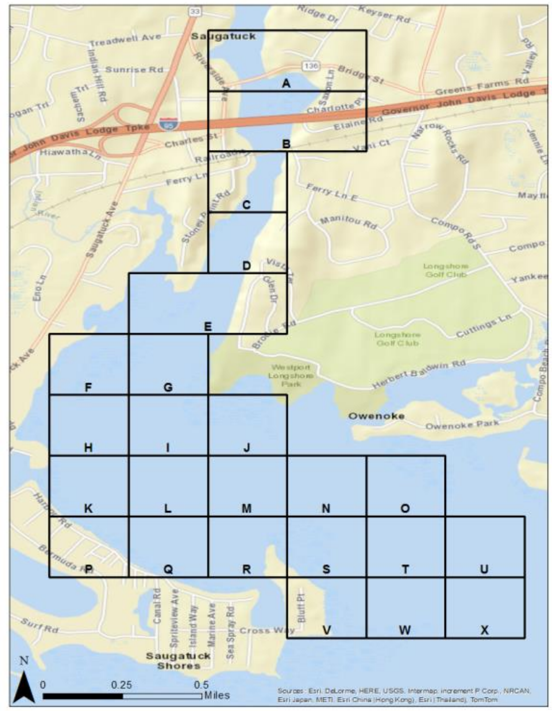
(b) 

Figure 5.A.1. Location of trawl sampling areas or "boxes" within (a) Norwalk Harbor and (b) Saugatuck Harbor.

5.B. Norwalk Harbor Embayment Biological Study Results and Discussion

Fish

During 2024, 665 individual fish from 25 different species were caught in Norwalk Harbor (Figure 5.B.1). The 3 most abundant species caught in 2024 were weakfish (*Cynoscion regalis*), pipefish (*Syngnathus spp.*), and summer flounder (*Paralichthys dentatus*), which accounted for 49% of the total number of individuals caught. Fish were observed in all of the 19 boxes sampled (Figure 5.B.2) (no trawls were conducted in Box C due to submarine cables). Box I had the greatest number of fish caught during 2024 with 81 individuals caught in nine trawls. The boxes in the middle harbor had a higher catch per trawl than boxes in the inner and outer harbor (Figure 5.B.3). Overall fish presence in trawls exhibited a significant increase between 2023 and 2024. In 2023, 45% of trawls resulted in no fish presence; however, in 2024, this figure decreased to 17% (Figure 5.B.4). 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.B.1).

Table 5.B.1. Total number of trawls per box, February through October 2024.

Box	Number of Trawls
A	7
B	9
C	0
D	6
E	8
F	6
G	7
H	7
I	9
J	7
K	8
L	7
M	7
N	10
O	7
P	9
Q	7
R	4
S	10
T	8

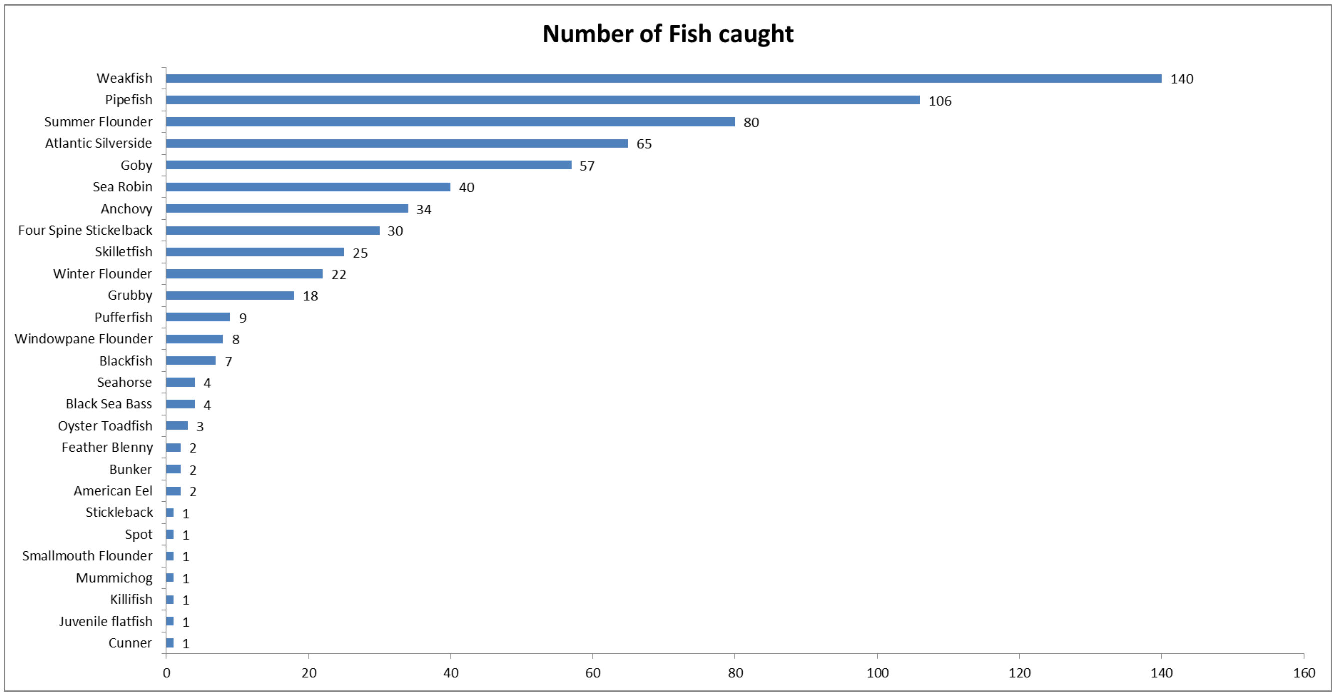


Figure 5.B.1. Total number of individuals caught for each fish species in Norwalk Harbor, February through October 2024.

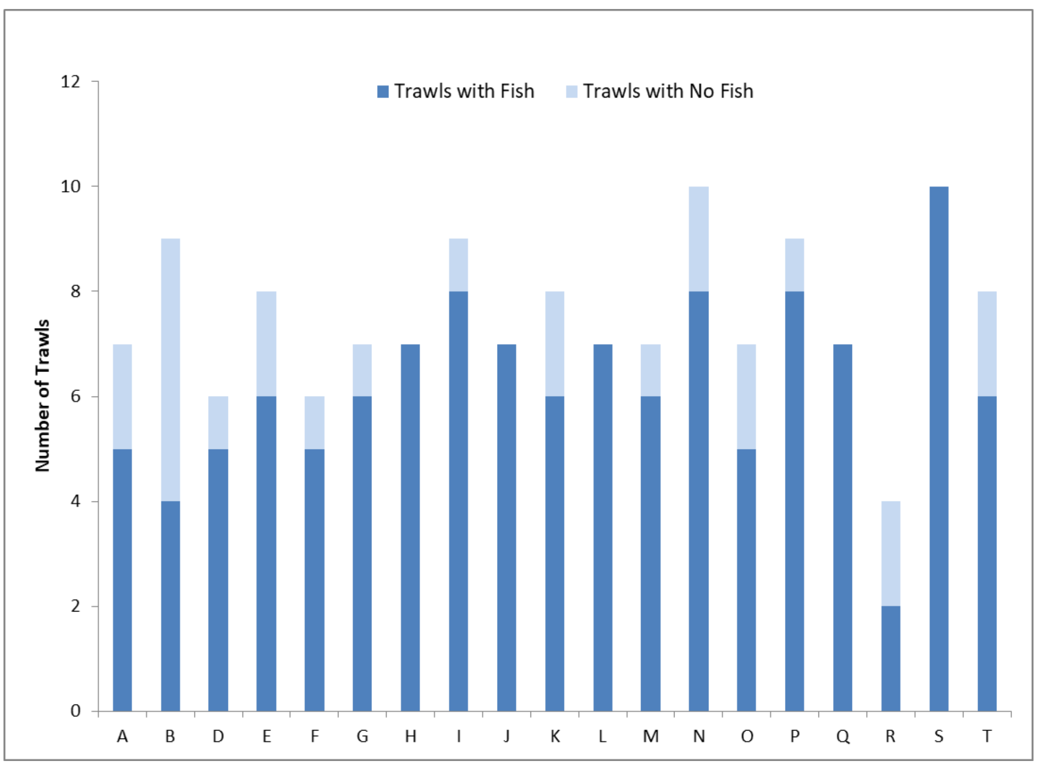


Figure 5.B.2. Number of trawls with fish or without fish in each "box" in Norwalk Harbor, February through October 2024.

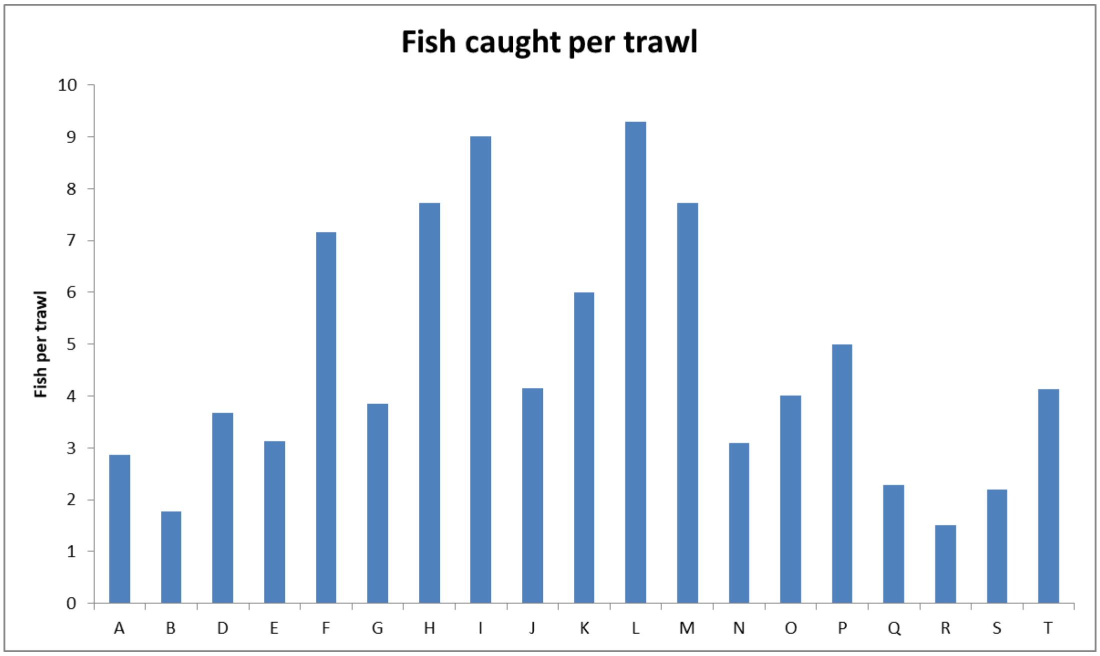


Figure 5.B.3. Number of fish caught per trawl (total number of individuals divided by total number of trawls) in Norwalk Harbor for each box trawled in 2024.

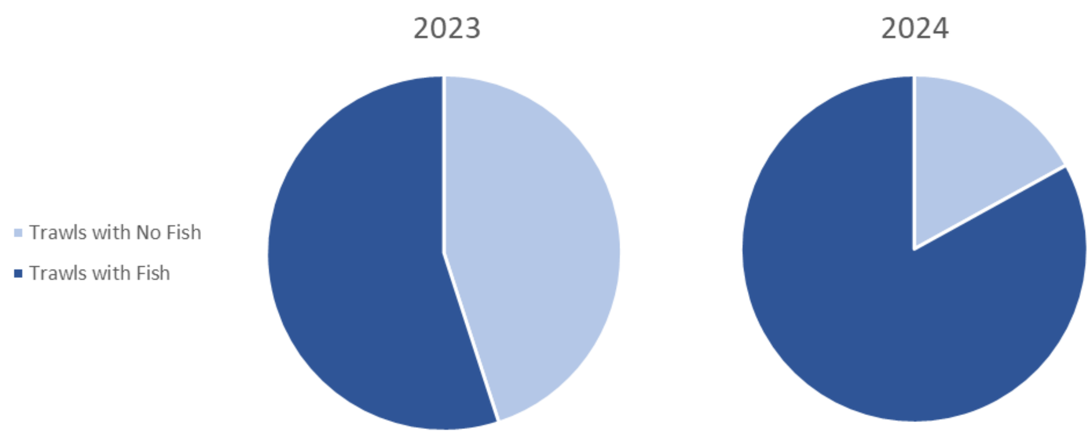


Figure 5.B.4. Percentage of trawls with fish or without fish in Norwalk Harbor in the 2023 and 2024 seasons (including trawls in February and April 2024).

The overall number of fish per trawl (catch per unit) in Norwalk in 2024 was 4.65 fish which is 3.3 higher than the fish per trawl in 2023 (Table 5.B.2). This is the first time in 8 years that the fish per trawl was greater than 4. In 2024, 143 trawls were conducted and a total of 665 fish were caught, the highest number of trawls in a single year and the second highest number of individual fish caught since the study began. The total number of fish species caught in 2024 was 25, the highest diversity since the start of the study. Factors that may be related to these high statistics include warming water temperature which is bringing traditionally more southern species northward and concerted efforts to reduce nutrient pollution to Long Island Sound which is improving dissolved oxygen concentrations. This study is expected to continue in 2025 to provide additional data to this long-term dataset.

Table 5.B.2 Trawling stats from 1990 to 2024 in Norwalk Harbor

Year	Total Fish Caught	Total Trawls	Catch Per Unit	Total Empty Nets	Percent Empty Nets	Number of Fish 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
2024	665	143	4.65	1	0.7%	25

Crustaceans

In 2024, 34,190 individual crustaceans representing 14 species were observed. Certain individual shrimp were too small to confidently identify and therefore were documented as "Juvenile Shrimp." The catch was dominated by juvenile shrimp, shore shrimp, and sand shrimp, accounting for approximately 95% of the total (Figure 5.B.5). In total, 5 different species of shrimp were caught, 1 of which was the nonnative Asian shrimp (*Palaemon macrodactylus*). Nonnative species were documented and shared with CT DEEP for identification confirmation and to be used in assessing the impacts of these species on the native populations. 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 2 species (*Libinia emarginata* and *Libinia dubia*) but was likely dominated by the nine-spined spider crab (*Libinia emarginata*). A notable catch during the 2024 monitoring season is the American Lobster (juvenile – stage 5), the first time Harbor Watch has caught one in the Norwalk Harbor in 18 years. Additionally, more than three times the amount of blue crab (*Callinectes sapidus*) were caught in 2024 than in 2023.

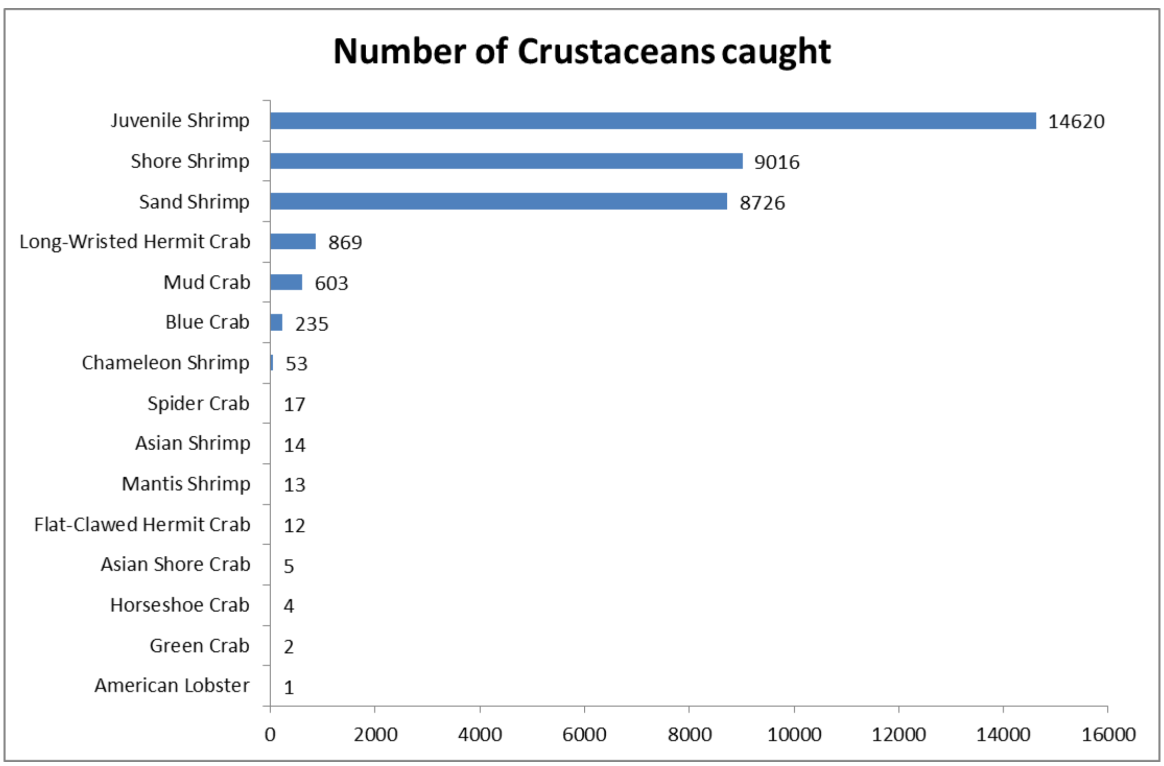


Figure 5.B.5. Crustaceans caught in Norwalk Harbor from February through October 2024.

5.C. Saugatuck Harbor Embayment Biological Study Results and Discussion

Fish

During the 2024 sampling season, 114 individual fish from 17 different species were caught in Saugatuck Harbor (Figure 5.C.1). The 3 most abundant species caught in 2024 were pipefish (*Syngnathus spp.*), skilletfish (*Gobiesox strumosus*), and goby (*Gobiosoma spp.*), which accounted for 61% of the total number of individuals. Fish were observed in 17 of the 22 boxes sampled (Figure 5.C.2). Box I had the greatest number of fish caught during 2024 with 26 individuals caught in three trawls. The number of fish caught per trawl in each box varied throughout the harbor with boxes I and K having the highest abundance (Figure 5.C.3). No trawls were conducted in boxes A and C due to height restrictions at a bridge crossing and submarine cables, respectively. 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.C.1).

Table 5.C.1. Total number of trawls per box, May through September 2024.

Box	Number of Trawls
A	0
B	2
C	0
D	1
E	3
F	2
G	1
H	1
I	3
J	2
K	2
L	1
M	2
N	2
O	1
P	2
Q	2
R	2
S	1
T	1
U	2
V	1
W	2
X	1

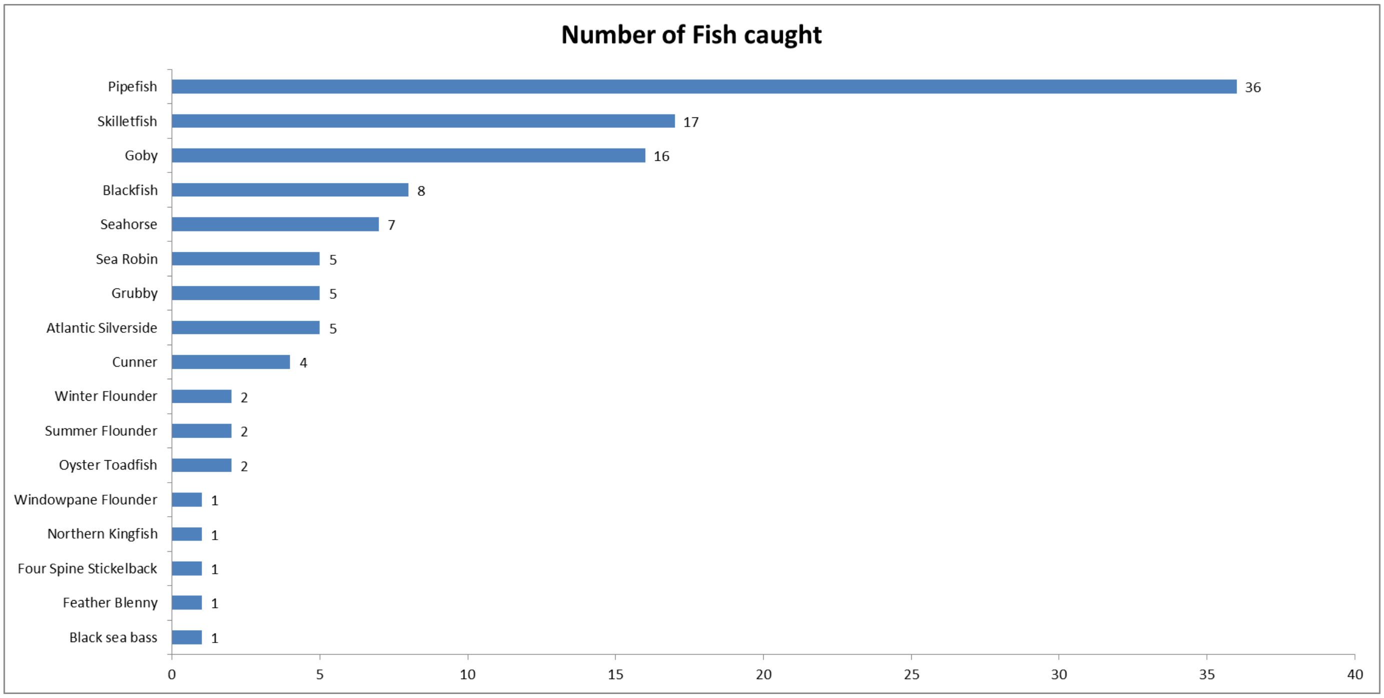


Figure 5.C.1. Total number of individuals caught for each fish species in Saugatuck Harbor, May through September 2024.

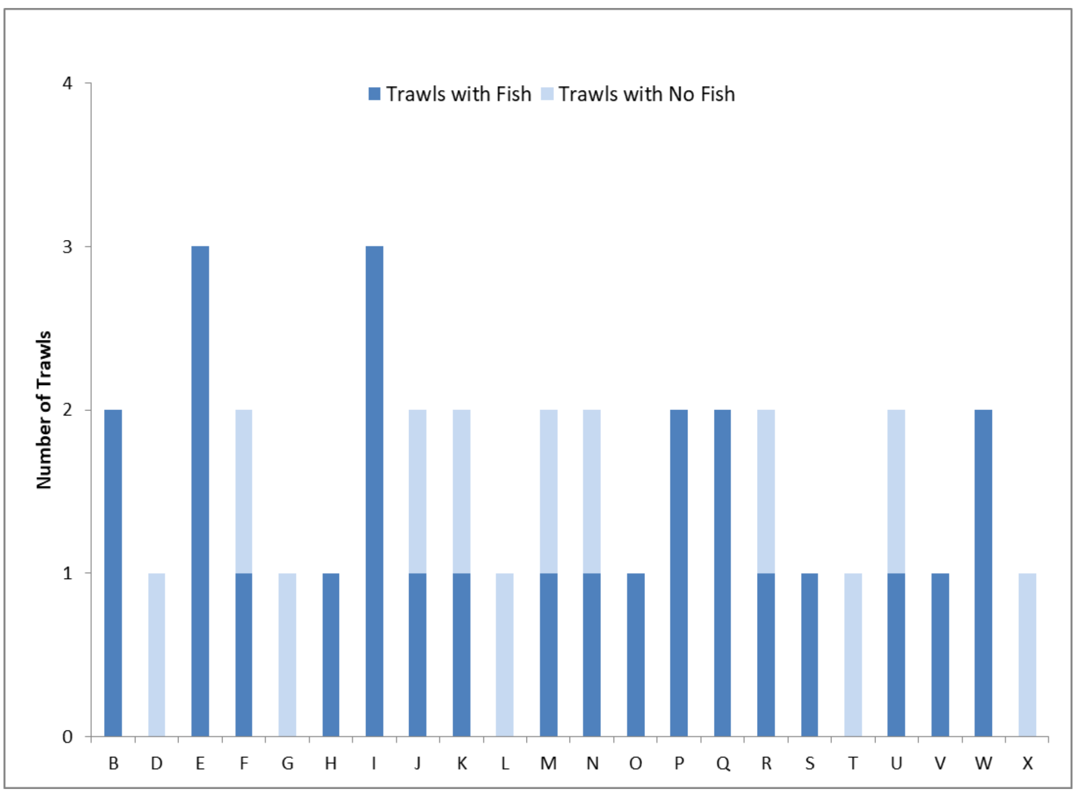


Figure 5.C.2. Number of trawls with fish or without fish in each “box” in Saugatuck Harbor, May through September 2024.

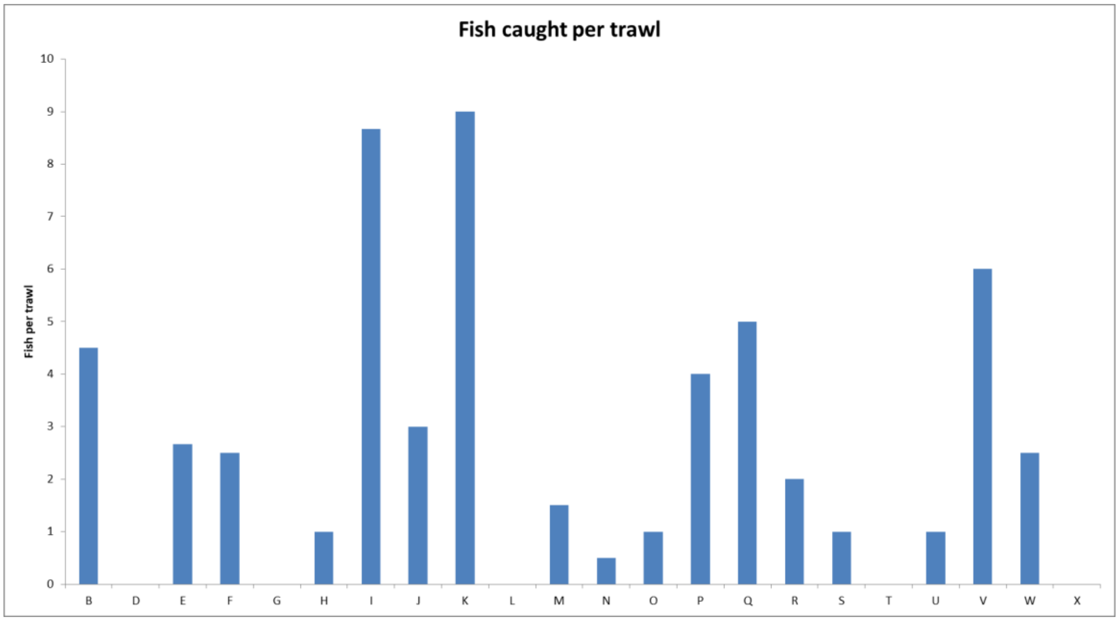


Figure 5.C.3. Number of fish caught per trawl (total number of individuals divided by total number of trawls) in Saugatuck Harbor for each box trawled in 2024.

The overall number of fish per trawl (catch per unit) in 2024 was 3.08 fish which is 2.28 higher than the fish per trawl in 2014 (Table 5.C.2). This is the highest fish per trawl since the 1990s. In 2024, 37 trawls were conducted and a total of 114 fish were caught, the highest number of fish caught since the 1990s as well, but that may be driven by the relatively low number of trawls conducted in recent years (Table 5.C.2). The total number of fish species caught in 2024 was 17, the highest diversity since the start of the study. This study is expected to continue in 2025 to provide additional data to this long-term dataset.

Table 5.C.2. Trawling stats from 1990 to 2024 in Saugatuck Harbor

Year	Total Fish Caught	Total Trawls	Catch Per Unit	Total Empty Nets	Percent Empty Nets	Number of Fish Species
1990	250	62	4.03	0	0%	15
1991	261	46	5.67	1	2%	14
1992	1028	60	17.13	0	0%	15
1993	285	74	3.85	0	0%	15
1994	493	53	9.30	0	0%	12
1995	340	44	7.73	0	0%	14
2002	3	3	1.00	0	0%	1
2011	19	20	0.95	1	5%	3
2012	30	19	1.58	0	0%	9
2014	4	5	0.80	0	0%	2
2024	114	37	3.08	0	0%	17

Crustaceans
In 2024, 4,473 individual crustaceans representing 12 species were observed. Certain individual shrimp were too small to identify confidently and therefore were documented as “Juvenile Shrimp.” The catch was dominated by sand shrimp (*Crangon septemspinosa*), juvenile shrimp, and long-wristed hermit crab (*Pagurus longicarpus*), accounting for approximately 82% of the total (Figure 5.C.3). 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 2 species (*Libinia emarginata* and *Libinia dubia*) but was likely dominated by the nine-spined spider crab (*Libinia emarginata*). Other notable catches include five different species of shrimp, 2 of which are nonnative (Asian shrimp, *Palaemon macrodactylus,* and Peppermint shrimp, *Lysmata spp.*). Nonnative species were documented and shared with CT DEEP for identification confirmation and to be used in assessing the impacts of these species on the native populations.

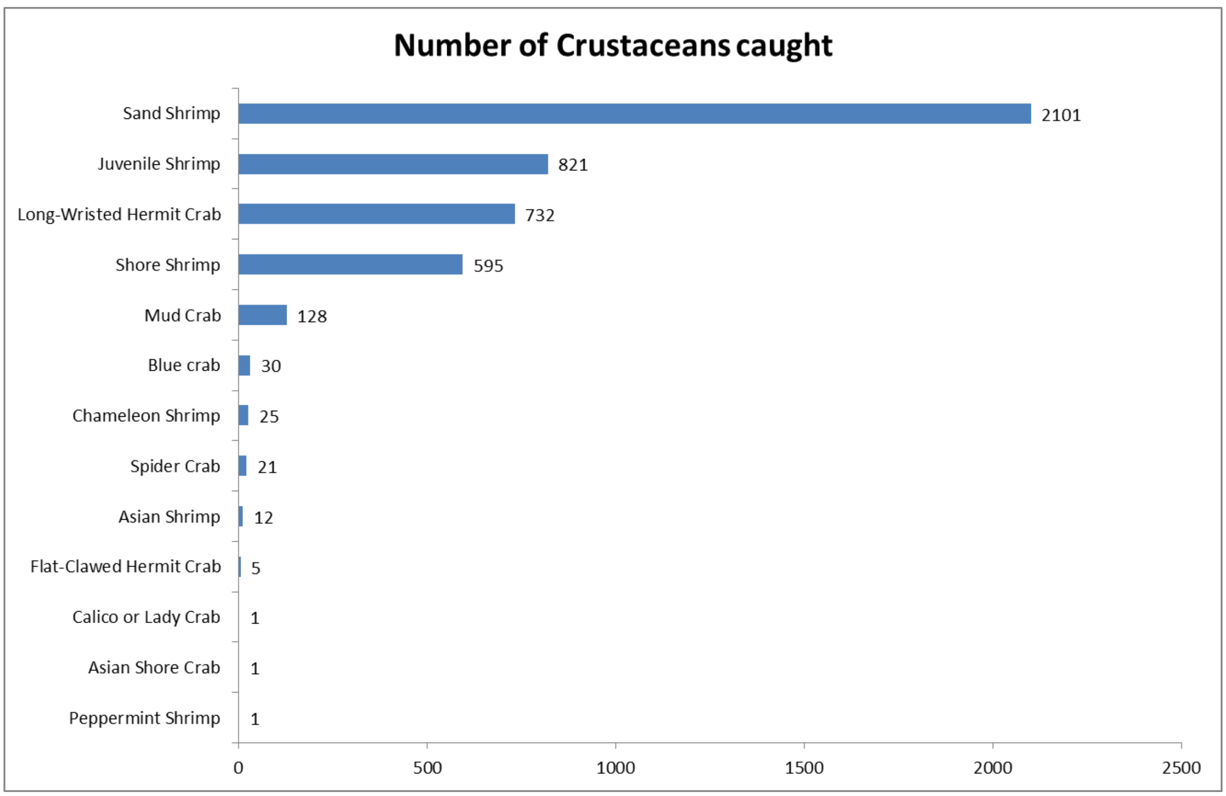


Figure 5.C.3. Crustaceans caught in Saugatuck Harbor from May through September 2024.

6. Water Quality Survey and Methods

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)

Five Mile River Harbor, Wilson Cove, Norwalk Harbor, Saugatuck Harbor, Housatonic Estuary, and New Haven Harbor (Quinnipiac River section) were studied in 2024. 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 2024, monitoring of these 6 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, in particular, shellfish beds. The parameters measured in this study included dissolved oxygen, salinity, water temperature, and water clarity. In 2024, Norwalk Harbor had the greatest percentage of dissolved oxygen observations below 3 mg/L (6%) of the 6 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 also observed in the New Haven Harbor which had 3% of observations less than 3 mg/L during the monitoring season. Five Mile River Harbor, Wilson Cove, Saugatuck Harbor, and Housatonic Estuary had no hypoxic conditions observed in this year's sampling. 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, 2023). In 2024, this trend continued with 95% of all sampling events having a dissolved oxygen value at the harbor bottom above 3 mg/L.

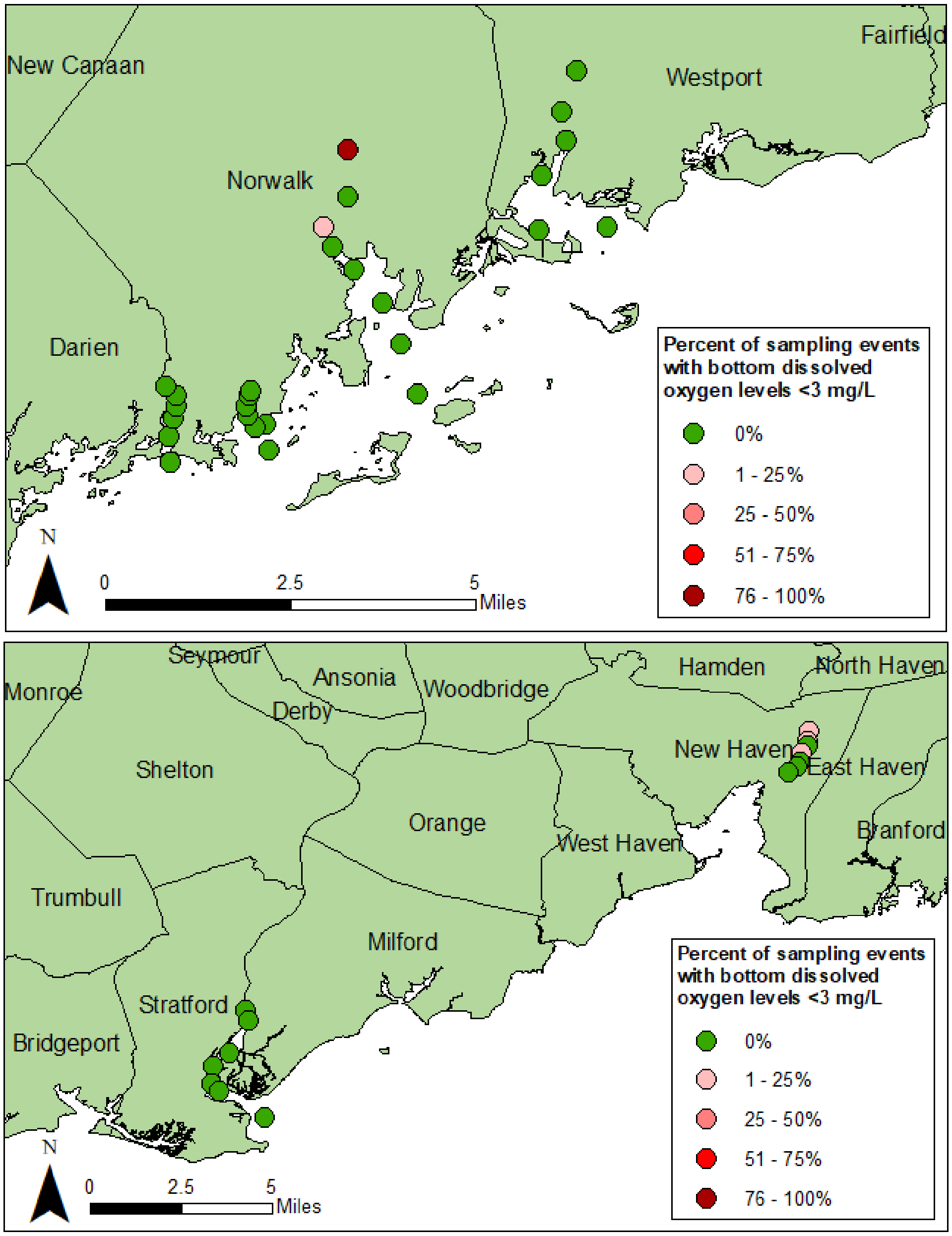


Figure 6.1. Percentage of readings where bottom dissolved oxygen values fell below 3 mg/L in 2024 in the western harbors (top) and the eastern harbors (bottom).

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 saltwater underlying a freshwater surface layer which is usually incoming water from a river. The denser saltwater 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, saltwater is entrained in the freshwater layer, reducing the stratification. This mixing of fresh and saltwater 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 saltwater 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.

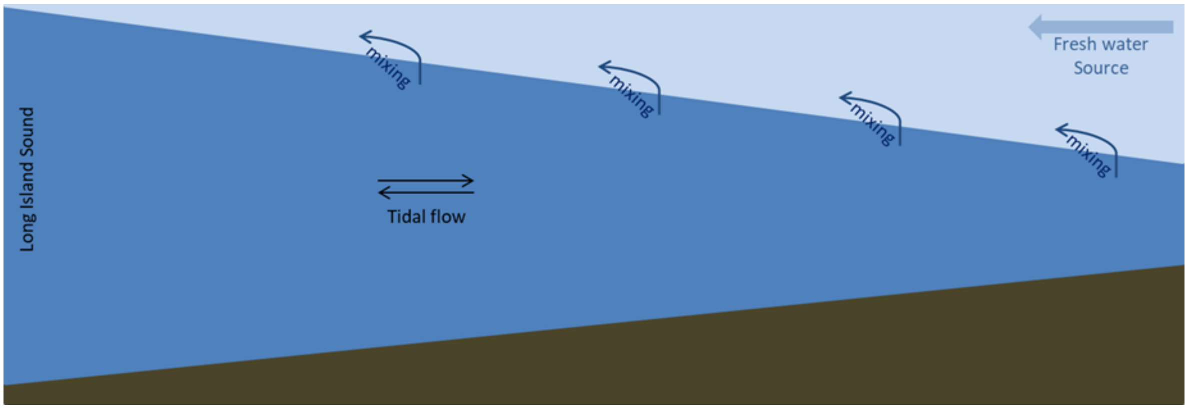


Figure 6.2. Sketch of estuary tidal wedge, water flow, and water column mixing.

Flushing of an estuary may also be assisted by 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. Two 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) and the Housatonic Estuary. 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. 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 2023 and 2024 varied greatly (Figure 6.3). In 2024 there was higher rainfall in May, June, and August and lower rainfall in July and September. September had a difference of 10.54 inches of total rainfall between 2023 and 2024. The total rainfall in 2023 from May to September was 8.81 inches greater than in 2024. This difference is reflected in the discharge (cubic feet per second) observed in the rivers that feed the harbors studied (see hydrographs in the following sections).

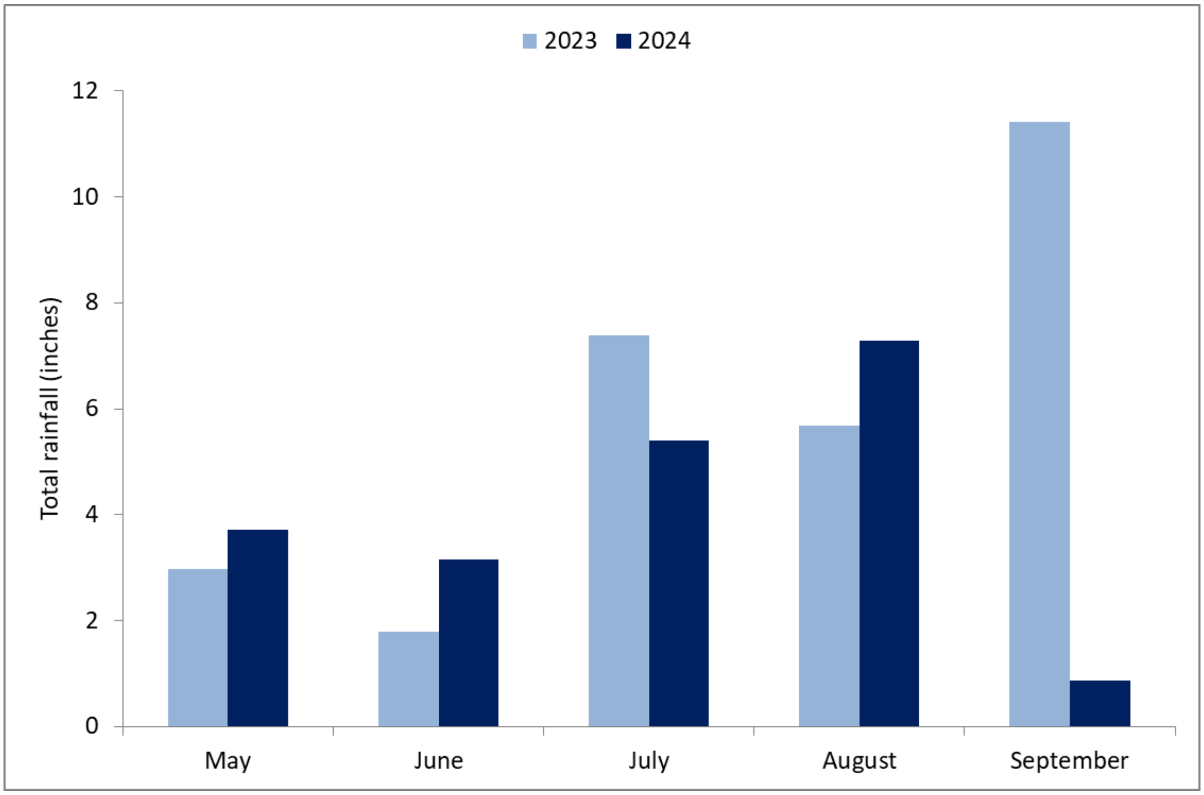


Figure 6.3. Monthly rainfall totals for 2023 and 2024 in Norwalk (Norwalk Health Department, n.d.).

In the following sections, we present a data summary of each of the 6 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, or to past monitoring seasons. In particular, some harbors' datasets started later in the summer than others, had fewer sampling events, 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.

Water Quality Profiling:
Seasonal monitoring was conducted in each of the 6 harbors between May and September by Richard Harris, employees of Copps Island Oysters and East Norwalk Blue, and volunteers. Each harbor had 5 to 8 monitoring stations. 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 2024 because no federal funds were used for this project). There were two deviations from the QAPP encountered in 2024: Wilson Cove was only sampled 4 times and Housatonic Estuary was only sampled 2 times, not meeting the minimum 5 times due to staffing restrictions and boat repairs.

Testing for each harbor was conducted 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 ensure that significant calibration drift (± 2%) did not occur. Harbor surveys were completed within approximately 2 hours on each monitoring day.

7. Water Quality Survey Results and Discussion

7.A. 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 River Harbor 5 (Figure 7.A.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.

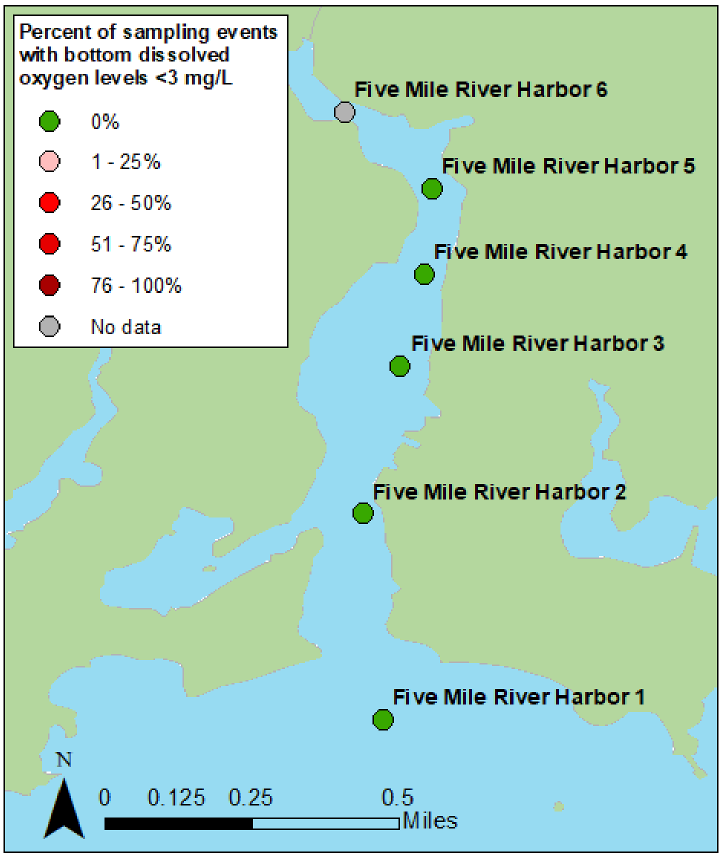


Figure 7.A.1. Map of Five Mile River Harbor sampling stations. Color of dots represents the percent of sampling events with bottom dissolved oxygen levels less than 3 mg/L in 2024.

Table 7.A.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 Five 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	Down under 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 5 sites along the length of the harbor (Figure 7.A.1, Table 7.A.1) on 5 days during the monitoring season from May through early September. Sampling was not conducted at Five Mile River Harbor 6 in 2024 due to inaccessibility during low tide. Mean surface and bottom dissolved oxygen values in Five Mile River Harbor ranged from a minimum of 6.35 mg/L on the bottom at Five Mile River Harbor 5 to a maximum of 8.08 mg/L at the surface at Five Mile River Harbor 2 (Figure 7.A.2). Dissolved oxygen concentrations generally decreased from May through July, after which there was evidence of a slight recovery in early September (Figure 7.A.3). Of all the bottom dissolved oxygen observations, 4% were less than 5 mg/L, and no observations fell below 3 mg/L.

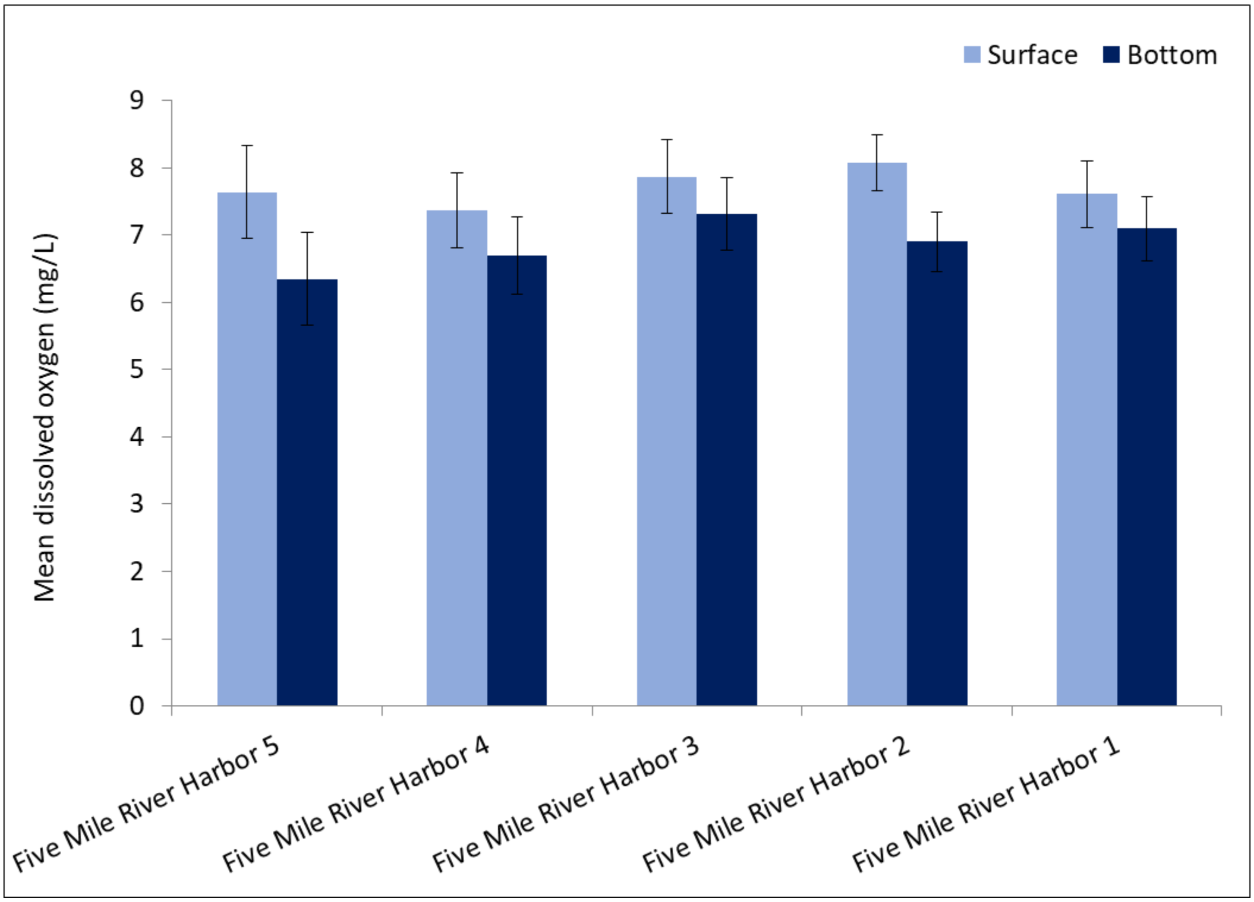


Figure 7.A.2. Mean dissolved oxygen concentrations at the surface and bottom at each sampling station in Five Mile River Harbor in 2024. Error bars represent standard error.

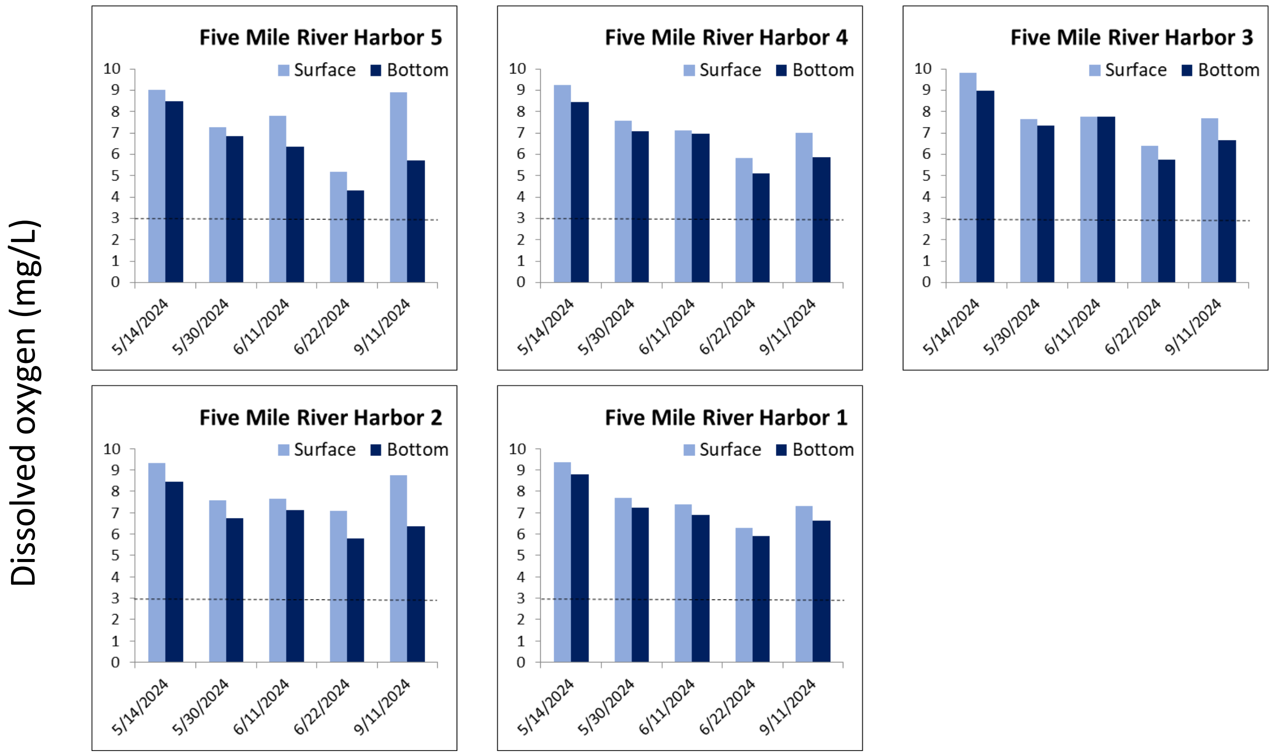


Figure 7.A.3. Surface and bottom dissolved oxygen values at each Five Mile River Harbor sampling station on each monitoring date during the 2024 season. The dotted line represents hypoxic conditions (3 mg/L). Please note x-axis is individual sampling dates, not a time scale.

Temperature and Salinity
Mean surface and bottom water temperatures in Five Mile River Harbor were similar throughout the harbor (Figure 7.A.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 River Harbor 5, where the harbor is less well mixed (Figure 7.A.1, Figure 7.A.5).

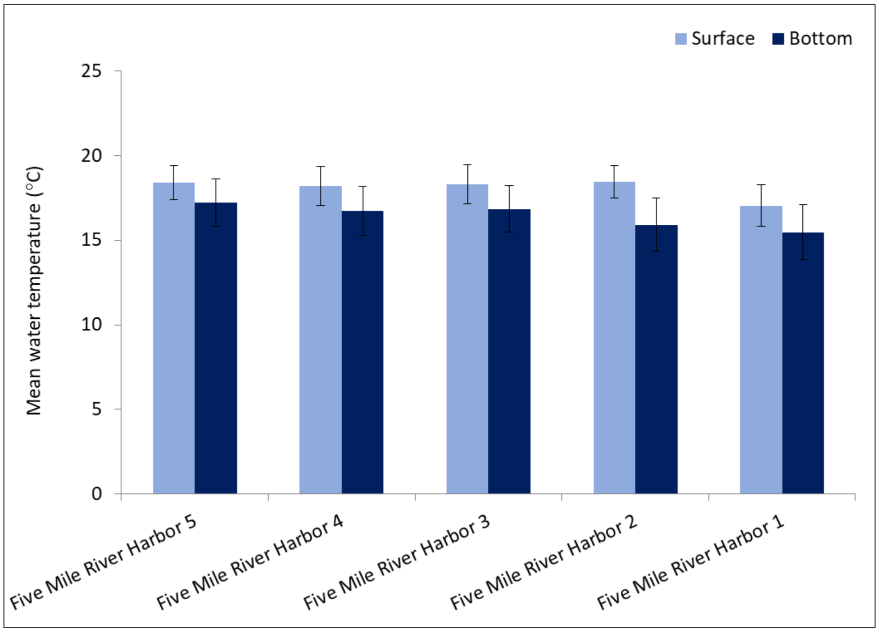


Figure 7.A.4. Mean water temperature at the surface and bottom at each sampling station in Five Mile River Harbor in 2024. Error bars represent standard error.

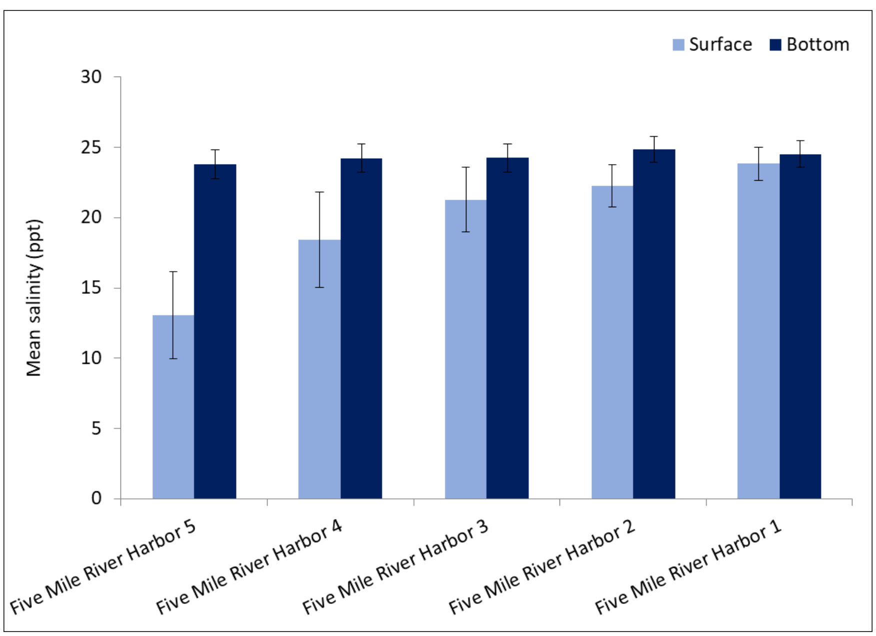


Figure 7.A.5. Mean salinity at the surface and bottom at each sampling station in Five Mile River Harbor in 2024. Error bars represent standard error.

Water Clarity

Mean secchi depth readings ranged from a minimum of 1.12m at station Five Mile River Harbor 4 to a maximum of 1.38m at station Five Mile River Harbor 1. Mean secchi depth readings slightly increase from station Five Mile River Harbor 5 to Five Mile River Harbor 1 (Figure 7.A.6).

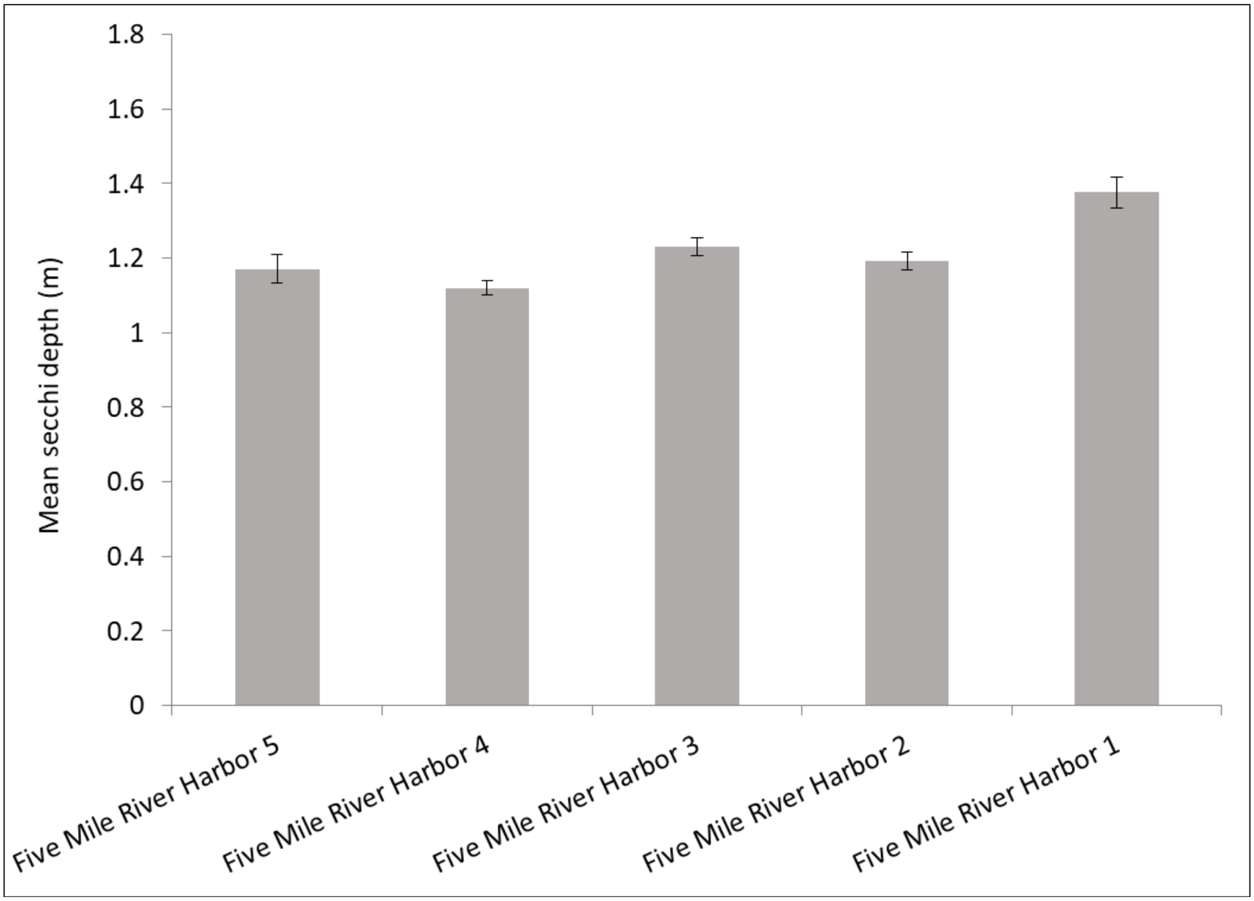
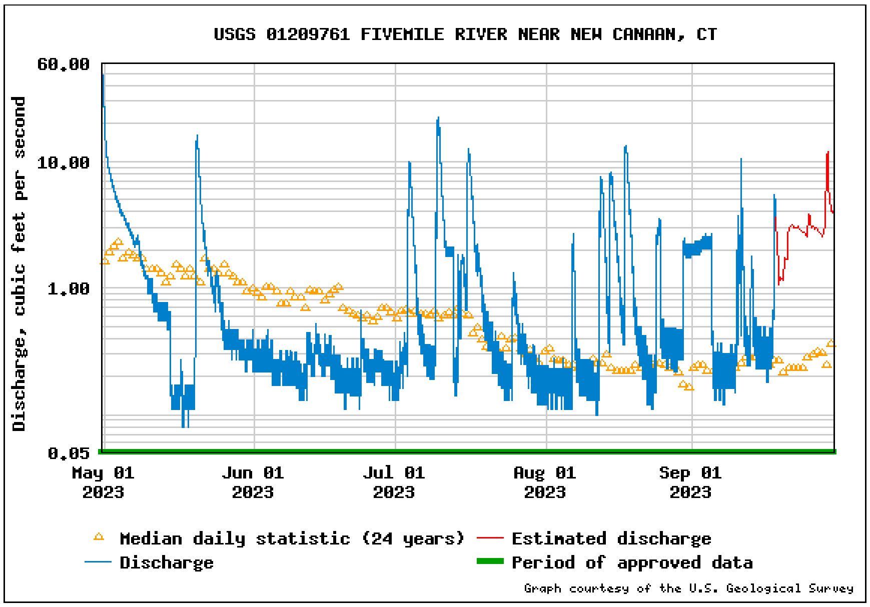


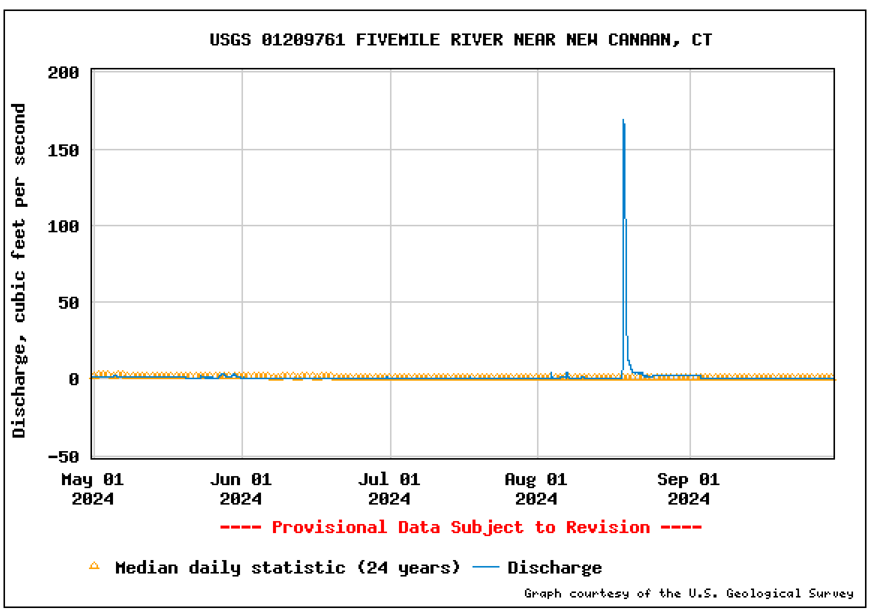
Figure 7.A.6. Mean secchi depth readings in Five Mile River Harbor in 2024. Error bars represent standard error.

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 24 years, and the blue line represents the recorded discharge for a particular date. In 2024, discharge oscillated around the median values for most of the monitoring season, except for the large amount of discharge that occurred on August 18th due to a large rain storm. Compared to 2023, the Five Mile River experienced less discharge in 2024 (Figure 7.A.7 (a-c)). Figure 7.A.7 (c) shows discharge before the large rain event so that values are easier to see.



(a)



(b)

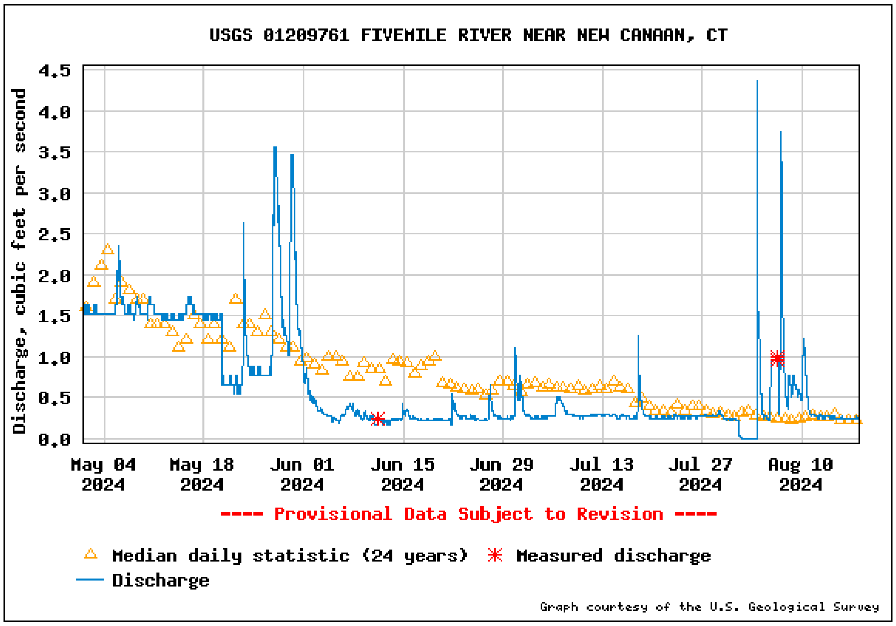
(c) 

Figure 7.A.7. USGS flow data in ft^3/s for the period of (a) May 1 through September 30, 2023, (b) May 1 through September 30, 2024, and (c) May 1 to August 17, 2024 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.

7.B. Wilson Cove

Wilson Cove is a small inlet in Norwalk, CT. At the north end of the cove enters a large stormwater system as well as a pond and in the southwest empties Farm Creek. There is a marina, yacht clubs, and single-family homes surrounding the cove. It is used by locals for boating, swimming, and fishing.

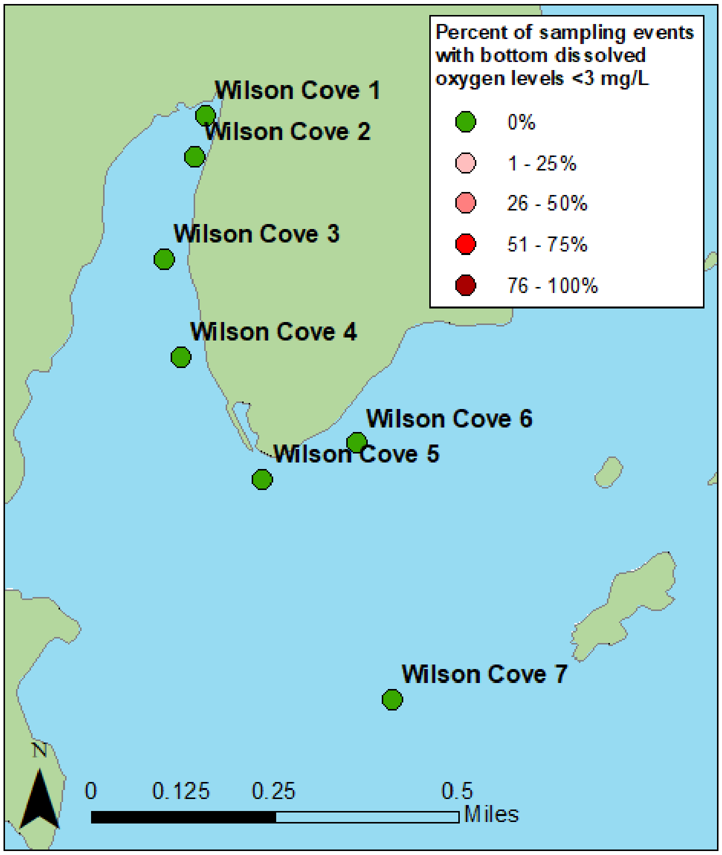


Figure 7.B.1. Map of Wilson Cove sampling stations for 2024. Color of dots represents the percent of sampling events with bottom dissolved oxygen levels less than 3 mg/L.

Table 7.B.1. Coordinates and descriptions for each sampling station in Wilson Cove

Site Name	Latitude	Longitude	Description
Wilson Cove 1	41.07015	-73.43022	Trolley Lane Discharge
Wilson Cove 2	41.06935	-73.43044	Pond Discharge Point
Wilson Cove 3	41.06732	-73.43104	Aluminum Pier at North End of Yacht Club
Wilson Cove 4	41.06539	-73.43069	Bathing Beach at Norwalk Yacht Club
Wilson Cove 5	41.06299	-73.42909	Pilings off Wilson Point
Wilson Cove 6	41.0637	-73.42724	Aluminum Dock East of Point
Wilson Cove 7	41.05865	-73.42655	West Side of Tavern Island

Dissolved Oxygen

Profiles of the water column were taken at 7 sites along the length of the inlet (Figure 7.B.1, Table 7.B.1) on 4 days during the monitoring season from late May through late September. Sampling was not conducted at Wilson Cove 1 – Wilson Cove 5 on 5/23/2024 due to inclement weather. Sampling was also not conducted at Wilson Cove 1 on 6/5/2024. Mean surface and bottom dissolved oxygen values in Wilson Cove ranged from a minimum of 5.49 mg/L at the bottom of Wilson Cove 1 to a maximum of 7.79 mg/L on the surface of Wilson Cove 7 (Figure 7.B.2). Dissolved oxygen concentrations generally decreased in July, and then recovered in late September (Figure 7.B.3). Of all the bottom dissolved oxygen observations, 14% were less than 5 mg/L, and no observations fell below 3 mg/L.

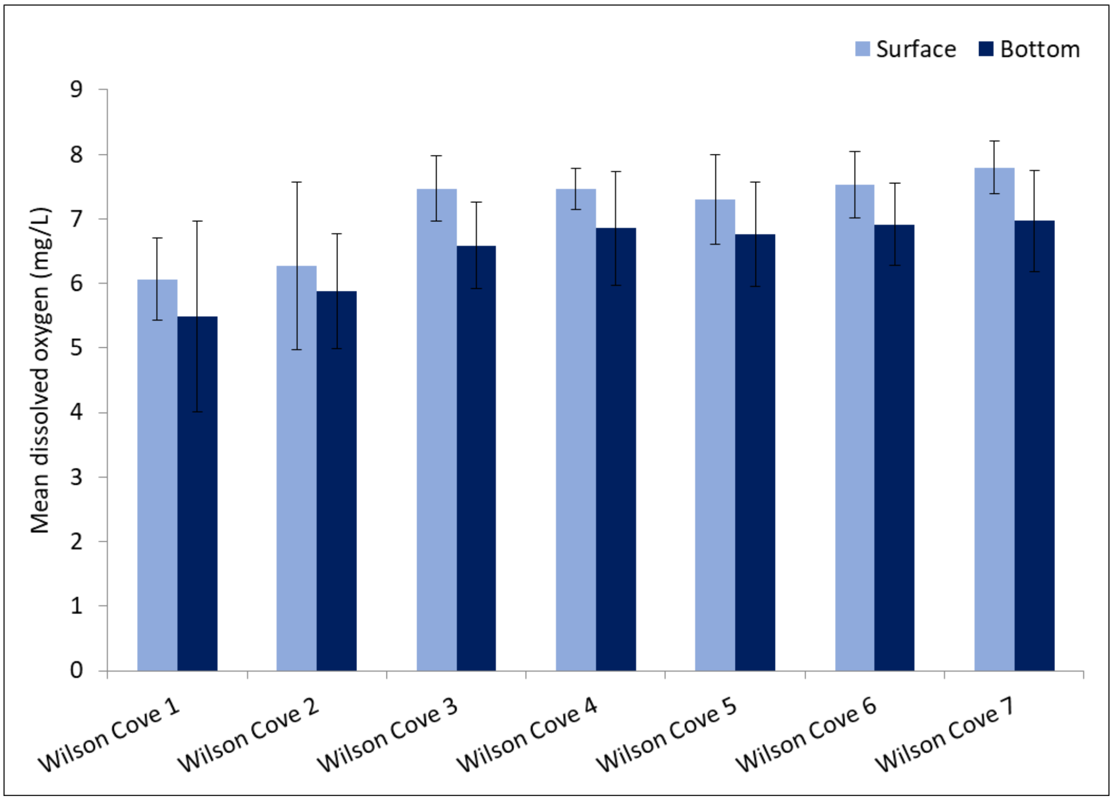


Figure 7.B.2. Mean dissolved oxygen concentrations at the surface and bottom at each sampling station in Wilson Cove in 2024. Error bars represent standard error.

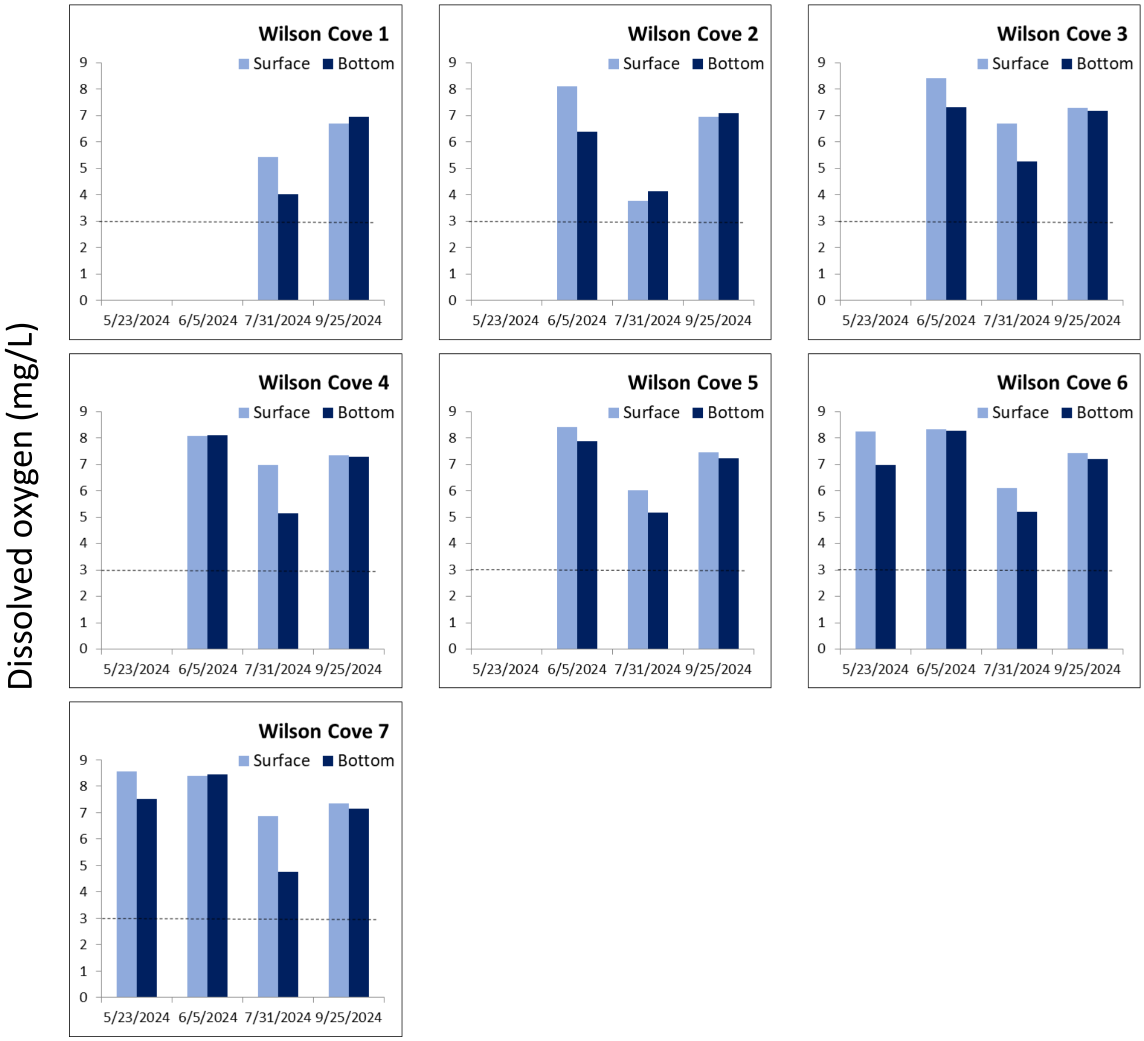


Figure 7.B.3. Surface and bottom dissolved oxygen values at each Wilson Cove sampling station on each monitoring date during the 2024 season. The dotted line represents hypoxic conditions (3 mg/L). Please note x-axis is individual sampling dates, not a time scale.

Temperature and Salinity
Mean surface and bottom water temperatures in Wilson Cove slightly decrease from the inner harbor to the outer harbor (Figure 7.B.4). Mean surface salinity starts low in the inner cove and then increases to a maximum at Wilson Cove 5, where it decreases until the outer most site (Figure 7.B.1, Figure 7.B.5). The mean bottom salinity generally decreases from the inner cove to the outer site.

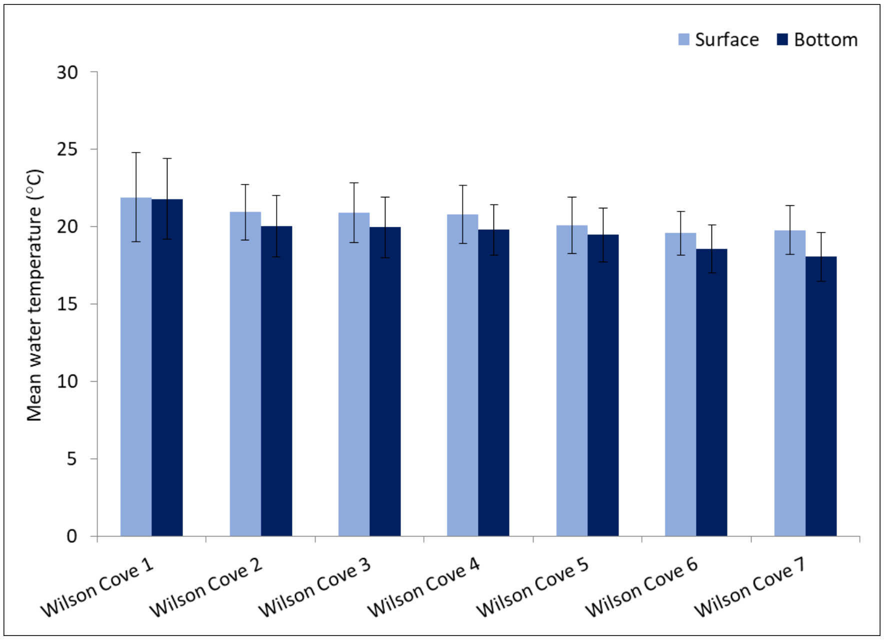


Figure 7.B.4. Mean water temperature at the surface and bottom at each sampling station in Wilson Cove in 2024. Error bars represent standard error.

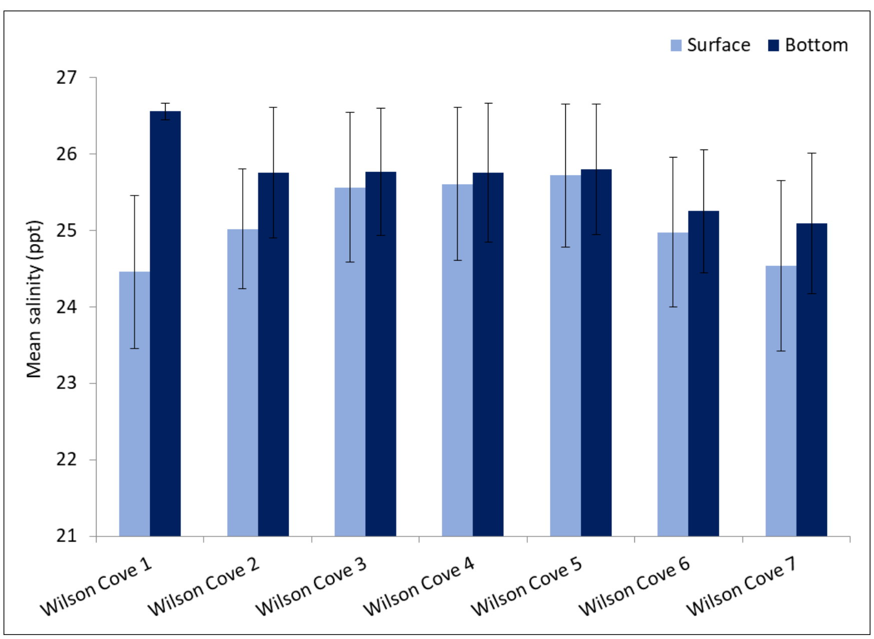


Figure 7.B.5. Mean salinity at the surface and bottom at each sampling station in Wilson Cove in 2024. Error bars represent standard error.

Water Clarity
Mean secchi depth readings ranged from a minimum of 1.08m at station Wilson Cove 3 to a maximum of 1.60m at station Wilson Cove 7. Mean secchi depth readings decrease from station Wilson Cove 1 to Wilson Cove 3 and then increase from Wilson Cove 3 to Wilson Cove 7 (Figure 7.B.6).

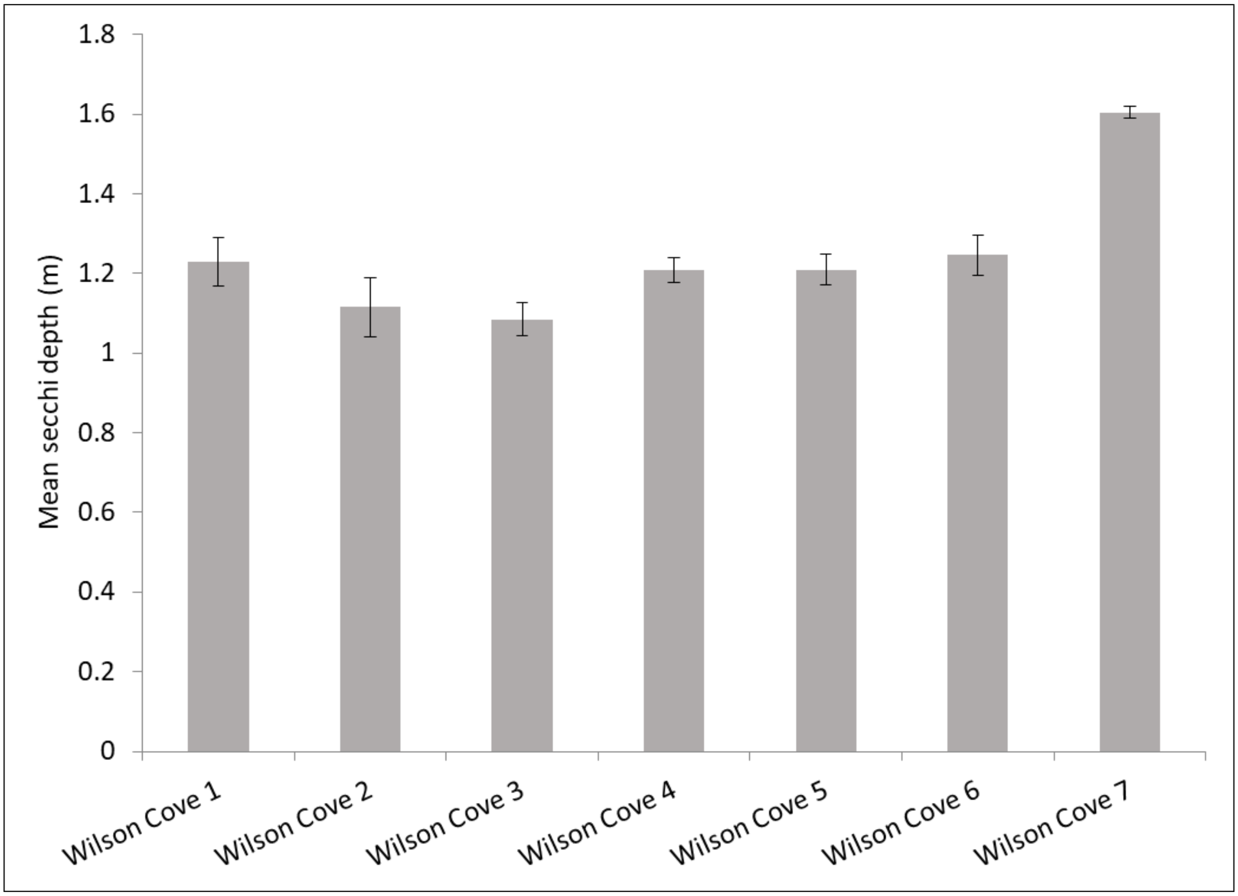


Figure 7.B.6. Mean secchi depth readings in Five Mile River Harbor in 2024. Error bars represent standard error.

7.C. Norwalk Harbor

Norwalk Harbor, located in Norwalk, CT, is fed with fresh water from the Norwalk River. Unlike other harbors monitored in this report, it does not have a tidal basin which could aid in flushing at ebb tide. The harbor once had extensive wetlands on both shorelines (Figure 7.C.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 data collected along the length of the estuary from Wall Street to the Norwalk Islands (Figure 7.C.2).

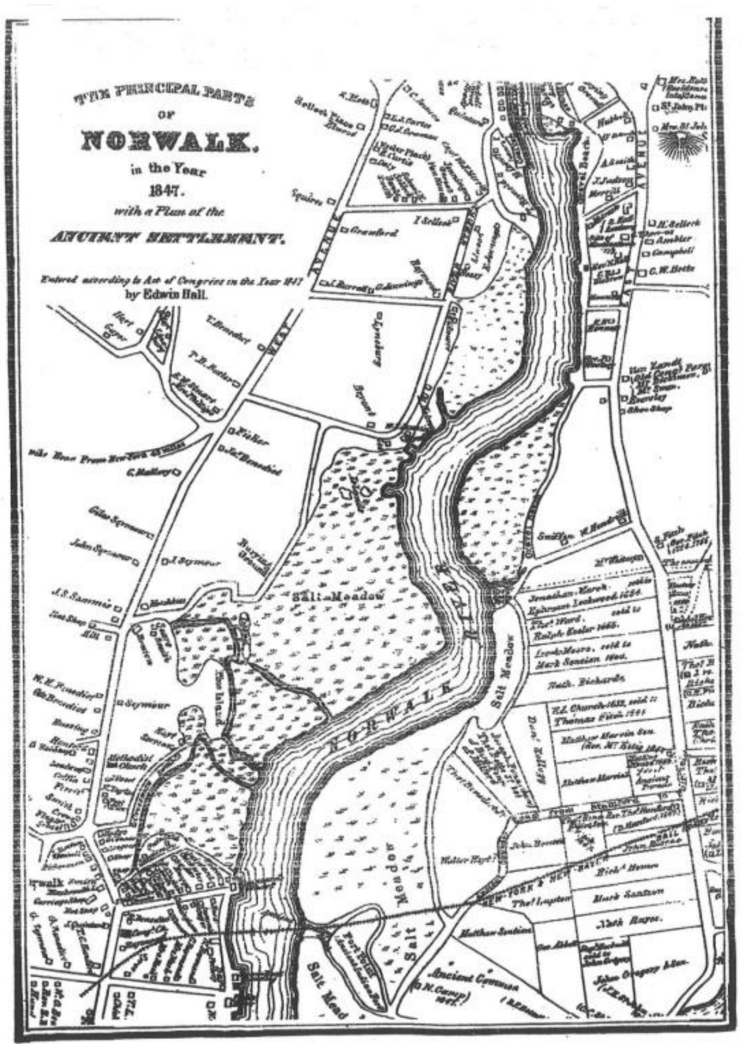


Figure 7.C.1. Norwalk Harbor estuary in 1847. Extensive wetlands once dominated both shorelines. Image credit: Norwalk Historical Society.

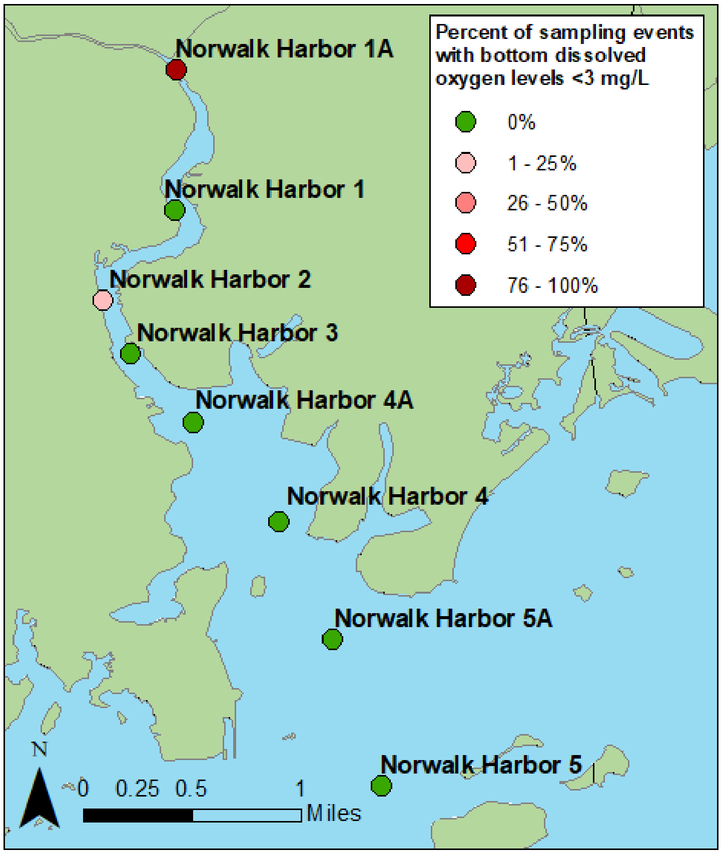


Figure 7.C.2. Map of Norwalk Harbor sampling stations in the inner harbor for 2024. Color of dots represents the percent of sampling events with bottom dissolved oxygen levels less than 3 mg/L.

Table 7.C.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 harbor at 8 sampling stations. Sampling occurred 7 times between May and September 2024. Mean surface and bottom dissolved oxygen concentrations ranged from a minimum of 2.72 mg/L on the bottom at station Norwalk Harbor 1A to a maximum of 8.9 mg/L at the surface at station Norwalk Harbor 3 (Figure 7.C.3). Station Norwalk Harbor 1A had the widest range between surface and bottom mean dissolved oxygen concentrations in Norwalk Harbor. Of all the bottom dissolved oxygen observations, 29% were less than 5 mg/L, and 13% 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 7.C.3, Figure 7.C.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 7.C.3, Figure 7.C.4). Station Norwalk Harbor 1A was the most impaired water in the harbor for dissolved oxygen, consistent with past years.

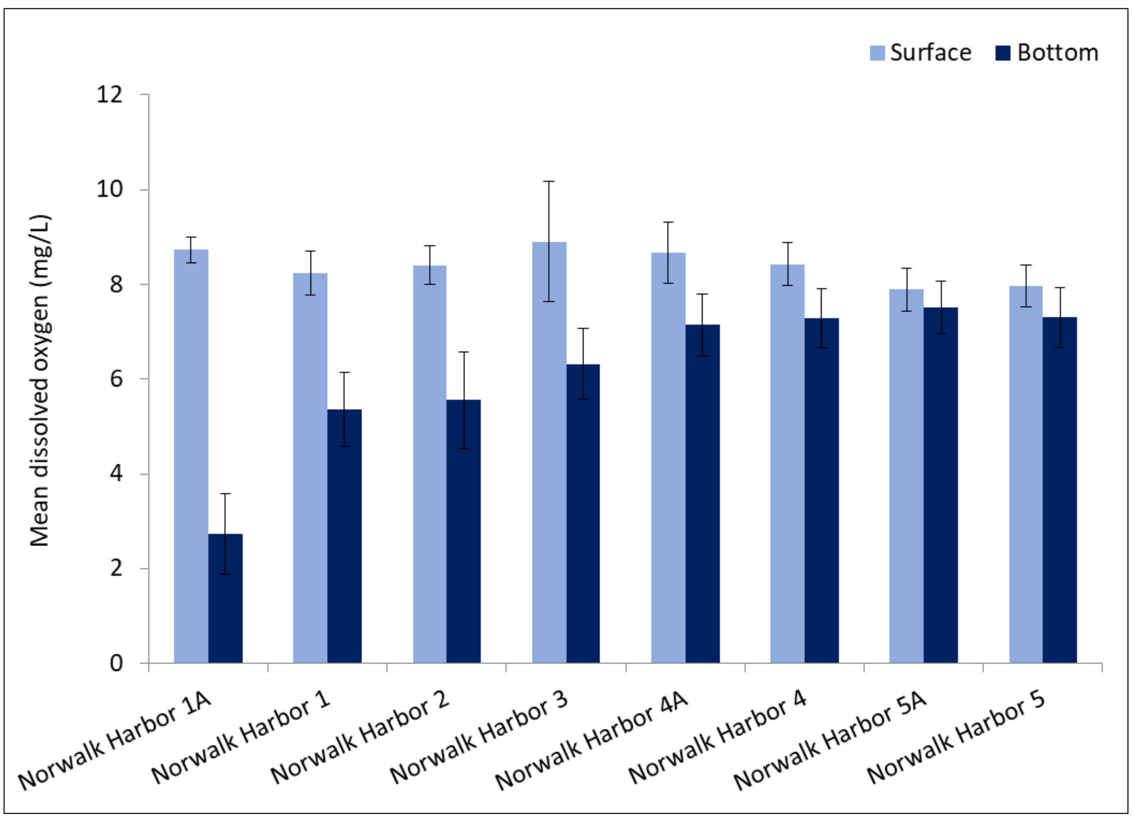


Figure 7.C.3. Mean dissolved oxygen concentrations at the surface and bottom at each sampling station in Norwalk Harbor during 2024. Error bars represent standard error.

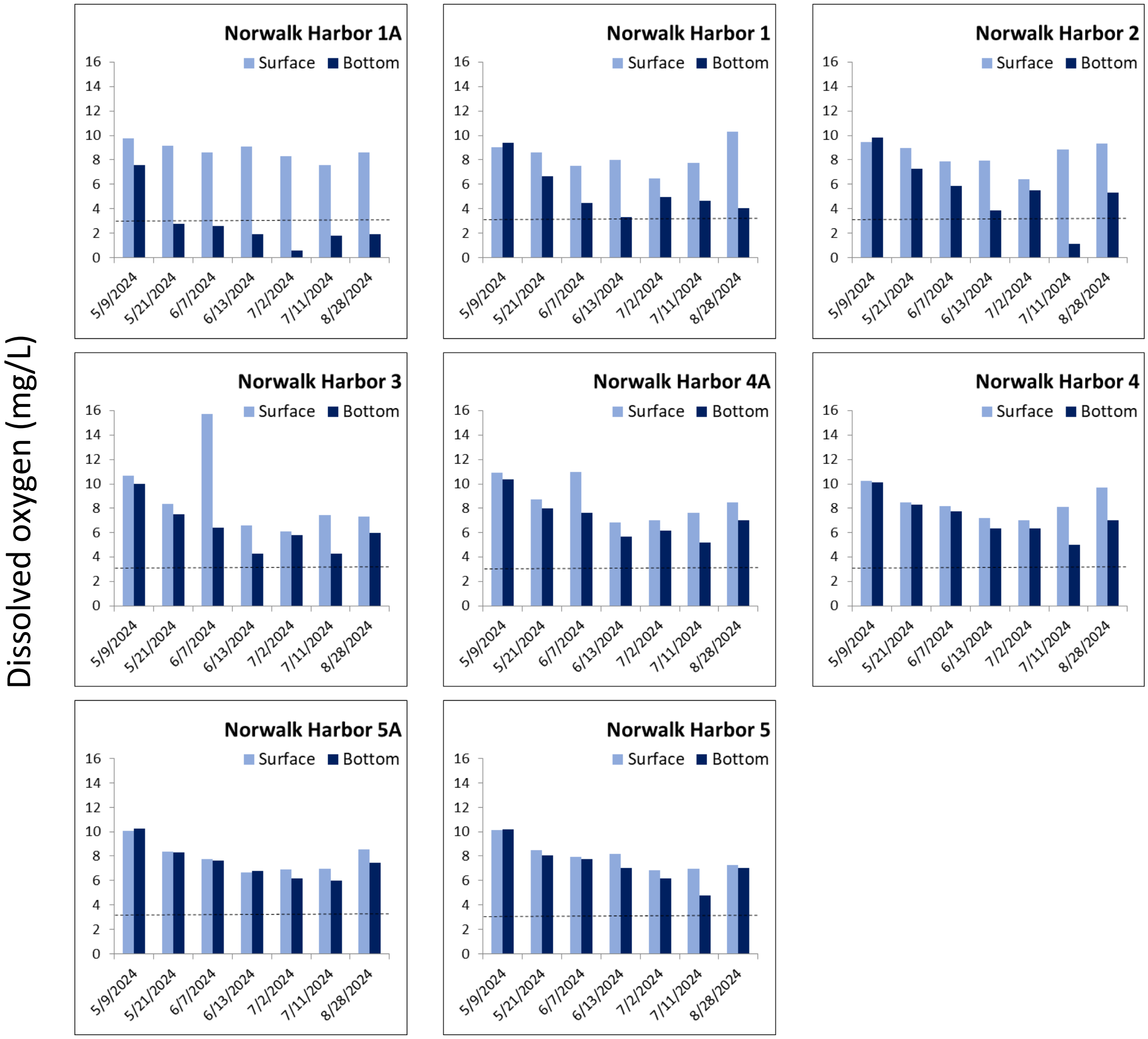


Figure 7.C.4. Surface and bottom dissolved oxygen values at each Norwalk Harbor sampling station on each monitoring date during the 2024 season. The dotted line represents hypoxic conditions (3 mg/L). Please note x-axis is individual sampling dates, not a time scale.

Temperature and Salinity

Mean water temperature was fairly consistent across all Norwalk Harbor stations (Figure 7.C.5). 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 7.C.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.

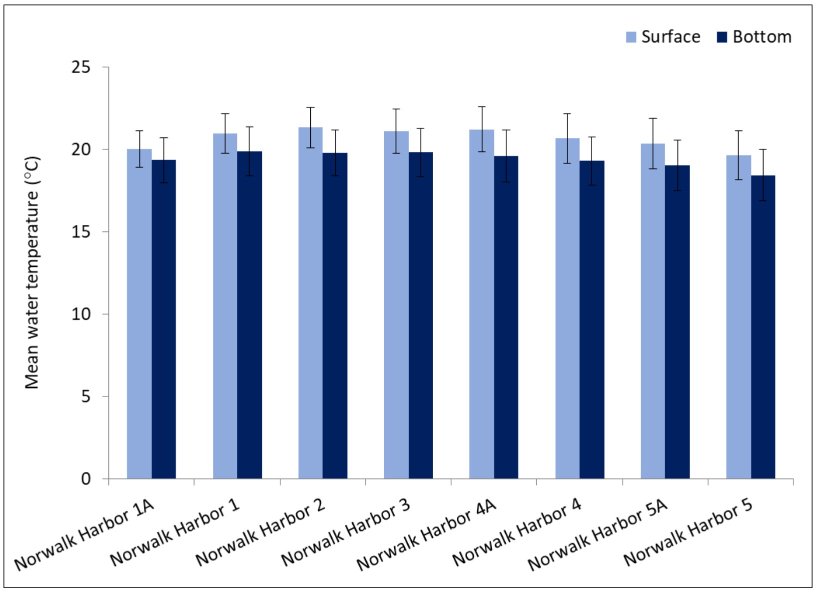


Figure 7.C.5. Mean water temperature at the surface and bottom at each sampling station in Norwalk Harbor in 2024. Error bars represent standard error.

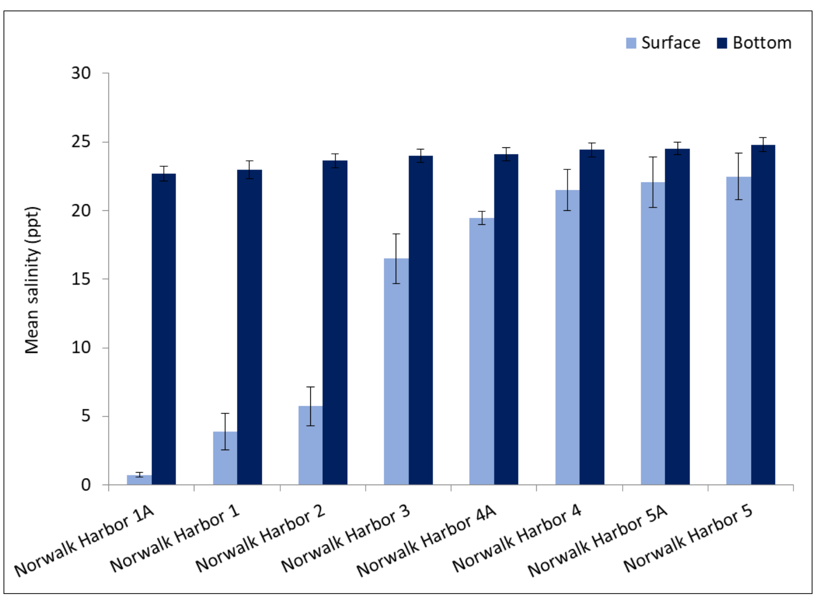


Figure 7.C.6. Mean salinity at the surface and bottom at each sampling station in Norwalk Harbor in 2024. Error bars represent standard error.

Water Clarity

Mean secchi depth readings ranged from a minimum of 1.05m at station Norwalk Harbor 3 to a maximum of 1.58m at station Norwalk Harbor 1A. Mean secchi readings decrease from station Norwalk Harbor 1A to Norwalk Harbor 3, after which they increase up to Norwalk Harbor 5 (Figure 7.C.7). This may have been a result of sediment and debris deposition during rainfall events in 2024 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).

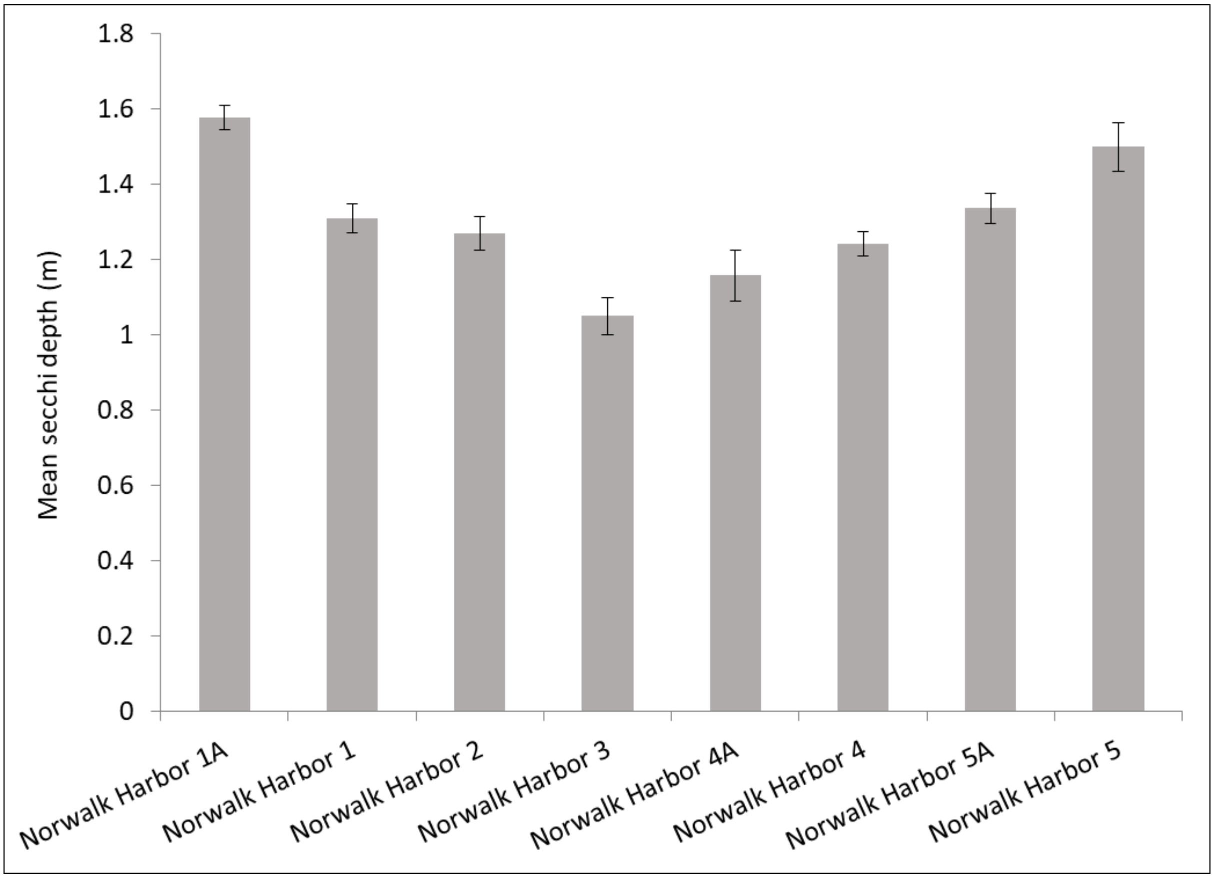
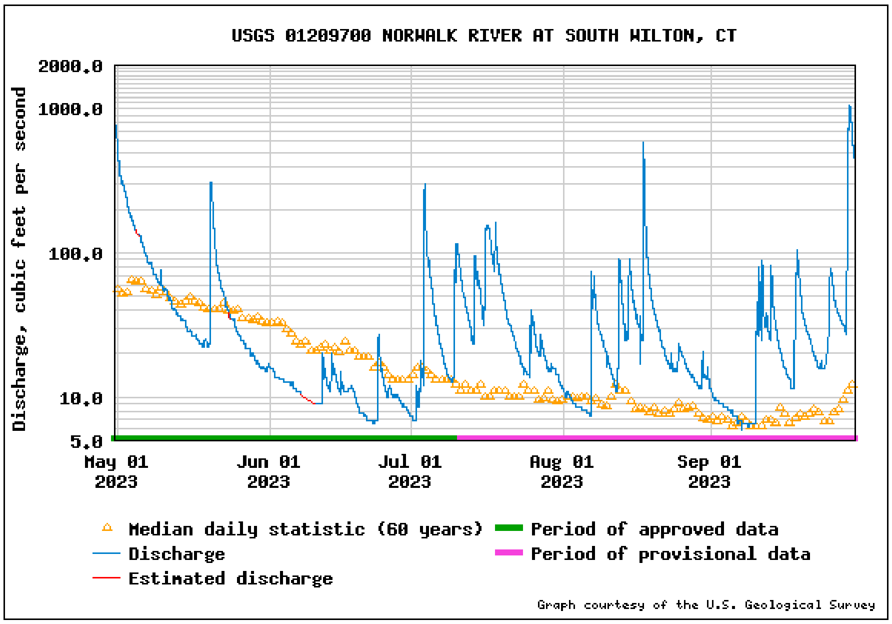


Figure 7.C.7. Mean secchi depth readings in Norwalk Harbor in 2024. Error bars represent standard error.

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 slightly higher than in 2024 throughout most of the season (Figure 7.C.8). The highest peak seen in the 2024 graph is due to a large rainstorm that fell within a short period of time on August 18th.



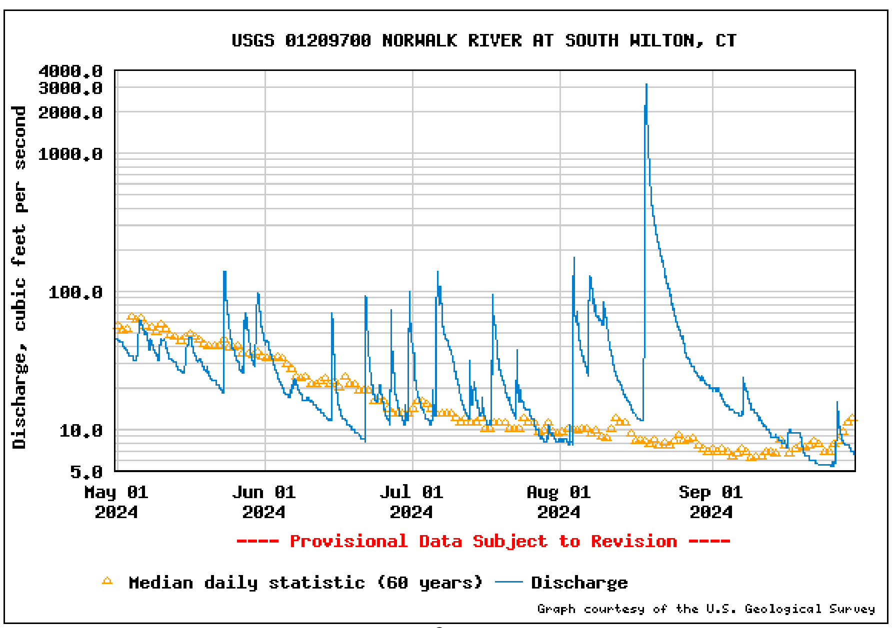


Figure 7.C.8. USGS flow data in ft^3/s for the period of May 1 through September 30, 2023 (top) and 2024 (bottom), respectively for the Norwalk River in South Wilton, CT (Graph courtesy of the U.S. Geological Survey). Please note the difference in scale on the y-axis.

7.D. Saugatuck Harbor

Situated at the mouth of the Saugatuck River, Saugatuck Harbor is approximately 3 miles long and relatively narrow with the exception of 2 basins. The first of these is a large basin located just to the north of station Saugatuck Harbor 6 (Figure 7.D.1, Figure 7.D.2). The second smaller basin is located just to the north of station Saugatuck Harbor 4 (Figure 7.D.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 7.D.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 2 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 7.D.2).

Figure 7.D.1. Looking upstream at the first basin from Saugatuck Harbor 6.

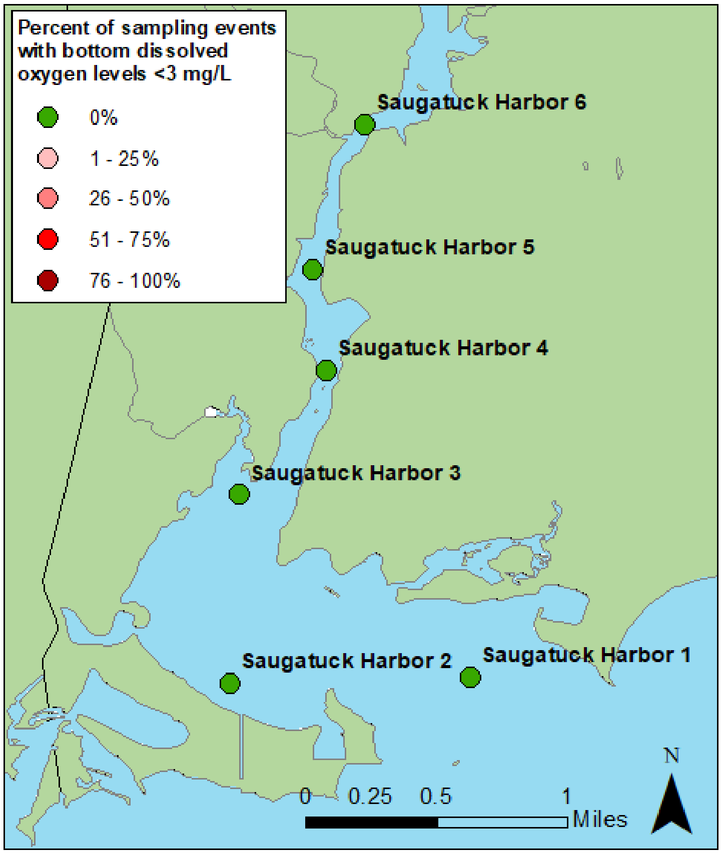


Figure 7.D.2. Map of Saugatuck Harbor sampling stations in 2024. Color of dots represents the percent of sampling events with bottom dissolved oxygen levels less than 3 mg/L.

Table 7.D.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 6 sampling days from May through September 2024. Station Saugatuck Harbor 1 was not sampled on 9/5/2024 due to rough water. Mean surface and bottom dissolved oxygen values ranged from a minimum of 5.96 mg/L at the bottom of station Saugatuck Harbor 6 to a maximum of 7.12 mg/L at the surface of station Saugatuck Harbor 4 (Figure 7.D.3). Dissolved oxygen concentrations varied throughout the monitoring season with most sites having the highest values in late May and early September (Figure 7.D.4). Of all of the bottom dissolved oxygen observations, 31% fell below 5 mg/L, and none fell below 3 mg/L.

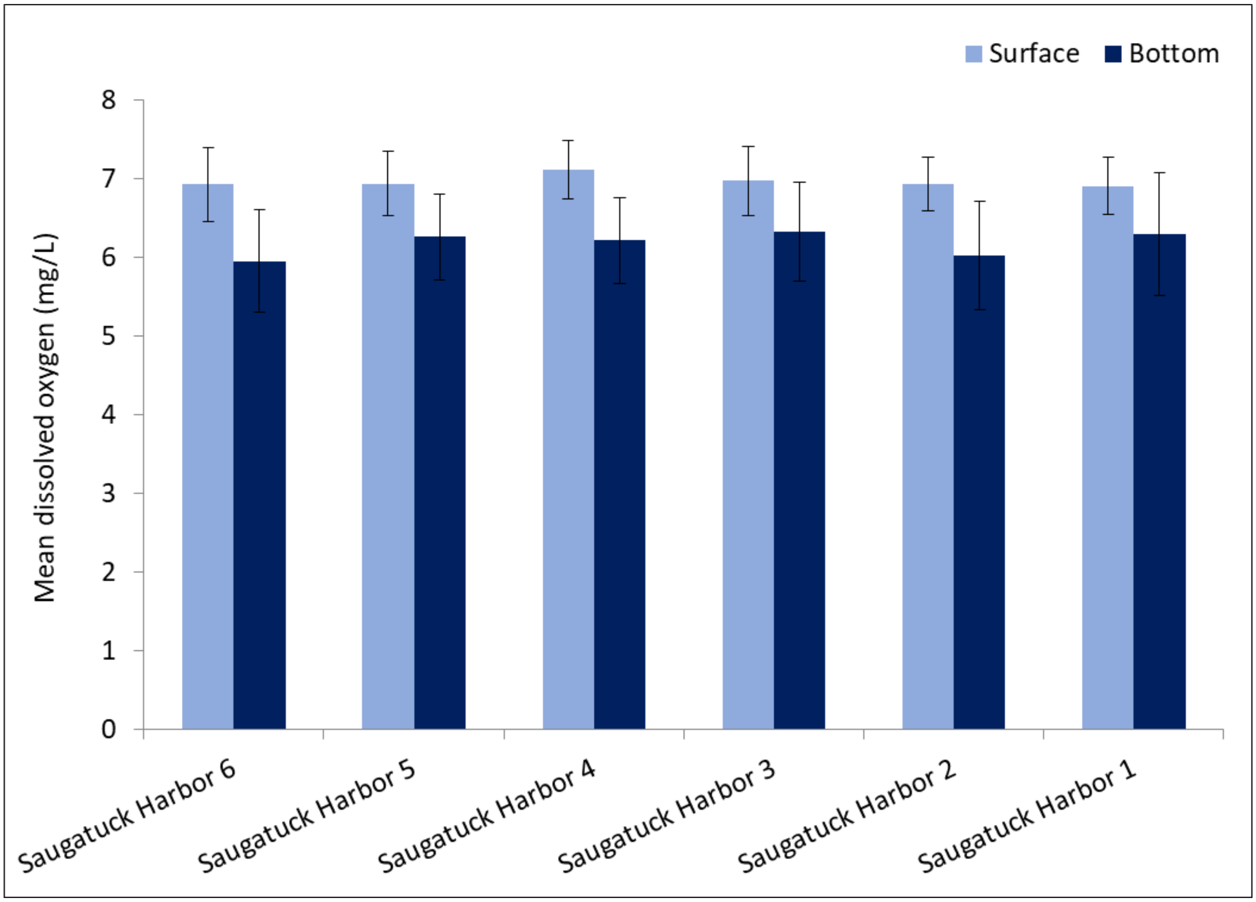


Figure 7.D.3. Mean dissolved oxygen concentrations at the surface and bottom at each sampling station in Saugatuck Harbor in 2024. Error bars represent standard error.

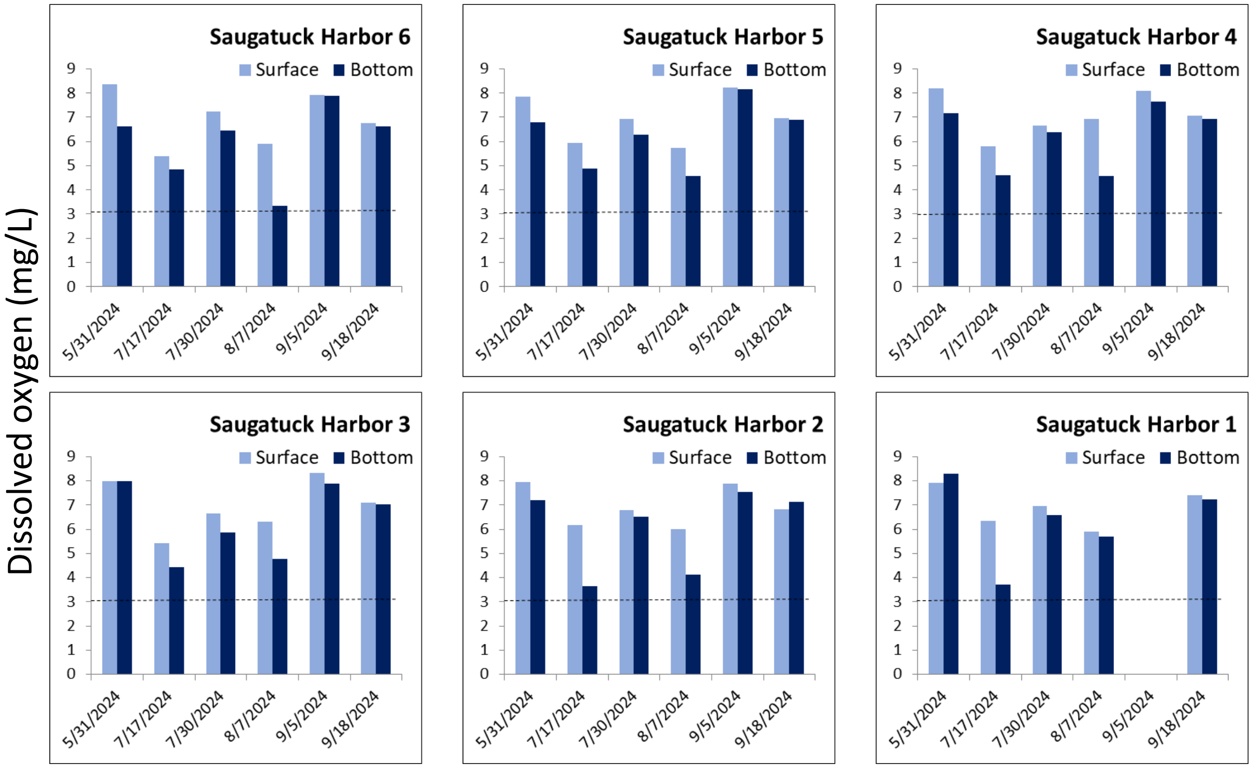


Figure 7.D.4. Surface and bottom dissolved oxygen values at each Saugatuck Harbor sampling station on each monitoring date during the 2024 season. The dotted line represents hypoxic conditions (3 mg/L). Please note x-axis is individual sampling dates, not a time scale.

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 innermost station to the outermost station (Figure 7.D.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 7.D.5, Figure 7.D.6).

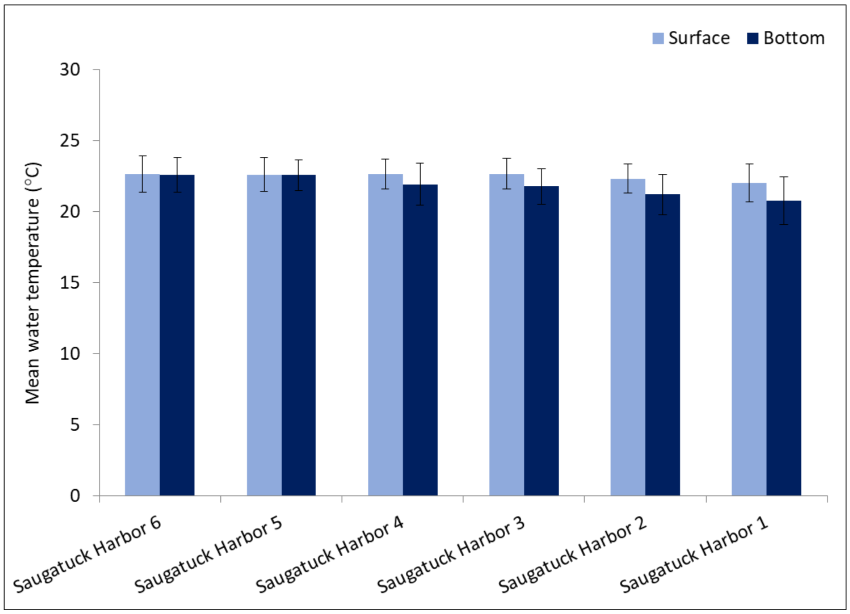


Figure 7.D.5. Mean water temperature at the surface and bottom at each sampling station in Saugatuck Harbor in 2024. Error bars represent standard error.

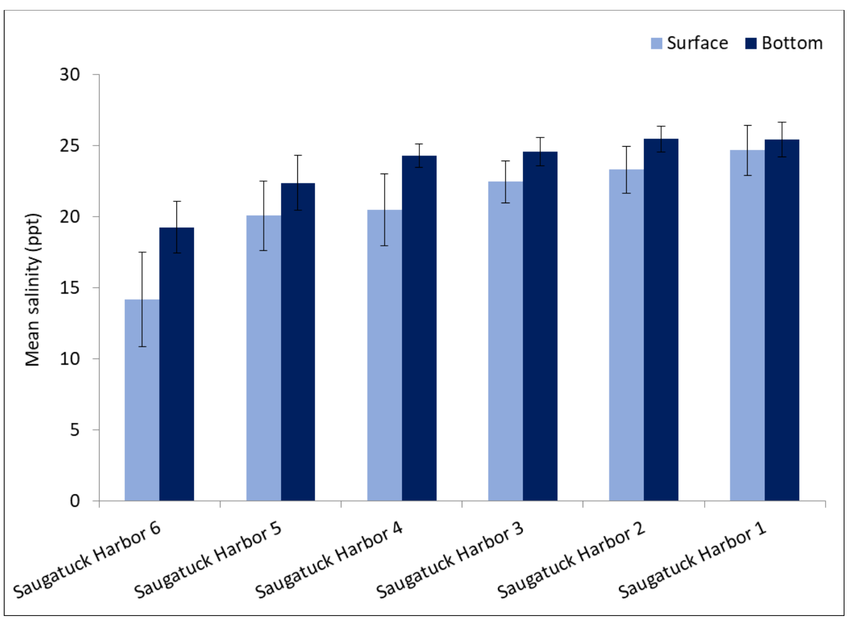


Figure 7.D.6. Mean salinity at the surface and bottom at each sampling station in Saugatuck Harbor in 2024. Error bars represent standard error.

Water Clarity
Mean secchi depth readings ranged from a minimum of 0.92m at station Saugatuck Harbor 5 to a maximum of 1.51m at station Saugatuck Harbor 1. Mean secchi readings steadily increased from the inner harbor stations to the outer harbor stations (Figure 7.D.7).

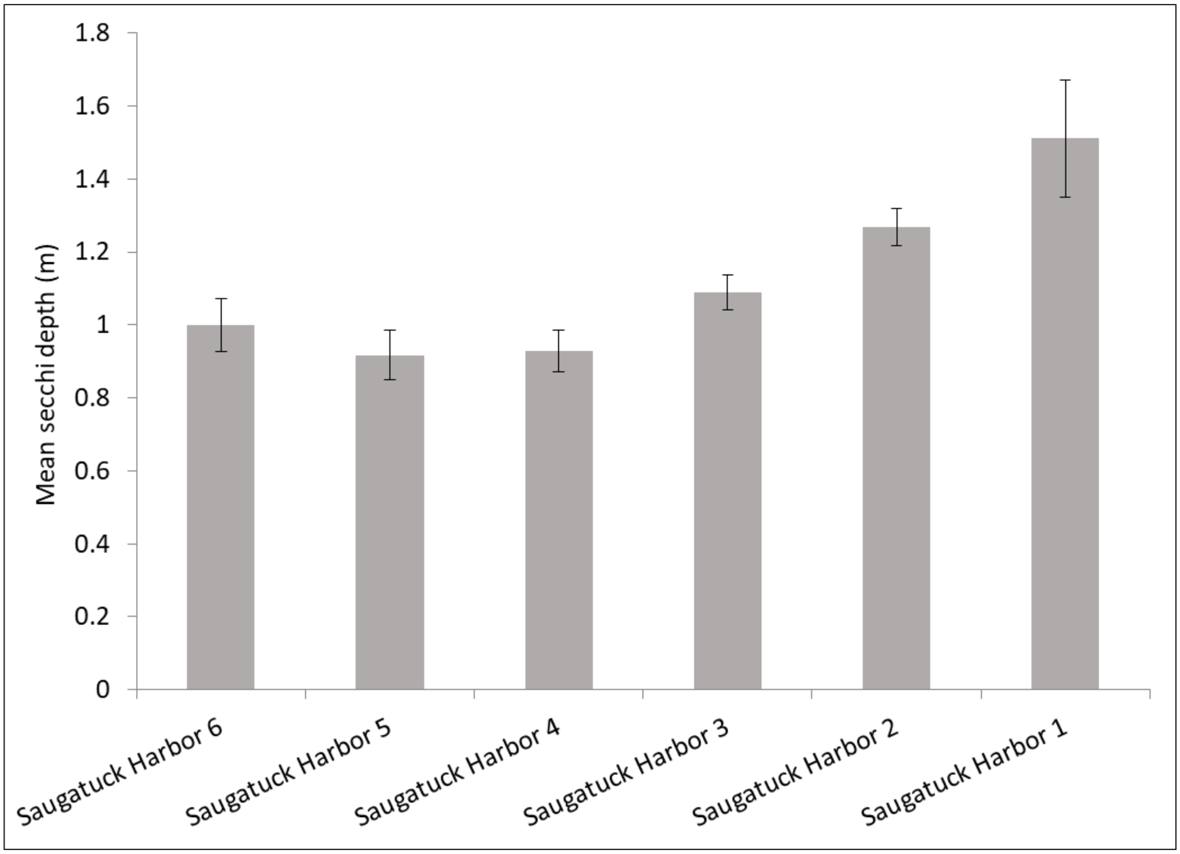
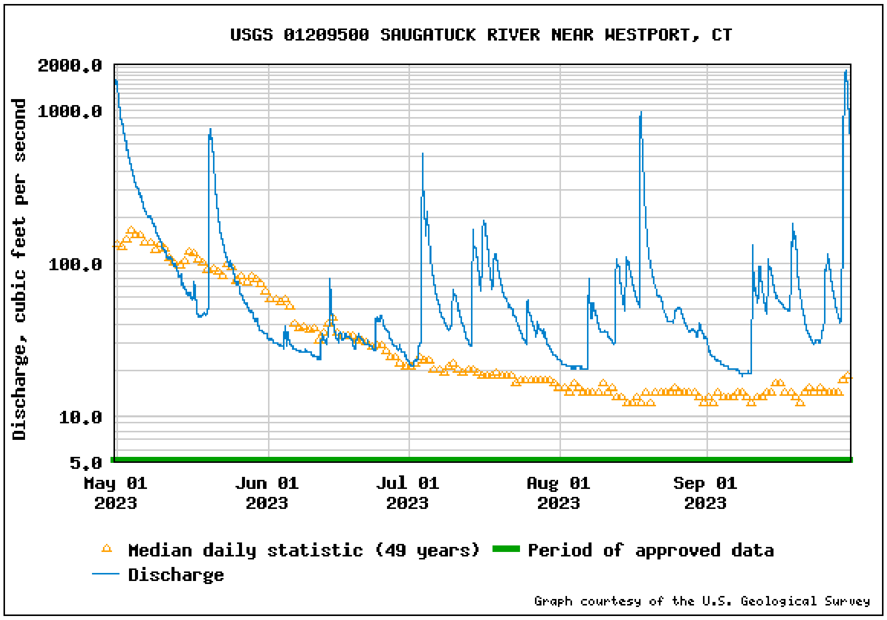


Figure 7.D.7. Mean secchi depth readings in Saugatuck Harbor in 2024. Error bars represent standard error.

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 49 years, and the blue line represents the recorded discharge for a particular date. Smaller and frequent rain events throughout 2024 resulted in shorter but more frequent peaks in discharge than in 2023. The largest peak in discharge observed was on August 18th, 2024 due to a large rain event that occurred over a short period of time.



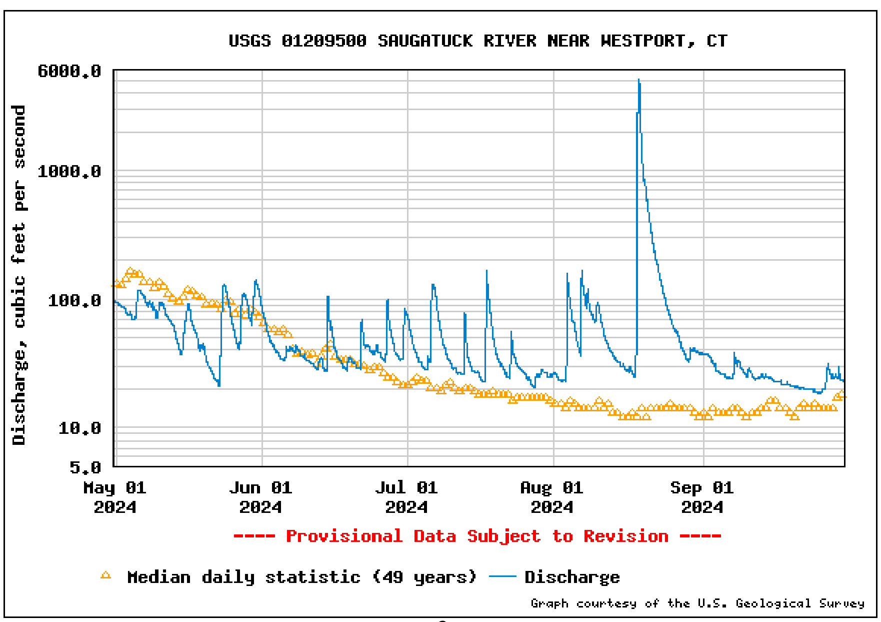


Figure 7.D.8. USGS flow data in ft^3/s for the period of May 1 through September 30 for 2023 (top) and 2024 (bottom) respectively for the Saugatuck River near Westport, CT (Graphs courtesy of the U.S. Geological Survey).

7.E. 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 2 small parks, an abandoned engine plant, an Air and Space Center, Sikorsky Memorial Airport, a wastewater treatment plant and 3 marinas (Figure 7.E.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 that 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 7.E.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 7.E.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 that sampling could only be conducted around 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.

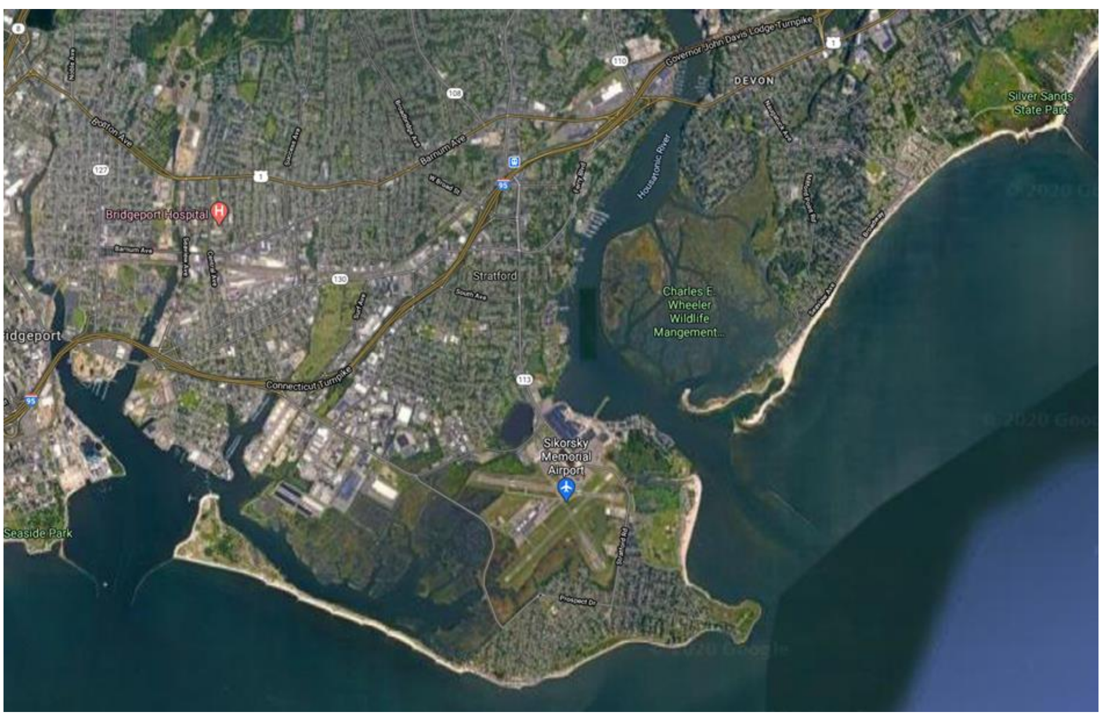


Figure 7.E.1. Aerial image of the Housatonic River and surrounding development and wildlife management area (photo source: Google Maps).

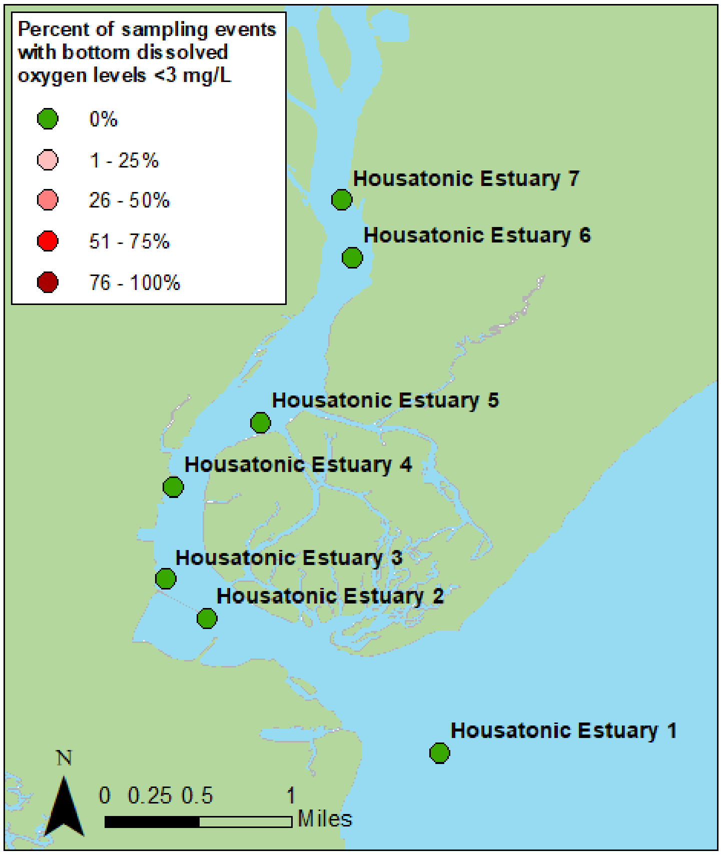


Figure 7.E.2. Map of Housatonic Estuary sampling stations in 2024. Color of dots represents the percent of sampling events with bottom dissolved oxygen levels less than 3 mg/L.

Table 7.E.1. Coordinates and descriptions for each sampling station in Housatonic Estuary

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 only 2 days, once in May and once in June, due to boat repairs. Mean surface and bottom dissolved oxygen concentrations ranged from a minimum of 7.37mg/L at the bottom of station Housatonic Estuary 6 to a maximum of 8.37 mg/L at the surface of station Housatonic Estuary 7 (Figure 7.E.3). Of all of the dissolved oxygen observations, none were below 5 mg/L. Because sampling events were only conducted during the early summer months, results may be biased to better water quality conditions. Typically, as the summer progresses and temperatures increase, a decrease in dissolved oxygen can be observed (N.C. Spiller et al., 2023, 2022) and should sampling have occurred minimally monthly throughout the monitoring season lower results may have been obtained.

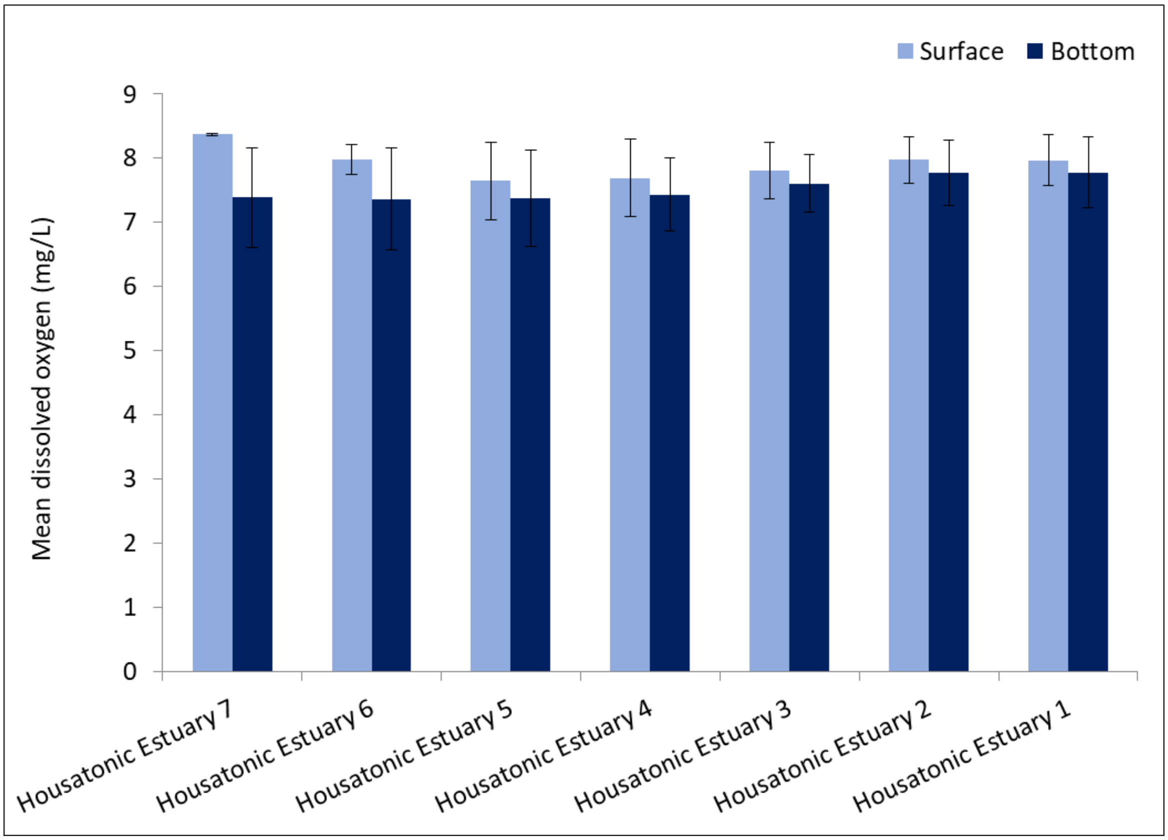


Figure 7.E.3. Mean dissolved oxygen concentrations at the surface and bottom at each sampling station in the Housatonic Estuary in 2024. Error bars represent standard error.

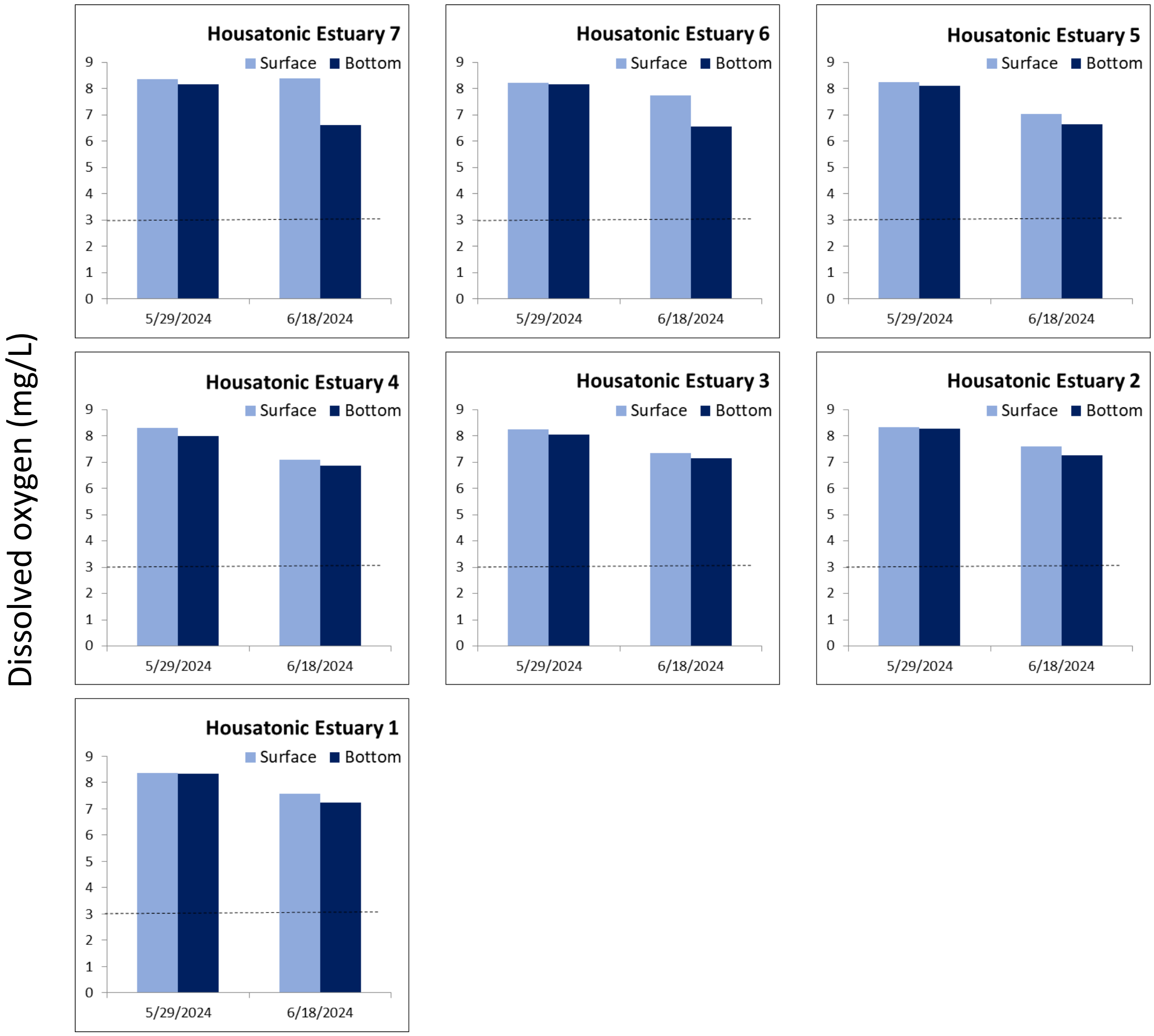


Figure 7.E.4. Surface and bottom dissolved oxygen values at each Housatonic Estuary sampling station on each monitoring date during the 2024 season. The dotted line represents hypoxic conditions (3 mg/L). Please note x-axis is individual sampling dates, not a time scale.

Temperature and Salinity
Mean water temperature in the Housatonic Estuary was similar throughout the water column for both sampling events in 2024 (Figure 7.E.5). Mean salinity was lower at the surface than the bottom at all stations likely due to the influence of rainfall runoff within the watershed and fresh water from the Housatonic River (Figure 7.E.6). Overall salinity was also quite low throughout the sampling sites due to random discharges from upstream dams (Figure 7.E.8).

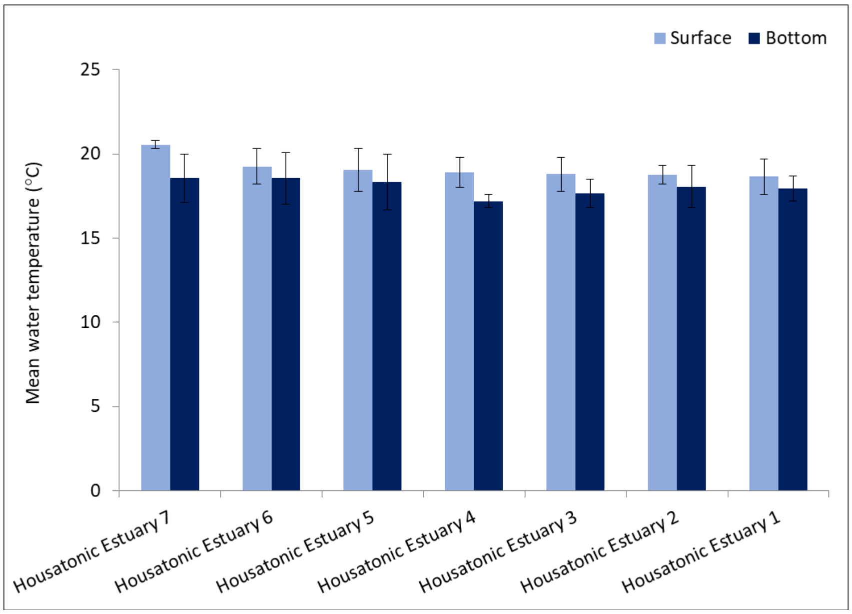


Figure 7.E.5. Mean water temperature at the surface and bottom at each sampling station in the Housatonic Estuary in 2024. Error bars represent standard error.

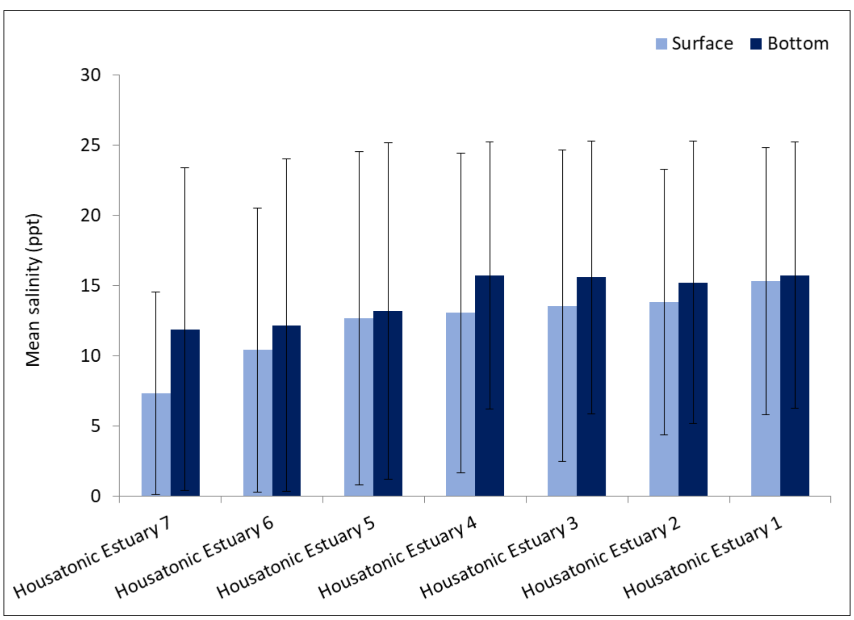


Figure 7.E.6. Mean salinity at the surface and bottom at each sampling station in the Housatonic Estuary in 2024. Error bars represent standard error.

Water Clarity
Mean secchi depth readings ranged from a minimum of 1.53m at station Housatonic Estuary 3 to a maximum of 2.06m at station Housatonic Estuary 1. Mean secchi readings were relatively consistent throughout most of the harbor, and then increased at stations Housatonic Estuary 2 and Housatonic Estuary 1 (Figure 7.E.7).

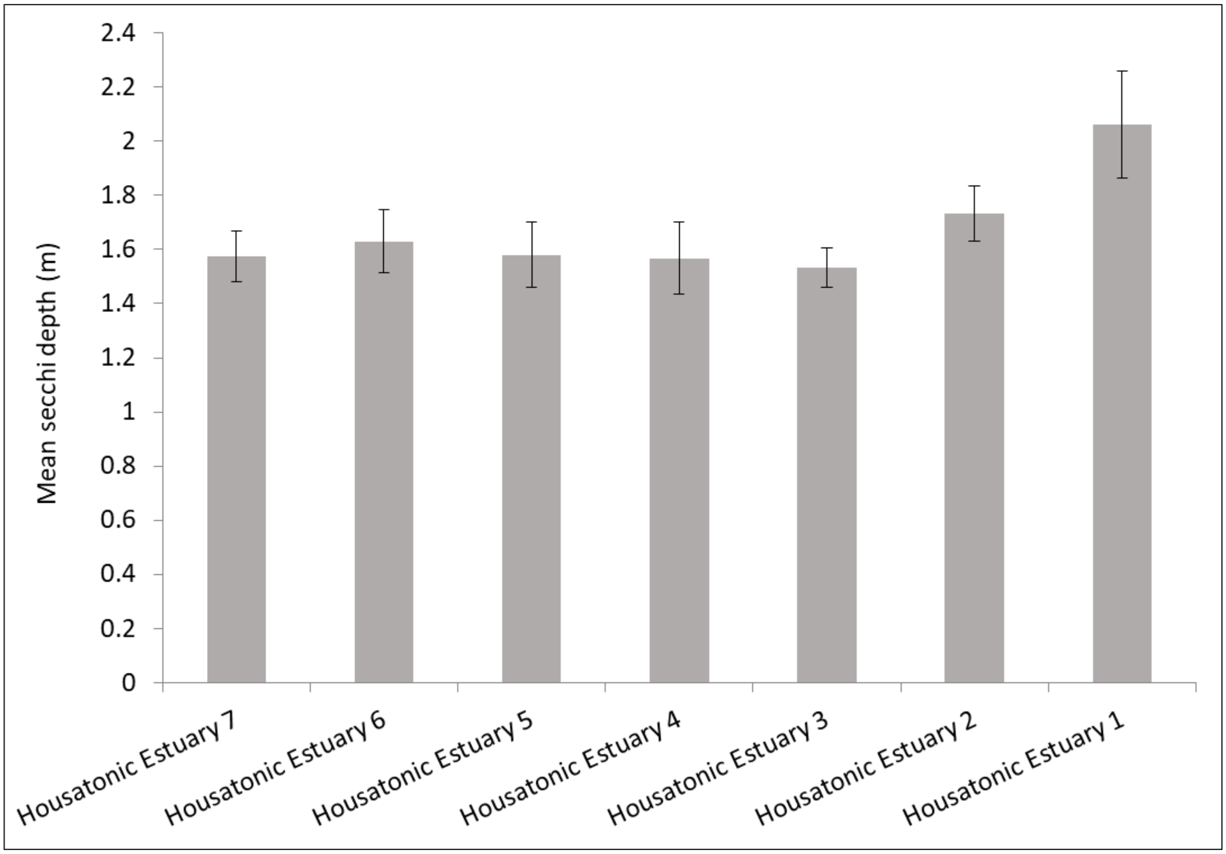
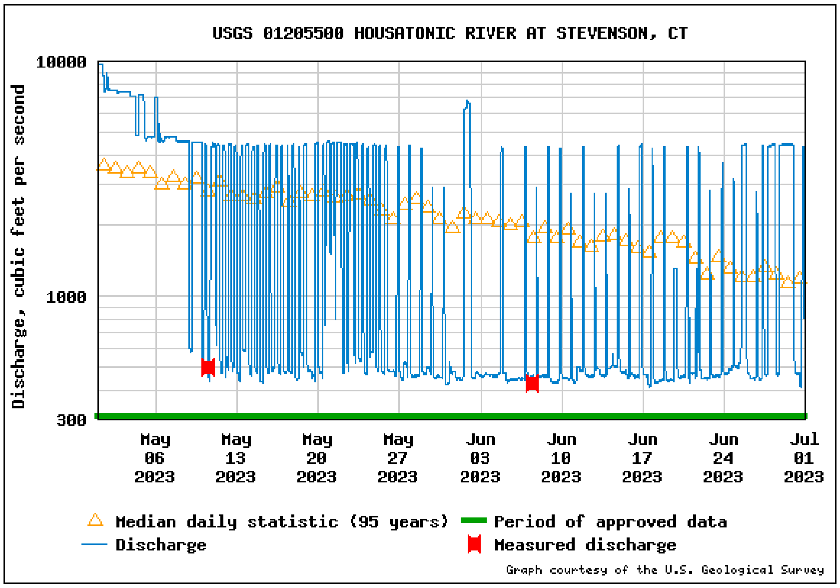


Figure 7.E.7. Mean secchi depth readings in the Housatonic Estuary in 2024. Error bars represent standard error.

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 95 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 was similar in May and June of 2023 and 2024 (Figure 7.E.8). There was a peak in discharge at the start of May 2023, but other than that the trends between both years were very similar.



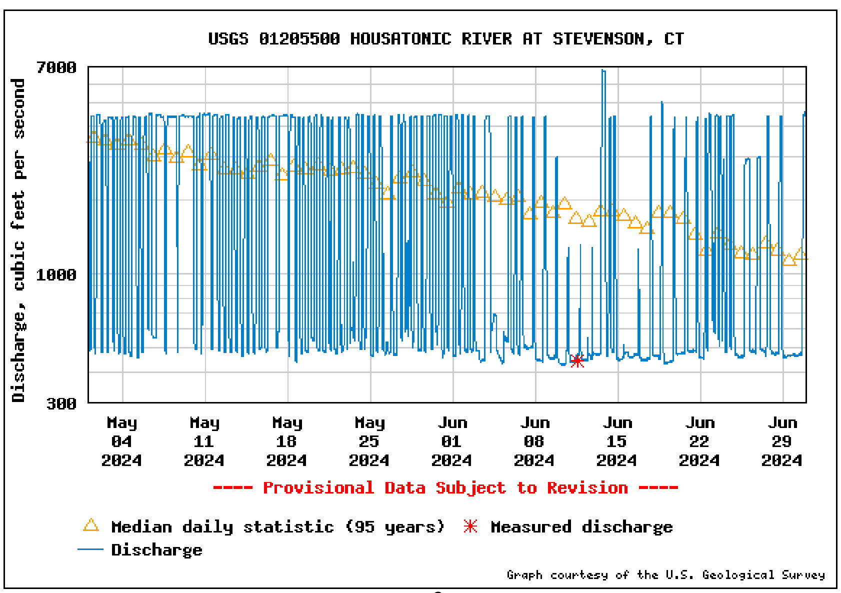


Figure 7.E.8. USGS flow data in ft^3/s for the period of May 1 through June 30 2023 (top) and 2024 (bottom), respectively for the Housatonic River in Stevenson, CT (Graphs courtesy of the U.S. Geological Survey). Please note the difference in scale on the y-axis.

7.F. 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 Quinnipiac River 4) provides excellent tidal flushing for the whole basin on an 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 7.F.1). The lower portion on the eastern shore, south of the Grand Avenue Bridge, is occupied by Copps Island Oysters harvesting facility, an oil terminal, 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 7.F.1. View of the large flushing basin in New Haven Harbor with extensive wetlands on the eastern shore.

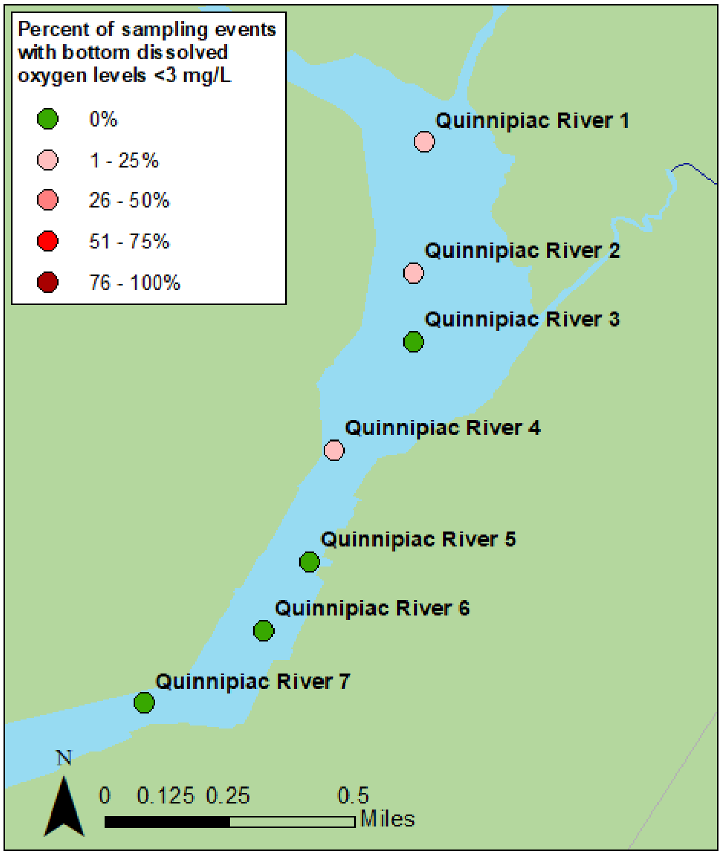


Figure 7.F.2. Map of Quinnipiac River sampling stations in 2024. Color of dots represents the percent of sampling events with bottom dissolved oxygen levels less than 3 mg/L.

Table 7.F.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 to October 1. Stations Quinnipiac River 6 and Quinnipiac River 7 were not sampled on 6/4/2024 due to engine problems and on 7/18/2024 there were no bottom measurements for Quinnipiac River 7 because the meter cable did not reach the bottom. Mean dissolved oxygen concentrations ranged from a minimum of 6.16 mg/L on the bottom at station Quinnipiac River 6 to a maximum of 6.96 mg/L at the surface at station Quinnipiac River 7 (Figure 7.F.3). Dissolved oxygen values followed expected seasonal trends with concentrations dropping from early June through August and then slightly rising through September (Figure 7.F.4). Of all the bottom dissolved oxygen observations, 33% fell below 5 mg/L while 8% fell below 3 mg/L. This year marks the first in the last 3 years in which dissolved oxygen values were observed to be below 3mg/L.

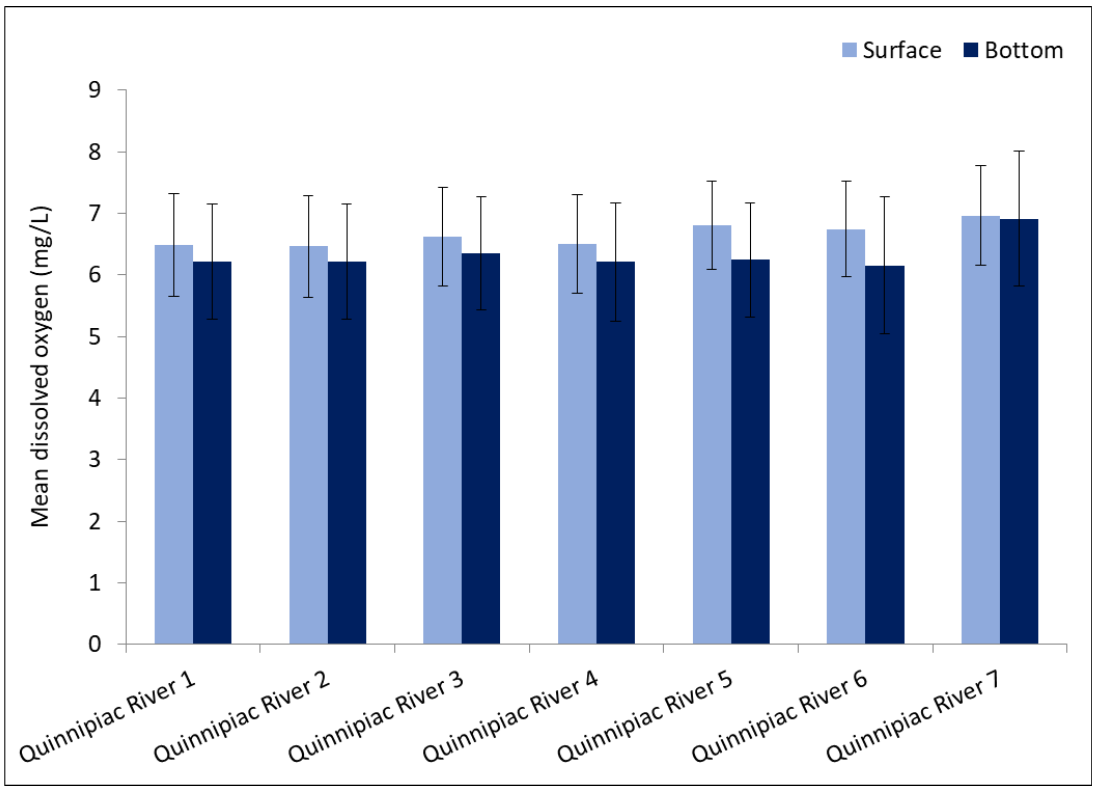


Figure 7.F.3. Mean dissolved oxygen concentrations at the surface and bottom at each sampling station in the Quinnipiac River in 2024. Error bars represent standard error.

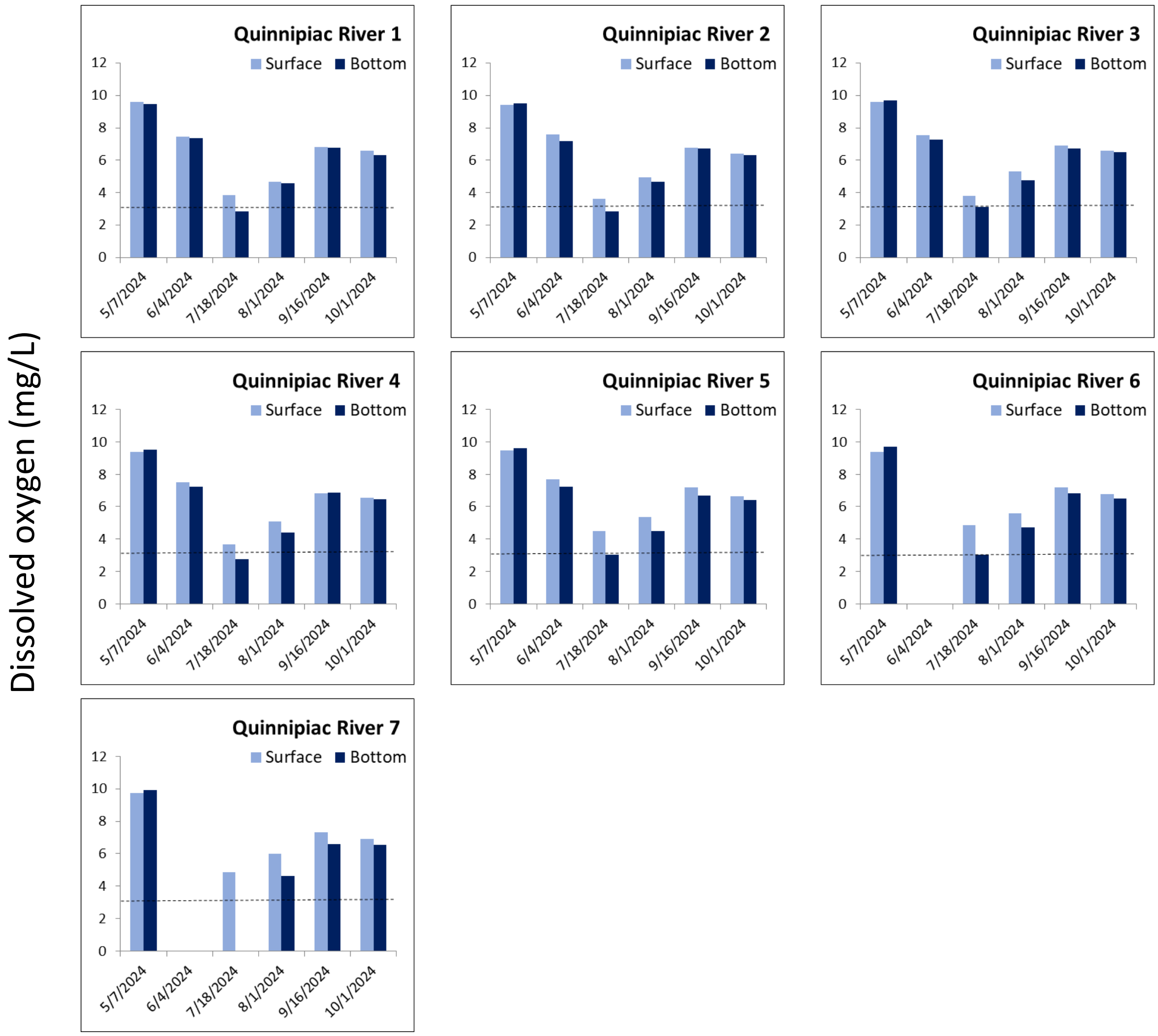


Figure 7.F.4. Surface and bottom dissolved oxygen values at each Quinnipiac River sampling station on each monitoring date during the 2024 season. The dotted line represents hypoxic conditions (3 mg/L). Please note x-axis is individual sampling dates, not a time scale.

Temperature and Salinity

Mean water temperature in the Quinnipiac River was observed to be similar throughout the water column in 2024 (Figure 7.F.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 7.F.6).

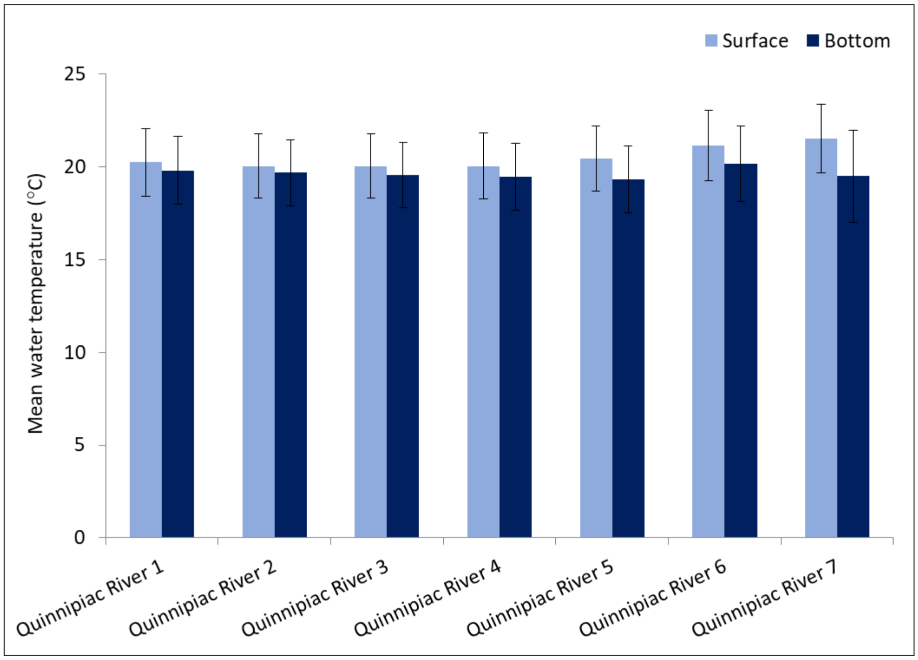


Figure 7.F.5. Mean water temperature at the surface and bottom at each sampling station in the Quinnipiac River in 2024. Error bars represent standard error.

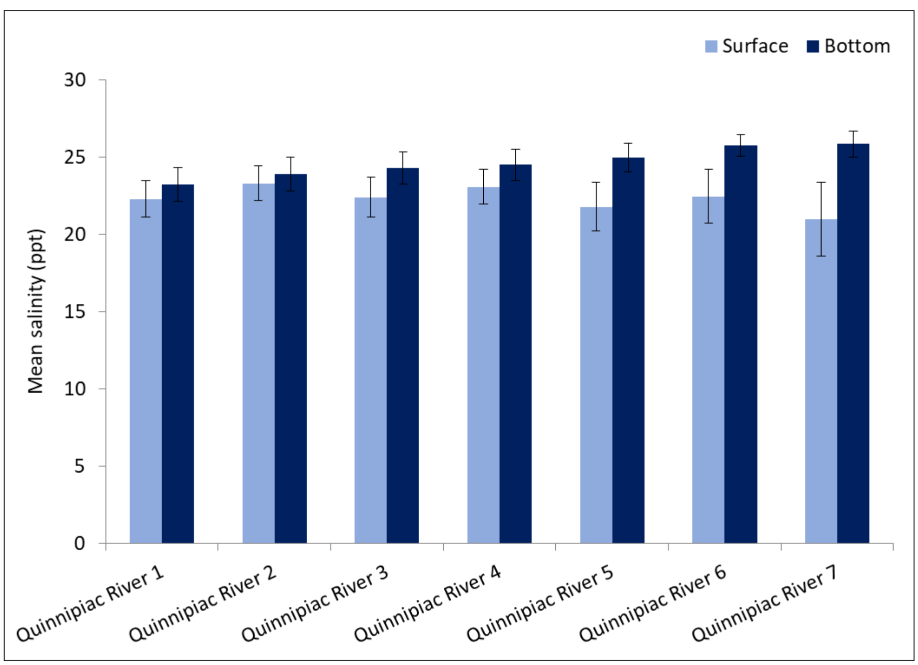


Figure 7.F.6. Mean salinity at the surface and bottom at each sampling station in the Quinnipiac River in 2024. Error bars represent standard error.

Water Clarity
Mean secchi depth readings ranged from a minimum of 1.31m at station Quinnipiac River 4 to a maximum of 1.53m at station Quinnipiac River 1. Mean secchi readings drop slightly after station Quinnipiac River 1, then rise at station Quinnipiac River 6, and then drop again at station Quinnipiac River 7 (Figure 7.F.7).

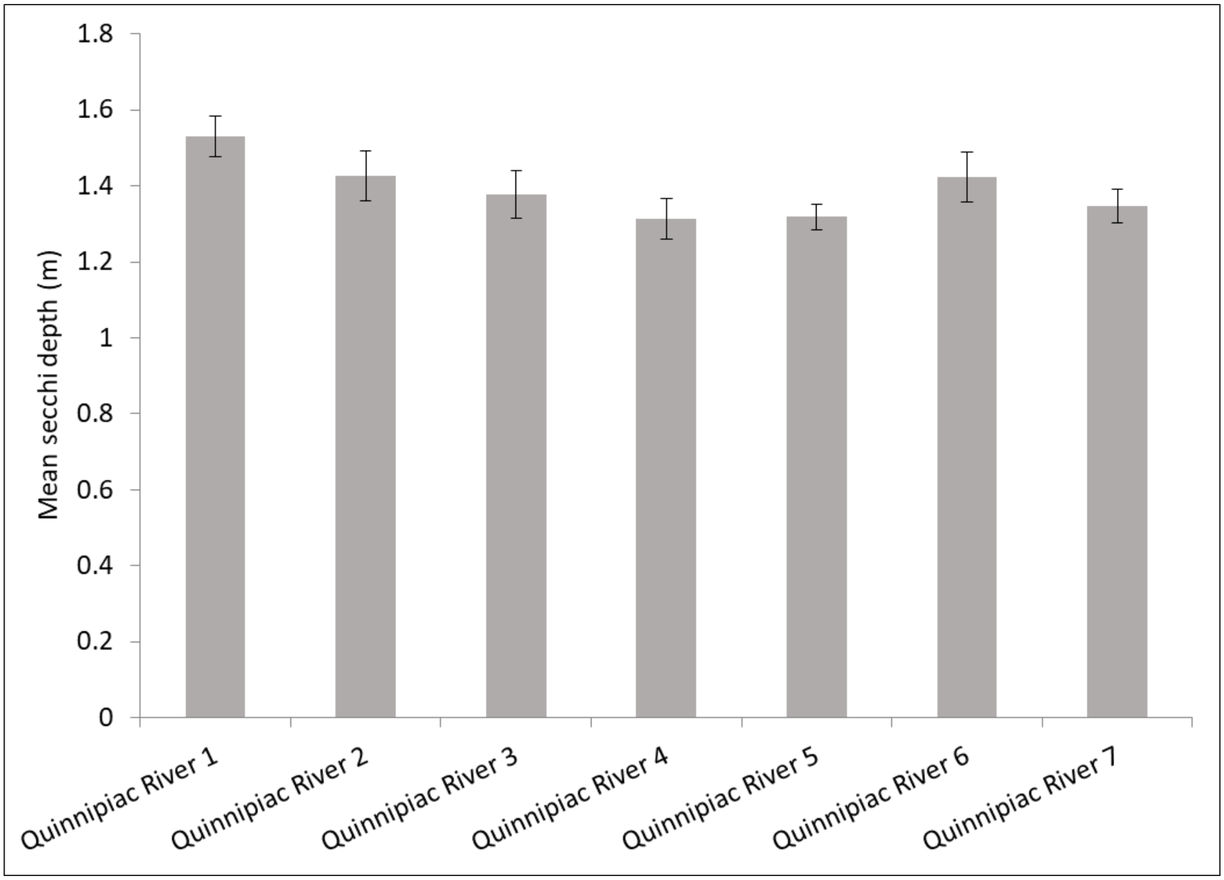
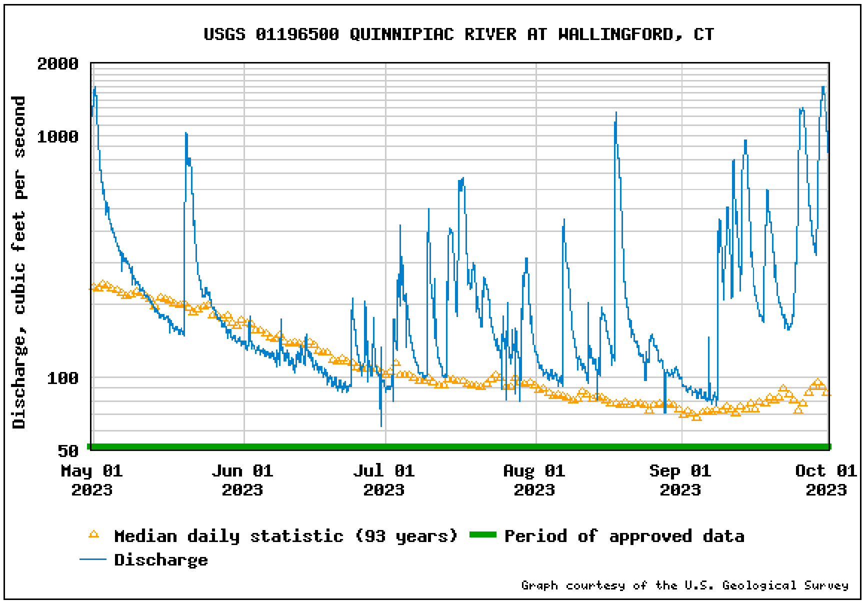


Figure 7.F.7. Mean secchi depth readings in the Quinnipiac River in 2024. Error bars represent standard error.

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 93 years, and the blue line represents the recorded discharge for a particular date. During May to early June 2024, more discharge was observed than in 2023. However, September 2024 witnessed much less discharge than in 2023 due to having less than one inch of rainfall for the entire month.



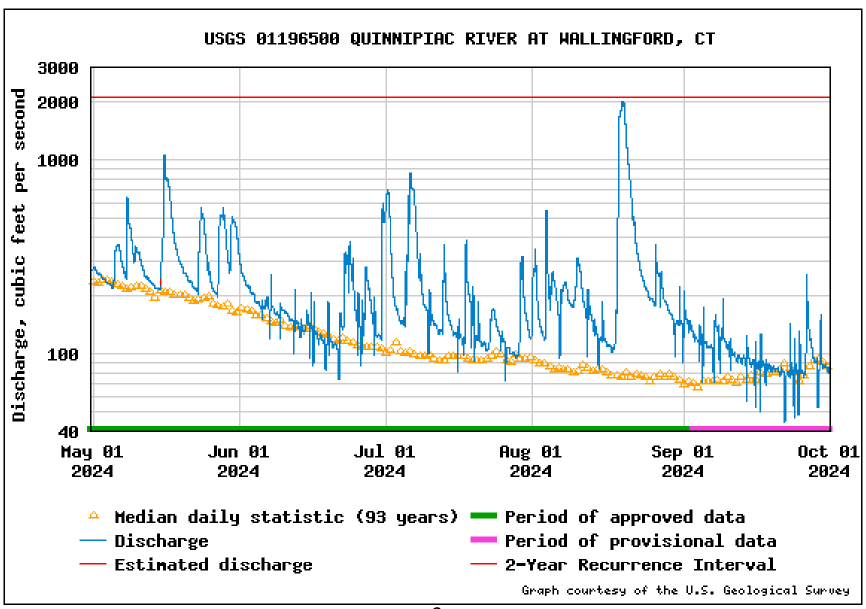


Figure 7.F.8. USGS flow data in ft^3/s for the period of May 1 through October 1, 2023 (top) and 2024 (bottom), respectively for the Quinnipiac River in Wallingford, CT (Graphs courtesy of the U.S. Geological Survey). Please note the difference in scale on the y-axis.

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9. QAPP Deviation Summary

Quality Assurance Project Plan (QAPP) Report (11/25/24)

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

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

Approved for: Monitoring Season 2023-2024

1.6 Project/Task Description

- Saugatuck was added as an additional harbor to be studied (the ability to trawl in Saugatuck Harbor was realized after QAPP approval, however, the same methods were followed as those in the approved QAPP, using sites from previous trawling seasons.)
- To ensure that the new vessel was functioning and to allow staff time to become accustomed to it, trawling began before the May-October window (eight trawls were conducted in February and four in April in Norwalk Harbor, but not between March 1st - April 14).
- Approximate depth was recorded at deployment and retrieval, rather than just deployment. The temperature was also recorded using the temperature reading on the Garmin navigation system.

2.1 Sampling Design

- Sampling occurred between the hours of 8 am – 5 pm (not 9 am) and teams met at 8:30 am instead of 9:30 am.
- Box C in Norwalk Harbor was not trawled due to pipe crossing/construction.
- Boxes A and C in Saugatuck Harbor were not trawled due to tidal restrictions and submerged cable crossings, respectively.
- In Norwalk Harbor, each box was trawled at least 6 times, and R was trawled the least at 4 times, due to tidal access.

2.2 Sampling Design

- The trawl sled was deployed off the aft port gunwale instead of the aft starboard gunwale.
- The sorting bin was not "a plastic bin with small holes on all four sides to act as a colander which is set inside a slightly larger solid bin with harbor water to keep the catch submerged at all times". Instead, it is a repurposed sink with a drain that is plugged when filled with harbor water.
- Macrophyte identification and recording were added.

2.3 Sample Handling and Custody

- Instead of "No specimens will be collected and transported for further study", potentially invasive species were removed from the boat and given to CT DEEP for further examination. A record is kept of any of these species that were removed.

2.5 Quality Control Requirements

- There were only 2 species identification discrepancies on the second trawl species QC ID, which were discussed as a team and re-identified.

4.1 Data Review, Verification, and Validation Requirements

- When shrimp were too small to be identified, they were recorded as “juvenile shrimp”
- After consulting with an expert in the field and concluding that “shore shrimp” could be 1 of 3 unique species, it was changed on the datasheet from “Palaemonetes vulgaris” to “Palamon spp”.
- We combined "thick-lipped oyster drill" with "oyster drill", so on the datasheet it is now “various spp” which includes “Urosalpinx cinereal” and “Eupleura caudata”.

Appendix 1: Sample Data Sheet

- A new data sheet was designed, it was updated in the following ways:
  - Added the recording of temperature at the beginning of trawling (temperature to be recorded based on Garmin reading) and depth at the end of trawling
  - Added macrophyte identification and quantification
  - Added trash identification and quantification
  - Modified how species (other than fish, shrimp, and crabs) were recorded from exact numbers to presence/absence