IPSWICH RIVER
WATERSHED ASSOCIATION
The Voice of the River

RiverWatch Water Quality Volunteer Monitoring Program

The Ipswich River Watershed Association (IRWA) is the voice of the Ipswich River. IRWA works to protect nature and make sure that there is enough clean water for people, fish and wildlife, today and for our children and theirs.

2018 Annual Results Report

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List of Abbreviations

Abbreviation	Definition
EEA	Executive Office of Energy and Environmental Affairs
USEPA	United States Environmental Protection Agency
ft	Foot
g	Gram
IRWA	Ipswich River Watershed Association
lb	Pound
MassDCR	Massachusetts Department of Conservation and Recreation
MassDEP	Massachusetts Department of Environmental Protection
MassDER	Massachusetts Division of Ecological Restoration
MassDFW	Massachusetts Division of Fish and Wildlife
MBL	Marine Biological Laboratory
MDL	Method Detection Limit
mg	Milli-gram
mL	Milli-liter
N/A	Not Applicable
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RL	Reporting Limit
RIFLS	River Instream Flow Stewards
s	Second
SOP	Standard Operating Procedure
TAC	Technical Advisory Committee
UNH	University of New Hampshire
USGS	United States Geological Survey

Executive Summary

In 1997 the Ipswich River was listed as one of the 20 most threatened rivers in America. The level of threat to the Ipswich River was heightened in 2003 when it was ranked the third most endangered river in America by American Rivers, a national nonprofit, primarily due to low flow problems (American Rivers 1997 and 2003, IRWA 2003).

Much of the upper half of the River dried up or was reduced to isolated stagnant pools in the summers of 1995, 1997, 1999, 2001, 2002, 2003, and 2005. In 1999, the River experienced record low-flows in May, June, July and August. In 2000, the United States Geological Survey (USGS) completed a model of river flow that linked withdrawals for regional water supply with low flows in the Ipswich River. Major fish kills were also documented in 1995, 1997, 1999, 2002, and 2005.

Low flows continue to be a threat to the Ipswich River. In order to assess the health of the Ipswich River, the Ipswich River Watershed Association has maintained the RiverWatch Volunteer Water Quality Monitoring Program since 1997. Volunteers collect data monthly from March-December on weather conditions, rain in the last 48 hours, water color, water odor, water temperature, dissolved oxygen, velocity, depth and conductivity. Channel cross-sections are recorded at selected sites in April and September. Streamflow was also monitored at three locations in addition to the official USGS gages. In 2018, volunteers monitored a total of 32 sites monthly from March to December.

Results

The Ipswich River and many of its tributaries continue to show impairment for dissolved oxygen and flow. Dissolved oxygen (DO) is necessary for all forms of life that depend on the river. DO is influenced by many factors including flow and temperature. Dissolved oxygen levels below 5 mg/L create a stressful environment for fish and other aquatic organisms. Levels below 3 mg/L can be fatal to organisms that cannot move to areas of higher concentration. Large fish kills can result from DO levels that fall below 1-2 mg/L, even if those levels are present for only a few hours. Certain fish species, like brook trout, are especially sensitive to low DO. Conductivity readings also indicate the presence of salts in the water at levels higher than is recommended for aquatic organisms.

Low DO conditions have been widespread and frequent since monitoring began in 1997. In 2018, 34% of the collected samples did not meet the state standard for dissolved oxygen concentration of 5 mg/L for class B waters. Sites located in the headwaters region of watershed continue to show a higher degree of impairment for dissolved oxygen than sites elsewhere. The headwaters region or upper watershed includes the towns of Wilmington and North Reading in the southwestern area of the watershed.

All temperature samples met Massachusetts State Water Quality Standards. This indicates that temperatures are in an acceptable range along the Ipswich River. This may be an indicator of the importance that cool groundwater plays in providing the river's baseflow in summer. Shading from trees along the river also benefits water temperature. It is important to note that this measure does not consider the most extreme conditions as temperatures cannot be recorded when there is little (or no) water present in the river during extreme low flows. Also, monitoring is conducted in the morning, and may not represent the highest temperatures that occur in the course of that day or month.

There must be water in the river for most aquatic organisms to survive. The Ipswich River experiences significant periods of extreme low flow during many years. Withdrawals for drinking and irrigation water are the primary cause of unnaturally low flows in the Ipswich River (Armstrong 2001, Zarrielo and Ries 2000). Low flows can be expected to occur seasonally, but the low flows observed in the Ipswich River are about 1/10th of what is considered "natural" (Zariello and Ries, 2000). Due to low flow, the Ipswich River is classified as highly stressed by the MA Water Resources Commission (2001) and impaired under section 303(d) of the Clean Water Act.

Streamflow gages maintained by the United States Geological Survey (USGS) have recorded regular episodes of extended extreme low flow events since monitoring began in 1997. "Extreme low flow" is defined based on the USGS summer "ecological protection flow" (Horsley and Witten 2002), that "provides adequate habitat for the protection of fisheries" (Ibid). Extreme low flows were observed for 59 days in 2018 primarily during the summer and early fall.

Conductivity measures the ability of water to pass an electrical current resulting from the presence of dissolved solids (or salts) such as chloride, sulfate, sodium and calcium. Significant changes in conductivity can be an indicator that a discharge or some other source of pollution has entered the water. Rivers that can support healthy fisheries should be in the range of 150 to 500 µS/cm. In 2018, conductivity levels greater than 500 µS/cm were recorded for 46% of samples, with many of these sites located in the upper watershed. High conductivity readings are most likely the result of road salt entering the river through stormwater and surface runoff. Conductivity readings at most sites were similar for summer and winter reflecting the persistence of road salt in the environment where readings tend to be above levels recommended for rivers and streams.

Conclusion

The upper watershed continues to experience low dissolved oxygen levels, especially during the summer months, despite low flow conditions not being as severe as in years prior to 2006 when the town of Reading discontinued using wells adjacent to the Ipswich River. Martins Brook continues to experience severe low flows near active groundwater wells. Low flows impact the biological health of the watershed.

The primary cause of impairments in the Ipswich River watershed are low flow alterations due to water withdrawals and impervious surfaces contributing to stormwater runoff. Under these conditions, dissolved oxygen levels decrease below what is suitable to aquatic life such as fish and macroinvertebrates that are an important part of the aquatic food web.

Water has remained in the river year-round since Reading discontinued well use, showing that reductions in water withdrawals and water restrictions by towns can have a beneficial effect on the Ipswich River.

Road salt is an emerging threat to water quality of the Ipswich River. Conductivity data is being used to identify hotspots where road salt contamination is believed to occur. This will require ongoing monitoring to document trends and conditions across the watershed. Results suggest concentrations are highest at sites in the headwaters region or upper watershed where there is a relatively higher density of treated surfaces.

Our deepest thanks to our volunteers that have monitored on sunny and rainy days, in cold and heat and high and low river flows. Thank you for your considerable efforts and dedication to the Ipswich River!

Section 1: Overview of the RiverWatch Monitoring Program

1.1 Description

The Ipswich River Watershed Association has conducted the RiverWatch water quality monitoring program since 1997. The program enlists a group of volunteers to collect water quality data on the Ipswich River and its tributaries. The purpose of the program is to establish and maintain monitoring of baseline data in order to identify and address impairments to water quality and quantity, as well as to promote awareness and stewardship of the river. The RiverWatch program expanded upon an earlier, informal water quality monitoring program that ran from 1988 – 1996. A USEPA-approved Quality Assurance Project Plan (QAPP) was finalized in 1999 and most recently updated and approved by MassDEP in 2016. The goal of the RiverWatch program is to provide high quality data regarding the health of the Ipswich River. This monitoring program has established a crucial baseline of water quality and biological data, which continues to enable IRWA to work with researchers and government officials to better manage the watershed and improve the condition of the Ipswich River.

The specific goals of regularly monitoring the Ipswich River and its tributaries include:

- Defining the baseline water quality conditions of the Ipswich River and key tributaries.
- Defining the range of dissolved oxygen concentrations, temperature and conductivity over the range of annual conditions in both mainstem and tributary locations.
- Determining the relative water level and flow at a variety of ungauged locations around the basin.
- To observe the River, habitat and wildlife, and report on observations.
- To identify pollution hotspots.
- To educate watershed residents about the river.
- To promote stewardship of the river.
- Inform ongoing restoration efforts

Monitors collect data monthly on weather conditions, rain in the last 48 hours, water color, water odor, water temperature, dissolved oxygen, conductivity, velocity and depth. Streamflow data is recorded at two official gaging stations maintained by the USGS. Streamflow is also monitored at three additional sites established in 2012 in cooperation with the Massachusetts Division of Ecological Restoration.

The purpose of this report is to summarize data collected in 2018 by volunteers for the RiverWatch program. Specific site data are available in the appendix.

Data collected by IRWA will be reported to IRWA members, state agencies, interested organizations, and conservation commissions through reports and presentations on the collected data. Atypical data will be reported to the appropriate agencies. Atypical data include dissolved oxygen data that vary significantly from adjacent sites over one or more months. Extended periods of no flow or extremely low dissolved oxygen (less than 2 mg/L) are also considered extremely important and will be presented to state agencies. When dissolved oxygen levels fall below 2 mg/L the health of fish and other aquatic organisms can be severely impacted.

Section 2: An Introduction to the Ipswich River

The Ipswich River Watershed Association (IRWA) is a non-profit organization incorporated in 1977. IRWA's mission is to protect the Ipswich River, now and for future generations. We work primarily in the 21 communities that are located in or draw water from the watershed. Our primary goals are:

- to ensure that the Ipswich River has enough clean water to provide for people's needs;
- to protect fish, wildlife and nature;
- to preserve the river's natural beauty and outstanding outdoor recreation; and
- to engage the public in protecting the environment

The Ipswich River watershed is 155 square miles and includes all or part of 21 communities in northeastern Massachusetts. The topography of this Atlantic coastal plain basin is characterized by low relief, with an average grade of 3.1 feet per mile. The length of the river is a meandering 40 miles. The surficial geology of the region consists primarily of glacial till with stratified sand and gravel deposits covering about 43 percent of the basin and alluvial deposits covering about 3 percent of the basin (Zariello and Ries, 2000). Extensive wetlands are present along the River and streams within the Ipswich River basin. These wetlands protect surrounding areas during flooding as well as positively affect the water quality of the River and streams in the basin.

This river system supplies water to more than 330,000 people and thousands of businesses, providing all or part of the water supply for 14 communities. The Ipswich River also sustains fish and natural communities, and provides a scenic natural corridor with outstanding opportunities for the residents and eco-tourists to enjoy the great outdoors. The Ipswich River is Massachusetts' most popular paddling destination north of Boston.

Water quality issues have been identified in the Ipswich River and the Ipswich River watershed by both independent researchers and the State of Massachusetts. Impairments include: repeated, exaggerated low flows, low dissolved oxygen, excessive nutrient and fecal coliform and many others (MassDEP, 2016). Low flows in summer have been linked to ground water withdrawals, particularly in the upper watershed (Zarriello and Ries 2000). Additionally, the diversion of wastewater to treatment plants outside the watershed also significantly reduces flow (Ibid). Many sub-basins in the watershed experience severe flow depletion seasonally due to groundwater withdrawals and significant annual flow depletion due to surface water withdrawals (Weiskel, *et al*. 2009). Water quality assessments have identified 53% of named river miles throughout the watershed as impaired for supporting healthy populations of aquatic life (MassDEP, 2000).

Low flow problems have resulted in the loss of flow dependent fish species that would otherwise occur in the Ipswich River (Armstrong et al. 2001). The study identified critical aquatic habitats and recommended minimum flows necessary to preserve those habitats. The Ipswich River Fisheries Restoration Task Group then developed recommendations to restore healthy fisheries to the Ipswich River (2002). These recommendations include maintaining flow over riffle areas, maintaining water to the channel margins and maintain seasonal flow variations near natural levels (Ibid).

Under the Massachusetts Surface Water Quality Standards (MassDEP 2013), most of the freshwater section of the Ipswich River is classified as a Class B water body and warm water fishery, except for public water supplies and certain tributaries (Table 1). The water quality goal for Class B waters is to be “fishable and swimmable” throughout the year. The tidal section of the river located downstream of the Ipswich Mills Dam in Ipswich is classified as a class SA water body. Class SA water bodies are tidal waters intended to be fishable, swimmable, and safe for shell fishing. Table 2 details the water quality standards associated with these classifications.

The RiverWatch water quality monitoring program is an effort to provide high quality data on the health of the Ipswich River in order to make informed decisions about water management practices and monitor ongoing restoration efforts.

Our thanks to our volunteers that have monitored on sunny and rainy days, in cold and heat, and high and low river flows. Thank you for your considerable efforts and dedication to the Ipswich River!

Table 1. Massachusetts surface water classifications for the Ipswich River watershed and coastal drainage area (MassDEP, 2013).

BOUNDARY	MILE POINT	CLASS	OTHER RESTRICTIONS
<u>Ipswich River</u>			
Source to Salem Beverly Waterway Canal	41.1 - 16.4	B	Treated Water Supply, Warm Water, High Quality Water
Salem Beverly Waterway Canal to tidal portion	16.4 - 4.5	B	Warm Water, High Quality Water
Tidal portion and tributaries thereto	4.5 - 0.0	SA	Shellfishing (O)
<u>Middleton Pond</u>			
Source to outlet in Middleton and those tributaries thereto	-	A	Public Water Supply
<u>Swan Pond</u>			
Source to outlet in North Reading and those tributaries thereto	-	A	Public Water Supply
<u>Mill Pond</u>			
Source to outlet in Burlington and those tributaries thereto	-	A	Public Water Supply
<u>Longham Reservoir</u>			
Source to outlet in Wenham and those tributaries thereto	-	A	Public Water Supply
<u>Wenham Lake</u>			
Source to outlet in Wenham and those tributaries thereto	-	A	Public Water Supply
<u>Putnamville Reservoir</u>			
Source to outlet in Danvers and those tributaries thereto	-	A	Public Water Supply
<u>Suntaug Lake</u>			
Source to outlet in Lynn and Peabody and those tributaries thereto	-	A	Public Water Supply
<u>Winona Pond</u>			
Pond to outlet in Peabody and those tributaries thereto	-	A	Public Water Supply
<u>Unnamed Reservoir (Emerson Brook Reservoir)</u>			
Reservoir to outlet in Middleton and those tributaries thereto	-	A	Public Water Supply

Table 2. Massachusetts Department of Environmental Protection water quality standards (MassDEP, 2013).

	Class B Standards	Class SA Standards
AQUATIC LIFE		
Dissolved Oxygen	5.0 mg/L *	6.0 mg/L
Temperature	83° F Max ** (28.3° C)	85 F (29.4° C) Max, 80 F Average
pH	6.5 - 8.3	6.5 - 8.5
PRIMARY CONTACT RECREATION		
Fecal Coliform	200 / 100 mL geo. mean 10% <= 400 / 100 mL	200 / 100 mL geo. mean 10% <= 400 / 100 mL
SECONDARY CONTACT RECREATION		
Fecal Coliform	1000 / 100 mL geo. mean 10% <= 2000 / 100 mL	1000 / 100 mL geo. mean 10% <= 2000 / 100 mL
SHELLFISHERY		
Fecal Coliform	Not applicable	14 / 100 mL geo. mean 10% <= 43 / 100 mL
AESTHETICS		
Taste and Odor	None that are objectionable	None other than natural

** Warm water fishery.

[1]314 CMR 4.05 (3) (b)1.b. states that Dissolved Oxygen “levels shall not be lowered below…60% of saturation in warm water fisheries due to a discharge.” This report will therefore assume 60% of saturation to be the Class B standard.

In 2008, the State eliminated standards pertaining to DO% saturation. Values in this report are based on the previous standard of a minimum of 60% DO saturation and presented for comparison with previous years.

[2]314 CMR 4.05 (4)(a)1.b.states that Dissolved Oxygen “levels shall not be lowered below 75% of saturation due to a discharge.” This report will therefore assume 75% of saturation to be the Class SA standard.

2.1 Program Description and Monitoring Methods

Monthly Water Quality Testing

As stated earlier, IRWA has conducted informal monitoring from 1988-1996. The RiverWatch program took its current form in 1997 and has since been continuously monitoring the Ipswich River Watershed. In order to best use our resources to gain an accurate picture of the Ipswich River, 10 tributary sites and 22 sites along the mainstem of the River from Wilmington to Ipswich, have been identified for monitoring once a month from March through December (table 3).

Volunteer monitors are responsible for monthly monitoring which takes place in the morning of the last Sunday of each month from March through December unless the date conflicts with a holiday, in which case, the previous or next Sunday will be chosen. All samples are collected between 8 am and 12:30 pm, except for the tidal locations, which are sampled within 1 hour of low tide closest to the 8 am to 12:30 pm time span. Sampling in the morning is extremely important because the lowest dissolved oxygen values are generally observed in the early morning. This is desirable, because low values have the most potential to affect the organisms living in the Ipswich River. As of the spring of 2006, sampling in January and February became optional. Historically, volunteers sampled during these months, but the River was often frozen and the data collected during these months was generally not used in management decisions.

Volunteers record information on weather, rain in the last 48 hours and river status (frozen or dry). Monitors then collect a grab sample using a bucket. While water is contained in the sampling bucket, observations of color, clarity and odor are made. Color is recorded as a range of pre-determined colors from Clear to Dark Tea. Clarity is recorded as the amount of turbidity in the water from a scale ranging from clear to highly turbid.

Water temperature is measured followed by a test for dissolved oxygen. Water Temperature is measured with H-B Enviro-Safe® Thermometers. Monitors are asked to round to the nearest 0.5 degrees Celsius.

Dissolved Oxygen (DO) is measured with a LaMotte Modified Winkler Method Test Kit. One drop of fluid from the direct reading titrator in the kit is approximately 0.4 mg/L. Thus, accuracy from the titrator is +/- 0.2 mg/L of dissolved oxygen. Field audits are conducted once per year comparing results from DO kits with results from other test kits or a dissolved oxygen meter, obtained by the trainer, with a goal of all sites being within 1mg/L of measured DO concentration. In addition, duplicate DO samples are taken at each site at least once during the monitoring year.

For DO, a percent saturation value is also calculated. This is a percentage of the DO measured in the water relative to the maximum DO water could theoretically hold at the testing water temperature (and elevation).

Velocity is measured by dividing the average of three times that it takes an orange peel to travel a known distance (often the width of a bridge). If times are disparate, another three readings are taken. Velocity measurements are multiplied by a correction factor of 0.85.

Depth is measured at a consistent location on the bridge with a weight attached to a decimal measuring tape. Cross-sections are taken at monitoring sites located at selected bridges twice each year (April and September). Monitors measure depth across the channel at one or two foot increments. On the cross section data sheet, volunteers indicate at what location they measure depth each month. A cross-section profile is plotted and an approximate flow value can be calculated by adding the product of average velocity by each cross-sectional area.

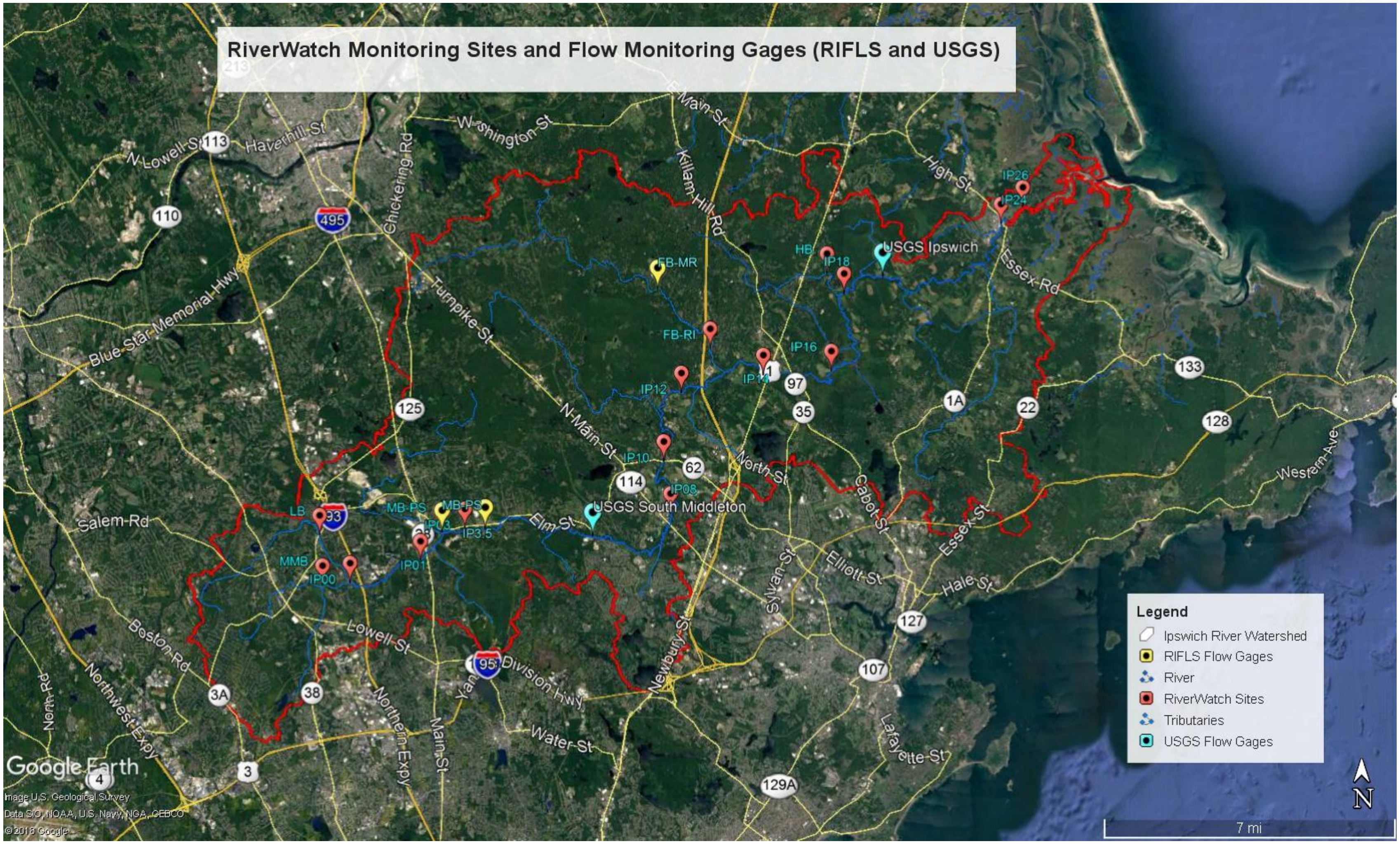
Conductivity is measured at selected sites as an indicator of human impact from sources such as stormwater runoff. Ions from sources such as road salts and leaking septic systems increase conductivity which can negatively impact aquatic life. All nine tributary sites are monitored for conductivity since these may be expected to vary more than along the mainstem of the river where five sites are monitored to detect variations. This is done using an Oakton Eco Testr EC Low or Oakton ECTestr Low conductivity meter. The meter is first rinsed with deionized or distilled water. The meter is calibrated using 447 µSiemens/cm conductivity standard solution. The meter is rinsed again and placed in the sampling bucket to record the conductivity value.

As stated previously, data collected will be reported to IRWA members, state agencies, interested organizations, and conservation commissions through reports and presentations on the collected data. Atypical data will be reported to the appropriate agencies. Atypical data include dissolved oxygen data that vary significantly from adjacent sites over one or more months. Extended periods of no flow or extremely low dissolved oxygen (less than 2 mg/L) are also considered extremely important and will be presented to state agencies. (When dissolved oxygen levels fall below 2 mg/L the health of fish and other aquatic organisms can be severely impacted.)

For data to be reported to state agencies, a Quality Assurance Project Plan (QUAPP) is maintained with MassDEP and most recently updated for the period 2016-2018. The QUAPP requires all new and returning monitors to receive annual training, and an annual site audit of each volunteer. Prior to monitoring, new monitors receive a walk-through of the monitoring manual and hands-on training at a monitoring site. All new and returning monitors must attend an annual training that consists of an overview of the program and procedures followed by a collection and analysis of temperature, dissolved oxygen and conductivity samples for comparison with readings obtained by the Monitoring Project Coordinator. Records of data generated during this training as well as attendance records are retained by IRWA.

During the year, each site is audited by the Monitoring Project Coordinator. This consists of the observation of the volunteer by the auditor. Any errors in procedure are recorded on the project audit sheet and problems discussed and resolved with the volunteers.

Figure 2. Monitoring sites for the RiverWatch Volunteer Water Quality Monitoring Program and Flow Monitoring Gages.



Site	Location	Town	Latitude	Longitude	Site Start Date	Dissolved Oxygen Start Date	Temperature Start Date	Conductivity Start Date	Depth Start Date	Velocity Start Date	Flow Gages (USGS, RIFLS)
MMB	Maple Meadow Brook, Wildwood Street	Wilmington	42.552842	-71.156567	Aug-97	Aug-97	Aug-97		Aug-97	Aug-97	
LB	Lubbers Brook, Glen Rd.	Wilmington	42.565944	-71.182792	Aug-97	Aug-97	Aug-97	Mar-08	Aug-97	Aug-97	
IP00	Woburn St.	Wilmington	42.553750	-71.110653	Jan-97	Jan-97	Jan-97	Mar-08	Jan-97	Jan-97	
IP00.5	Reading Town Forest	Reading	42.554464	-71.107633	Nov-97	Nov-97	Nov-97	Mar-13	Nov-97	Nov-97	
IP01	Mill St.	Reading	42.561361	-71.110653	Jan-97	Jan-97	Jan-97		Jan-97	Jan-97	
IP02	Route 28	Reading	42.564583	-71.107633	Jan-97	Jan-97	Jan-97		Jan-97	Jan-97	
MB-62	Martins Brook, Rt. 62	Wilmington	42.579774	-71.138944	Jan-11	Jan-11	Jan-11	Mar-11	Jan-11	Jan-11	Jun-12
MB-PS	Martin's Brook, Park Street and RIFLS Gage	North Reading	42.571475	-71.101233	Mar-99	Mar-99	Mar-99	Mar-11	Mar-99	Mar-99	
IP2.7	Parish Park	North Reading	42.571783	-71.094967	Jan-99						
IP3.5	Haverhill St. RIFLS Gage	North Reading	42.572425	-71.080336	Jun-12						Jun-12
IP03	Central St.	North Reading	42.570047	-71.029386	Jan-97	Jan-97	Jan-97		Jan-97	Jan-97	
IP04	Washington St. (Route 62)	North Reading	42.576553	-71.069583	Jan-97	Jan-97	Jan-97	Mar-08	Jan-97	Jan-97	
IP06	Boston St. and USGS South Middleton Gage	Middleton	42.570047	-71.029236	Jan-97	Jan-97	Jan-97		Jan-97	Jan-97	
IP08	Log Bridge Road	Middleton	42.577892	-70.996964	Mar-99	Mar-99	Mar-99		Mar-99	Mar-99	
IP10	Maple St. (Route 62)	Middleton	42.595131	-70.997014	Jan-97	Jan-97	Jan-97	Mar-12	Jan-97	Jan-97	
IP11	Peabody St.	Middleton	42.616442	-70.996964	Jan-97	Jan-97	Jan-97		Jan-97	Jan-97	
IP12	Thunder Bridge (East St.)	Middleton	42.619575	-70.988239	Jan-97	Jan-97	Jan-97		Jan-97	Jan-97	
FB-MI	Fish Brook, Middleton Rd.	Boxford	42.658294	-71.143658	Mar-99	Mar-99	Mar-99	Mar-08	Mar-99	Mar-99	
FB-MR	Fish Brook, Mill Rd. RIFLS Gage	Boxford	42.655261	-70.999325	Nov-14						Nov-14
FB-RI	Fish Brook, River Rd.	Topsfield	42.634808	-70.974772	Mar-17	Mar-17	Mar-17	Mar-17	Mar-17	Mar-17	
IP13	Rowley Bridge Road	Topsfield	42.627017	-70.966953	Jan-97	Jan-97	Jan-97		Jan-97	Jan-97	
IP14	Salem Road	Topsfield	42.625722	-70.949758	Jan-97	Jan-97	Jan-97	Mar-12	Jan-97	Jan-97	
IP16	IRWS - Boat Launch	Topsfield	42.627197	-70.917922	Jan-97	Jan-97	Jan-97	Mar-17	Jan-97	Jan-97	
HB	Howlett Brook, East St.	Topsfield	42.660726	70.919879	May-17	May-17	May-17	May-17	May-17	May-17	
IP18	Asbury Road	Topsfield	42.653761	-70.911933	Jan-97	Jan-97	Jan-97	Mar-17	Jan-97	Jan-97	
GB	Gravelly Brook, Willowdale State Forest	Ipswich	42.661817	-70.903883	Jun-11	Jun-11	Jun-11	Mar-12	Jun-11	Jun-11	
IP19A	100' Above Willowdale Dam	Ipswich	42.659917	-70.894683	Mar-10	Mar-10	Mar-10		Mar-10	Mar-10	
IP19	Below Willowdale Dam and USGS Ipswich Gage	Ipswich	42.659864	-70.894367	Jan-97	Jan-97	Jan-97		Jan-97	Jan-97	
IP20	Winthrop Street	Ipswich	42.658706	-70.890539	Jan-97	Jan-97	Jan-97		Jan-97	Jan-97	
IP22	Mill Road	Ipswich	42.658372	-70.861939	Jan-97	Jan-97	Jan-97		Jan-97	Jan-97	
IP24	Sylvania Dam	Ipswich	42.677539	-70.837686	Jan-97	Jan-97	Jan-97	Mar-17	Jan-97	Jan-97	
MR-1A	Miles River, Rt. 1A	Ipswich	42.657800	-70.843431	Mar-99	Mar-99	Mar-99	Mar-12	Mar-99	Mar-99	
ER-1A	Egypt River, Rt. 1A	Ipswich	42.698179	-70.869172	Mar-11	Mar-11	Mar-11	Mar-17	Mar-11	Mar-11	
IP25	Green Street	Ipswich	42.679883	-70.831222	Jan-97	Jan-97	Jan-97		Jan-97	Jan-97	
IP26	Town Landing	Ipswich	42.683522	-70.830467	Jan-97	Jan-97	Jan-97		Jan-97	Jan-97	

Streamflow Monitoring

Having adequate amounts of flowing water is essential for the health of rivers and streams. The Ipswich River has a history of flow alterations from water withdrawals, particularly in the headwaters region of the watershed, so measuring streamflow is important to understanding low-flow impacts.

Two real-time streamflow gages are maintained by USGS on the Ipswich River in South Middleton and Ipswich that transmit real-time discharge data. These gages have recorded flow levels since the 1930's, as both a historical record of the river and vital source of real-time information needed to manage municipal water supplies. However, many sections of the river and streams in the watershed are not gaged.

Beginning in 2012, additional streamflow gages were added in partnership with the Massachusetts Division of Ecological Restoration (MassDER) to further document streamflow patterns. MassDER supports the River Instream Flow Stewards (RIFLS) program, which enables local groups to monitor streamflow as a way to investigate signs of flow alteration, with the goal of restoring more natural flow patterns. Three RIFLS monitoring sites were established where additional flow data would be beneficial: Martins Brook at Park St. in North Reading (MB-PS), the Ipswich River at Haverhill St. in North Reading (IP3.5) (table 3) and at Fish Brook at Mill Rd. in Boxford in November 2014 (FB-MR). Volunteers read staff gages at these sites on a regular basis and enter data to the RIFLS website (www.rifls.com) where it is converted to a streamflow value in cubic feet per second (cfs) from rating curves maintained by the RIFLS staff with MassDER. Water level data loggers were generously donated by the Nor'East Chapter of Trout Unlimited and installed at all the 3 RIFLS site locations and activated beginning in June 2014. These loggers will collect time series data at 15 min. intervals that will allow for detailed analysis.

Analysis is conducted by downloading data from the RIFLS and USGS websites. Individual gage data are compared by converting mean daily streamflow values from cfs to cubic feet per second per square mile (cfsm). The drainage area values needed for this conversion are obtained from either the USGS or RIFLS websites for each gage. Daily discharge values in cfsm can be compared relative to an ecological protection flow value determined by USGS for the entire watershed.

Section 3: Monthly Water Quality Testing

3.1 Monthly RiverWatch Monitoring Results by Parameter

Temperature

In 2018, all samples met the Class B standard or Class SA standard for maximum water temperature. The Class B standard is a maximum of 28.5° Celsius (83°F); the Class SA standard is a maximum of 29.4° Celsius (85°F), and applies to the tidal sites of IP25 and IP26.

Temperature is an important measure of water quality, as temperatures higher than the natural observed range can reduce the amount of dissolved oxygen that the water can hold (more on dissolved oxygen in the next section). This can create a stressful environment for aquatic organisms. For example, some fish, like brook trout, cannot survive in warm water.

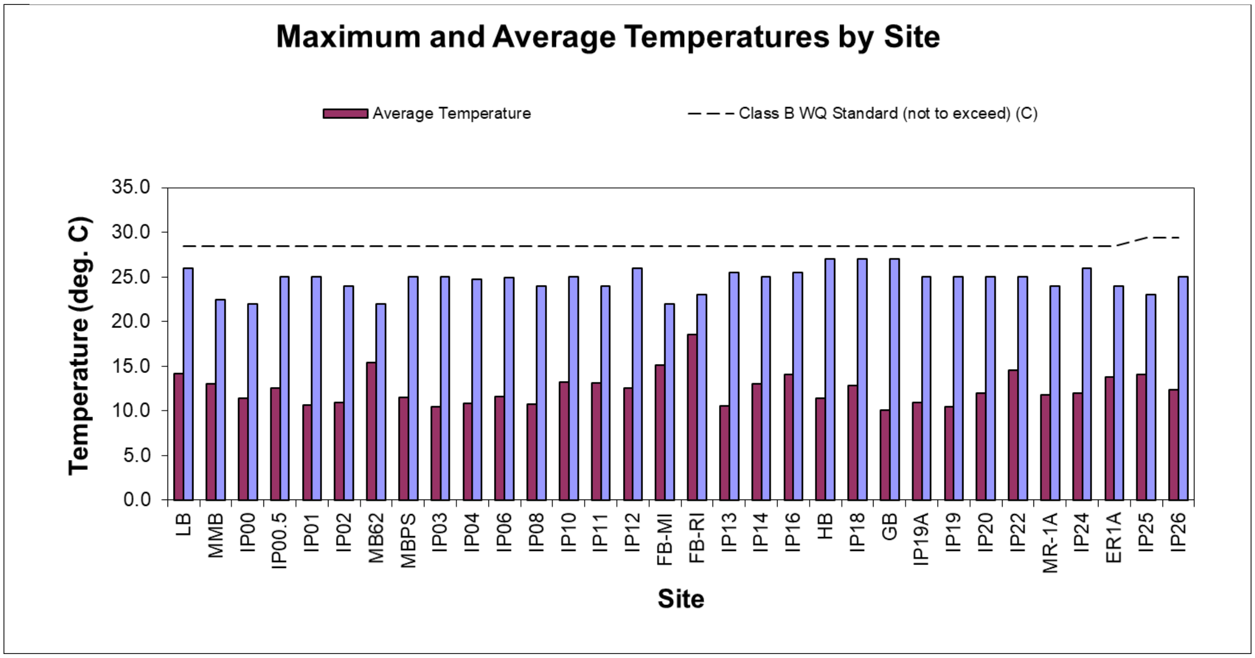
Annual Statistics

Table 4 is a summary of annual statistics for temperature. Temperature has exceeded the state standard only 5 times since 1997. This does not reflect the times the river has dried up and monitoring could not take place. Figure 4 is a comparison of average annual and maximum water temperature for 2018.

Table 4: Annual temperature statistics for all sites.

Year	# Samples (March-December)	Minimum (°C)	Maximum (°C)	Annual Average (°C) (March-December)	Summer Average (°C) (June-August)	# Samples Outside Class B, Class SA Standard	% Violations (% of samples not meeting standard)
1997	172	-4	31.0	11.6	21.0	2	1.2%
1998	227	1	26.0	14.5	21.2	0	0.0%
1999	257	0	28.0	13.7	22.9	0	0.0%
2000	247	0	25.0	13.1	20.5	0	0.0%
2001	236	-3	25.3	12.1	20.4	0	0.0%
2002	241	0	25.5	11.7	20.2	0	0.0%
2003	226	0	29.0	12.8	21.6	1	0.4%
2004	234	-2	25.0	12.2	20.2	0	0.0%
2005	237	-2.5	34.0	12.1	22.0	2	0.8%
2006	212	0	28.0	13.1	21.3	0	0.0%
2007	213	0	26.0	13.8	21.7	0	0.0%
2008	209	-1	29.0	13.1	21.2	1	0.5%
2009	202	0	24.0	14.2	19.2	0	0.0%
2010	217	0	27.5	14.7	22.5	0	0.0%
2011	224	0.5	26.0	12.8	20.6	0	0.0%
2012	266	0	30.0	14.2	22.2	1	0.4%
2013	234	1	26.0	14.7	21.8	0	0.0%
2014	274	0.5	26.0	13.3	21.7	0	0.0%
2015	244	0	26.0	13.7	21.0	0	0.0%
2016	277	0	28.0	13.1	22.7	0	0.0%
2017	279	0	25.2	14.5	20.6	0	0.0%
2018	289	0	27.0	13.1	21.4	0	0.0%
Entire Record	5217	-0.4	27.2	13.3	21.3	7.0	0.2%

Figure 5: Maximum and Average Water Temperatures, by Site, 2018. The dashed line indicates the maximum temperature for class B (28.5°C) and Class SA waters (29.4°C).



General Findings

Water temperature readings met state standards throughout 2018 across the watershed (i.e., temperatures remained below the state standard maximum temperature). It is important to note that recorded temperatures are conservative, as temperatures are not recorded when there is no water present in the river during extreme low flows. Also, monitoring is conducted in the morning, and may not represent the highest temperatures that occur in the course of that day or month.

Dissolved Oxygen

The amount of dissolved oxygen (DO) in water depends on numerous factors, including the temperature of the water and the gas exchange across the air-water interface. DO can increase when water is at lower temperatures and in areas where there is turbulence in the water (e.g., riffles or rapids). Other primary factors affecting DO include oxygen production through photosynthesis and depletion through respiration and other oxygen-demanding processes. DO changes on a diurnal basis as well as seasonally, and is affected by cloud cover and other weather conditions. The most critical time for organisms is in the early morning hours on hot summer days when water temperatures are high, flows are low and photosynthesis has ceased producing oxygen since sunset. The interactions of factors affecting DO in the natural environment are quite complex, and a full exploration of this topic is beyond the scope of this report, but warrants further investigation.

Sampling was conducted during morning hours because DO is typically lowest at or just after dawn, so morning sampling is likely to capture relatively low DO. Therefore the values observed generally represent a more stressed condition than if the values were mid-day or later.

For dissolved oxygen concentration, the Class B standard requires a minimum of 5.0 mg/L; the Class SA standard is a minimum of 6.0 mg/L DO, and applies to the tidal sites of IP25 and IP26. For dissolved oxygen percent of saturation, 60% is considered the minimum for good water quality in class B waters and 75% in class SA waters. The state of Massachusetts no longer uses the standard for percent of saturation; however, we continue to refer to this figure.

Table 5 presents annual statistics for DO concentration and percent saturation for all sites monitored. The number of samples for percent saturation can differ from concentration if either a concentration or water temperature value is missing since it is calculated from both.

Annual Statistics

Table 5: Annual statistics for dissolved oxygen concentration (A) and percent of saturation (B) for all sites.
Note: In 2008, the State eliminated standards pertaining to DO% saturation. Numbers are presented for comparison with previous years and are based on the previous standard of 60% saturation for class B and 75% saturation for class SA sites.

Table 5 A. Dissolved Oxygen Concentration (mg/L)

Year	# Samples (March-December)	Minimum (mg/L)	Maximum (mg/L)	Annual Average (mg/L) (March-December)	Summer Average (mg/L) (June-August)	# Samples Outside Class B, Class SA Standard	% Violations (% of samples not meeting standard). Average for entire record
1997	100	1.0	14.4	7.6	6.1	30	30%
1998	230	0.0	12.2	6.3	4.1	78	34%
1999	262	0.4	14.8	7.3	5.0	65	25%
2000	264	1.0	14.0	7.1	5.2	56	21%
2001	240	0.2	14.0	6.9	4.6	73	30%
2002	239	0.2	12.4	7.1	5.3	57	24%
2003	225	0.1	12.4	6.5	3.9	75	33%
2004	240	0.0	12.4	6.6	4.3	61	25%
2005	240	0.6	13.2	6.8	4.5	62	26%
2006	213	0.2	13.0	6.4	4.1	74	35%
2007	216	0.6	16.2	6.3	4.9	68	31%
2008	207	0.6	13.0	6.6	4.0	71	34%
2009	203	0.8	12.7	6.1	4.5	72	35%
2010	219	0.0	12.6	6.3	4.5	69	32%
2011	205	0.6	12.6	7.2	4.6	56	27%
2012	270	0.5	14.0	6.2	4.1	86	32%
2013	239	0.1	13.4	6.2	4.0	82	34%
2014	277	0.4	12.6	6.4	4.4	93	34%
2015	244	0.0	14.0	6.3	4.4	73	30%
2016	275	0.0	15.4	6.5	4.0	81	29%
2017	279	0.0	13.0	5.6	3.9	129	46%
2018	290	0.2	13.4	6.4	4.1	100	34%
Entire Record	5177	0.3	13.4	6.6	4.5	1611.0	31.1%

Table 5 B. Dissolved Oxygen Percent of Saturation

Year	# Samples (March-December)	Minimum	Maximum	Annual Average (March-December)	Summer Average (June-August)	# Samples Outside Class B, Class SA Standard	% Violations (% of samples not meeting standard)*
1997	89	7.8	122.6	66.0	67.6	27	30%
1998	224	0.0	101.2	59.2	45.7	109	49%
1999	249	4.4	101.7	67.7	58.1	84	34%
2000	239	11.7	112.9	64.1	56.7	98	41%
2001	214	2.2	105.5	61.1	51.8	103	48%
2002	231	2.1	119.7	63.8	58.6	96	42%
2003	217	0.7	99.2	58.9	43.7	105	48%
2004	229	0.0	97.4	59.1	47.4	108	47%
2005	227	6.7	115.9	59.9	50.9	109	48%
2006	209	2.4	117.9	58.2	45.4	107	51%
2007	207	6.2	123.6	59.0	54.6	112	54%
2008	197	6.5	104.0	58.7	45.1	96	49%
2009	199	9.1	112.5	58.1	48.3	104	52%
2010	216	0.0	94.6	59.0	51.8	103	48%
2011	203	6.9	115.5	64.9	51.3	84	41%
2012	262	5.7	98.5	57.7	46.1	144	55%
2013	234	1.2	110.0	58.5	45.7	116	50%
2014	274	0.0	100.4	57.9	49.9	144	53%
2015	240	0.0	105.5	57.4	49.6	111	46%
2016	252	0.0	106.9	55.9	45.4	136	54%
2017	277	0.0	114.4	52.1	42.6	170	61%
2018	284	2.3	107.8	57.0	45.5	154	54%
Entire Record	4973	3.4	108.5	59.7	50.1	2420	48%

In 2018, 34% of all samples taken by volunteers did not meet the combined state standards of 5 mg/L for class B and 6mg/L for class SA waters (100 of 290 samples). When calculating percent saturation of dissolved oxygen, 54% of these same samples fell below the combined standards of 60% saturation for class B and 75% saturation for class SA waters.

Site Statistics

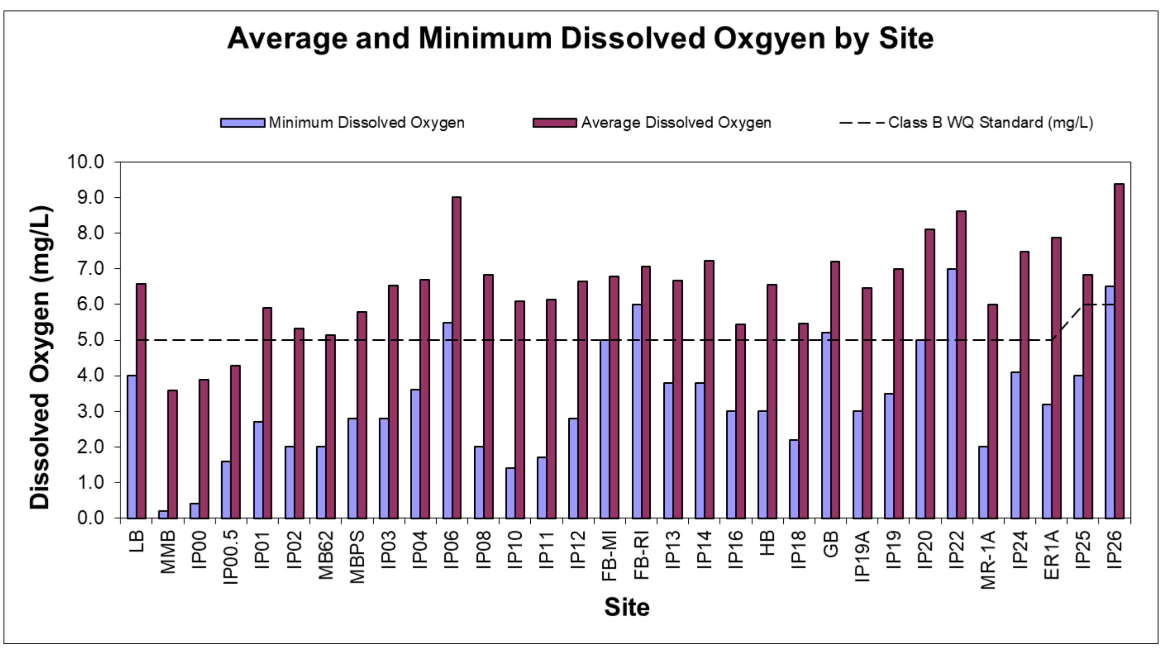
Low DO conditions have been widespread and frequent during the past 20 years of monitoring. In 2018:

- Summer averages (June, July, August) for 23 sites (out of 32) were less than 5.0 mg/L DO concentration. Eight sites had summer DO averages below 3.0 mg/L.
- Annual averages for 3 (out of 32) sites were less than 5.0 mg/L DO concentration.
- Twenty six sites out of 32 had a minimum DO concentration below 5.0 mg/L DO.
- 34% of the 279 samples for dissolved oxygen were below the standard for concentration (5 mg/L).

Figure 6 shows average and minimum dissolved oxygen concentration values for all sites in 2018.

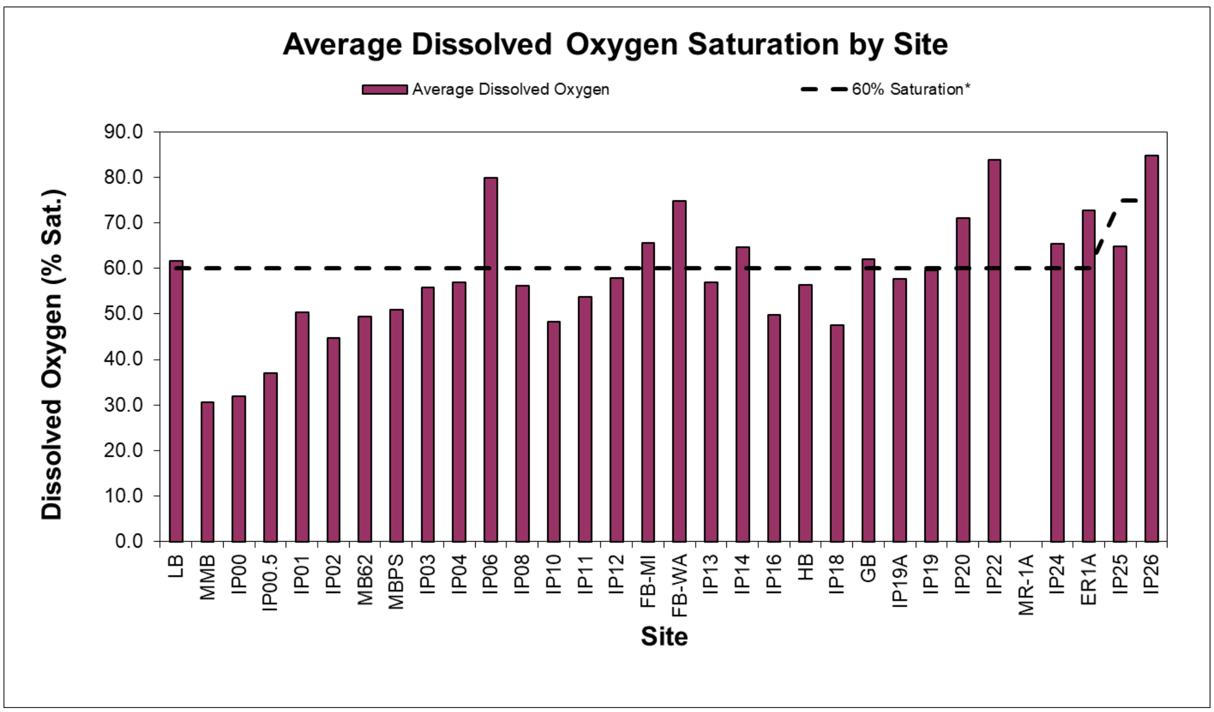
The fact that DO levels were very low consistently over the past decade represents a significant impaired condition on the river, and indicates that many aquatic organisms are under high stress conditions. Many organisms may not likely survive during most summers.

Figure 6. Average annual and minimum dissolved oxygen concentration (mg/L) for all sites monitored in 2018. The dashed line indicates the minimum standard for class B (5.0 mg/L) and class SA waters (6.0 mg/L)



Dissolved oxygen, percent of saturation is defined as the amount of oxygen that can be absorbed by water at a given temperature. Colder water can absorb more oxygen than warmer water. The Commonwealth of Massachusetts discontinued use of a water quality standard for dissolved oxygen, percent of saturation in 2008, but the data are presented here for comparison with dissolved oxygen concentration (mg/L) measurements and for comparison with previous years. The previously used standard of 60% (class B) and 75% (class SA) saturation can be used to confirm water oxygen depletion, particularly in the upper watershed. Most sites in the upper watershed did not achieve 60% saturation over the course of the year and especially in summer months when water temperatures are highest. Site statistics for dissolved oxygen, percent saturation are presented in table 4 and figure 7.

Figure 7: Average Dissolved Oxygen Percent Saturation Statistics for 2018.* The dashed line represents the minimum standard for class B waters (60%) and class SA waters (75%).



**In 2008, the state discontinued use of the 60% saturation standard for dissolved oxygen percent saturation. Values are presented here for comparison with previous years.*

General Findings

Dissolved oxygen (DO) is usually lowest at or shortly after dawn, and then increases during daylight hours. Sampling was conducted during morning hours, likely capturing lower DO than what occurs in the afternoon, and therefore the values observed represent the lower end of the daily DO fluctuation.

Frequent and prolonged low DO conditions represent a serious threat to aquatic organisms that are dependent on the river for survival. State standards represent a minimum condition that is protective of the health of aquatic organisms and the Ipswich River repeatedly and for extended periods of time does not meet those minimum standards. Fish kills were observed in 1995, 1997, 1999, 2002, and 2005. Under natural conditions, DO varies considerably daily and seasonally, as well as in response to weather conditions and numerous other factors, so conclusively stating the causes of the extremely low DO documented on the Ipswich River is beyond the scope of this report. It might be expected that DO levels in the Ipswich River tend towards the lower end of that 5-10 mg/L healthy DO concentration range because of the relatively low gradient of the river and the presence of numerous wetlands and forest that contribute organic matter (like leaves) to the water. For example, sites IP08 and IP18 are both located downstream of wetlands. Both sites exhibit average summer DO levels lower than other surrounding sites (figures 6 and 7). However, the Ipswich River experiences DO levels that fall consistently lower than this natural range, and consistently lower than state standards for a healthy river.

A statistical investigation into the causes of low DO was conducted by IRWA in 2002, and indicated that variables most linked with DO levels are water temperature, river kilometer (how far upstream the site is), depth, and the previous 28-day rainfall amount (IRWA, 2002). While this study provides insight towards better understanding of variation in DO in the Ipswich River, there remain a number of unanswered questions warranting further study. For example: what is the role of these variables and their interactions on DO levels; what are the causes of the observed changes in these variables; what is the extent and health of wetlands adjacent to the river; and, how can management actions and behavioral changes alleviate low DO levels in the river?

Depth, Velocity and Streamflow

There must be enough flowing water in the river for fish and aquatic organisms to thrive. Low flows reduce the amount of habitat available and contribute to rising water temperatures and decreased oxygen levels. Depth, velocity and streamflow are measured Depth and velocity are measured as rough indicators of channel coverage and flow at individual sites. Because depth is measured from the middle of the channel at most sites, generally it is an optimistic indicator of depth across the channel, since drying will typically occur first at the channel margins. There are, however, occasions when flow is too high to accurately measure depth (or velocity), such as during flooding events. Conversely, velocity is a conservative indicator, since volunteers insert the floatable object only where there is noticeable current. Immeasurable velocities cannot be quantified. A summary of annual velocity and depth data is shown in table 6.

Water velocity is measured as an indicator of the amount of flow in the river. Monitors record the time it takes a floating object such as an orange peel to travel a known distance, usually the width of the bridge spanning the river or between two points along the bank. Only sites with a bridge or where it is convenient to do so will measure velocity. Water velocity is typically lowest in the headwaters of watershed where there is a low gradient to the river, tributaries and surrounding wetlands (figure 9). Site IP01 is located at a bridge where the channel width narrows, increasing water velocity during spring runoff events beyond what would be expected naturally. Water depth varies by site, time of year and data completeness, but is typically greatest during the October-March period (figure 10). The deepest location measured is at the bridge on Washington St. in North Reading.

Flow is an obvious and important measure of river health. Observations of a dry riverbed or very low flow associated with very small amounts of water in the river are indicative of a serious impairment. Unfortunately, numerous episodes of little or no flow have been documented for the Ipswich River.

Streamflow gages maintained by USGS have recorded regular episodes of extended extreme low flow events. “Extreme low flow” is defined by the USGS as discharge levels below a minimum summer “ecological protection flow” (Horsley and Witten 2002). This “ecological protection flow” is the minimum flow threshold that “provides adequate habitat for the protection of fisheries” (Ibid). The summer ecological protection threshold for the Ipswich River is 0.42 cubic feet per second per square mile (cfsm).

Percent of summer days (June-August) were compared for all flow monitoring gages, including the RIFLS gages. Daily average flows recorded by data loggers at the RIFLS gages allowed these sites to be included in the low flow analysis (figure 14).

Table 6. Annual statistics for water velocity and depth data.

Water Quality Parameter	Year	Number of Samples	Minimum	Maximim	Annual Average (March-December)	Summer Average (June-August)
Velocity (ft./sec)	1997	158	0.0	10.2	1.1	0.8
	1998	198	0.0	6.0	0.1	0.0
	1999	253	0.0	7.3	1.1	0.3
	2000	232	0.0	6.1	1.6	1.2
	2001	190	0.0	16.0	1.4	1.3
	2002	181	0.1	54.5	1.8	1.5
	2003	183	0.0	5.1	1.6	1.3
	2004	210	0.0	25.3	1.7	2.1
	2005	209	0.0	23.9	1.0	0.3
	2006	185	0.1	9.8	1.7	1.5
	2007	150	0.1	8.3	1.5	0.8
	2008	172	0.0	16.6	1.6	2.0
	2009	162	0.0	21.7	1.6	1.6
	2010	133	0.1	35.1	1.5	0.6
	2011	173	0.0	5.9	1.7	1.2
	2012	174	0.1	4.4	1.0	0.8
	2013	140	0.0	5.0	1.1	1.2
	2014	159	0.1	7.2	1.6	1.0
	2015	115	0.0	14.1	1.0	0.7
	2016	113	0.1	5.1	0.9	0.5
	2017	170	0.1	5.0	1.1	0.9
	2018	167	0.0	5.3	1.6	0.9
	Entire Record	3827	0.0	13.5	1.3	1.0
Depth (ft.)	1997	141	0.0	10	3.1	2.6
	1998	212	0.0	9	2.8	2.9
	1999	248	0.0	8	2.3	1.6
	2000	241	0.0	11	2.9	2.4
	2001	219	0.0	22	2.6	2.1
	2002	223	0.0	9	2.7	1.8
	2003	198	0.0	9	3.1	2.5
	2004	209	0.5	10	3.3	3.1
	2005	200	0.0	9	3.0	2.2
	2006	192	0.4	11	3.6	3.1
	2007	189	0.1	11	3.3	2.5
	2008	192	0.4	10	3.4	3.4
	2009	177	0.5	11	3.3	3.5
	2010	186	0.1	9	2.8	2.1
	2011	204	0.2	9	3.4	2.7
	2012	237	0.2	6	2.4	2.1
	2013	190	0.0	19	3.0	2.7
	2014	211	0.1	15	3.1	2.1
	2015	187	0.1	8	2.6	2.4
	2016	198	0.0	7	2.6	2.0
	2017	224	0.1	15	3.0	2.7
	2018	210	0.4	11	3.6	2.7
	Entire Record	4488	0.1	10.8	3.0	2.5

Figure 7: Comparison of average annual, summer and winter water velocity by site.

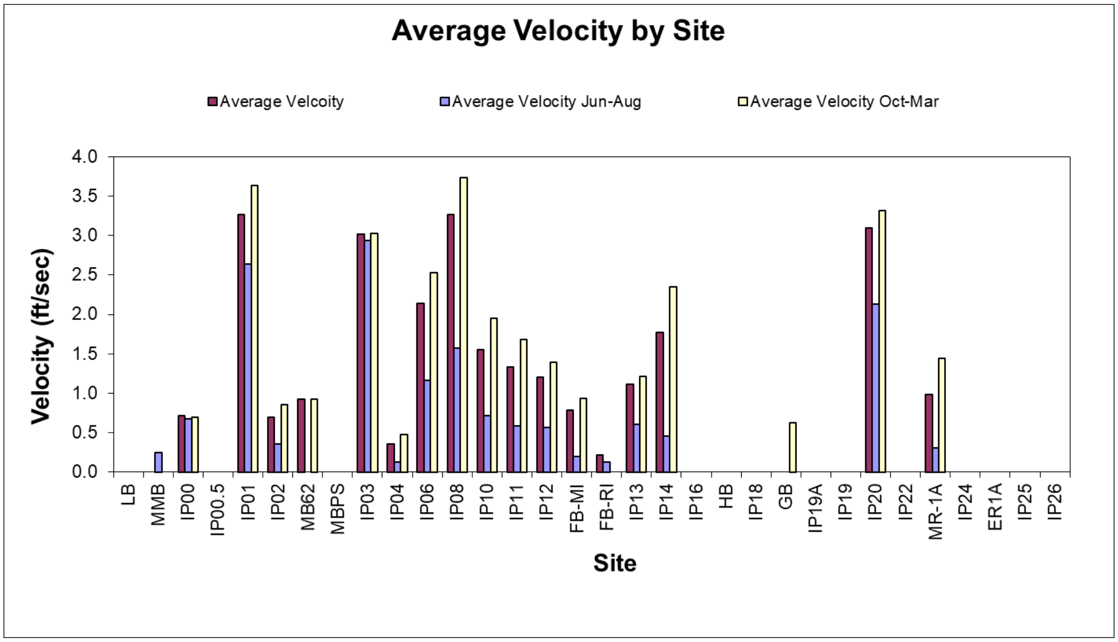


Figure 8: Comparison of average annual, spring and summer water depths by site.

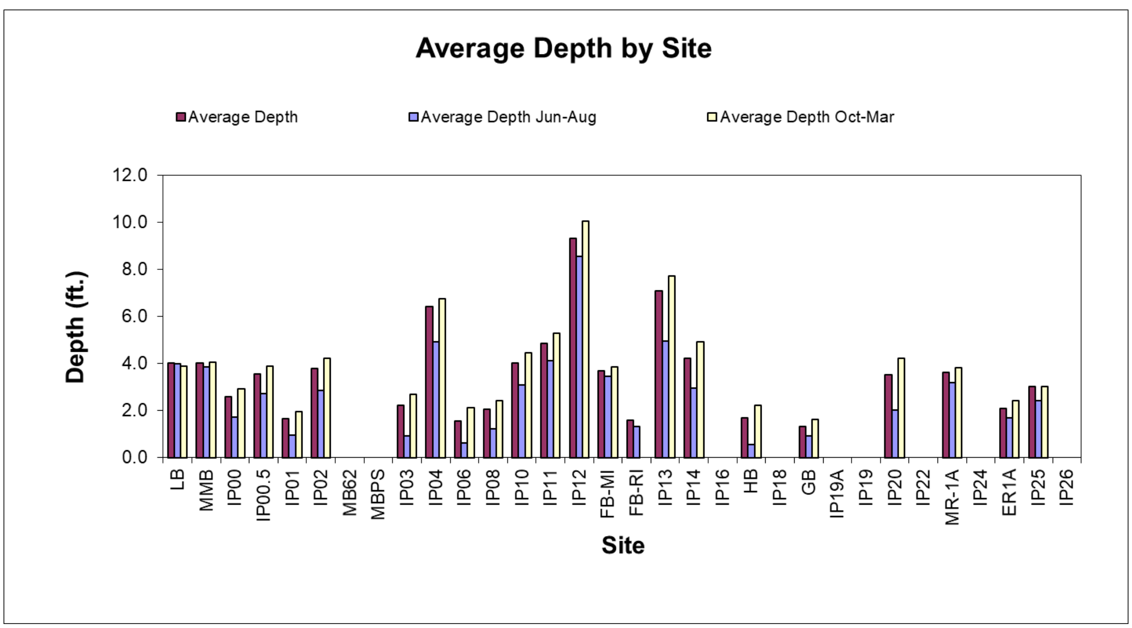
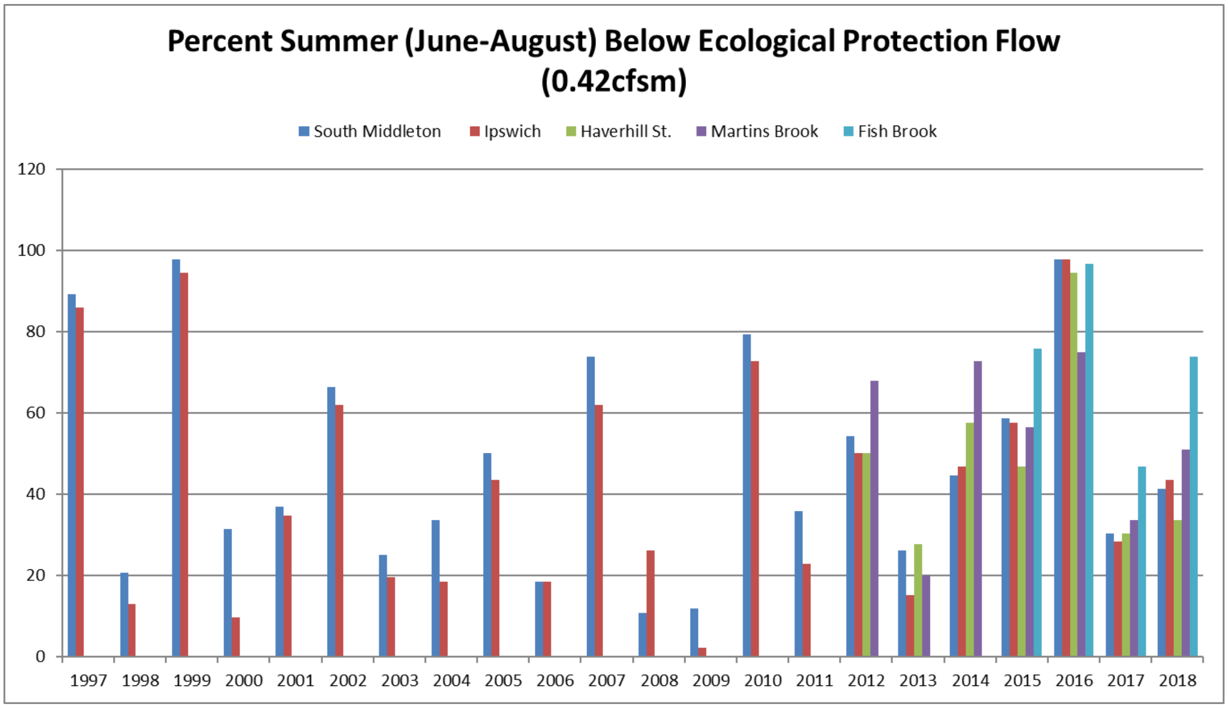


Figure 10. Percent of days during summer months (June-September) when flows fall below ecological streamflow threshold of 0.42 cfsm at flow monitoring sites that include USGS gages at South Middleton and Ipswich as well as RIFLS gages maintained by the Massachusetts Division of Ecological Restoration.



General Findings

Withdrawals for drinking water are the primary cause of unnaturally low flows in the Ipswich River (Armstrong 2001, Zarrielo and Ries 2000). While it might be expected that low flows occur seasonally, the low flows observed in the Ipswich River are about 10%of what might be considered "natural." Due to low flows, the Ipswich River is classified as highly stressed by the MA Water Resources Commission (2001) and impaired under section 303(d) of the Clean Water Act.

Flow monitoring data indicate that fluctuations and differences in flows are more pronounced below the established threshold of 0.42 cfsm. Further analysis is needed to determine the exact role that groundwater withdrawals and land cover may have in causing the observed changes. Having access to continuous data at the RIFLS gages will also be important to determine the statistical significance of the observed trends. Water level loggers will continue to be used at the RIFLS sites on Martins Brook, Ipswich River at Haverhill St. and Fish Brook.

Conductivity

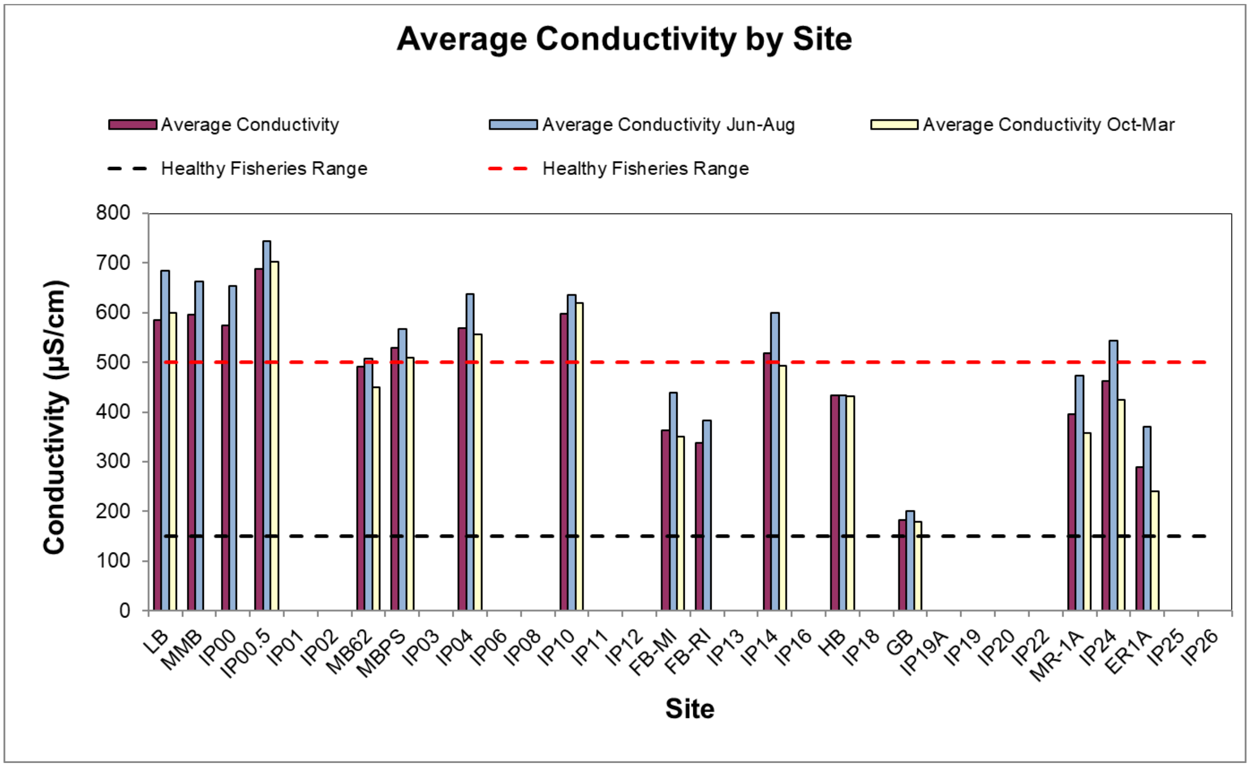
Conductivity measures the ability of water to pass an electrical current resulting from the presence of dissolved solids (or salts) such as chloride, sulfate, sodium and calcium, among others. Many factors can affect conductivity including local geology, rainfall, low flows and salt water concentrations in tidal areas. Most streams have a fairly constant range of conductivity under normal circumstances. Therefore, significant changes in conductivity can be an indicator that a discharge or some other source of pollution has entered the water. According to the EPA, the conductivity of rivers in the United States generally ranges from 50 to 1500 µS/cm (micro Siemens per centimeter). Rivers that can support healthy fisheries should be in the range of 150 to 500 µS/cm.

Conductivity was measured at 22 sites in 2018. Tributary sites may be expected to vary more than sites on the mainstem of the Ipswich River, so all 10 tributary sites were selected for this parameter, with 12 out of 23 sites selected to be representative of conditions on the mainstem of the Ipswich River. In 2018, 10 tributary and 12 mainstem sites reported data.

Table 7: Annual statistics for conductivity.

Year	# Samples (March-December)	Minimum (µS/cm)	Maximum (µS/cm)	Annual Average (March-December) (µS/cm)	Summer Average (June-August)	# Samples > 500µS/cm	% Samples Exceeding Water Quality Recommendations
2008	28	150	517	352	319	4	14.3%
2009							
2010							
2011	37	180	620	395	414	5	13.5%
2012	79	170	610	424	454	14	17.7%
2013	79	200	840	469	425	37	46.8%
2014	102	200	770	472	538	47	46.1%
2015	93	360	880	593	860	69	74.2%
2016	97	150	999	648	679	77	79.4%
2017	152	190	999	545	513	94	61.8%
2018	180	150	910	502	550	83	46.1%

Figure 15. Average conductivity by site for annual, summer and winter time periods. The conductivity range considered suitable for healthy fisheries is between 150-500 µS/cm (micro Siemens per centimeter).



General Findings

Conductivity readings are frequently elevated above the range of 150 and 500 µS/cm recommended for supporting healthy fisheries. Studies have demonstrated a high influx of road salt to wetlands and wellfields in the Ipswich River watershed that are adjacent to major highways that are the result of road applications in winter (Heath, et al., 2012). Elevated conductivity readings are observed in the headwaters region of the watershed where there are more impervious surfaces including major highways that are treated with road-salt. Tributary sites show more variability compared to sites on the mainstem of the Ipswich River most likely due to different land use patterns associated with tributary sub-watersheds. Conductivity levels decrease slightly among sites further downstream along the mainstem of the river. Some seasonal variability of conductivity is observed, but it is modest and there is no consistent pattern. Continuing to monitor conductivity will be important to establish baseline trends and resolve underlying regional or seasonal differences.

Color and Odor

The Ipswich River is a tea-like color naturally. This color is due primarily to dissolved organic carbon (e.g., tannins from leaves and plants). There is a lot of dissolved organic carbon in the Ipswich River due to the wetlands that drain into the river throughout the watershed.

Each month monitors noted the color and odor of the river on their data sheets in order to track changes or events where color changed significantly. Color was measured on a scale of clear, very light tea, light tea), tea, and dark tea. If a particular odor was noticed, this was noted on the data sheet. Most colors noted were in the very light tea to light tea range. The river tended to be a light tea throughout the year.

Darker colors (tea to dark tea) were typically recorded in the summer months (July – August or September) and so may be associated with lower flow periods. However, in general it seems that there is no clear relationship between darker color and higher flow periods. Some sites were darker when it rained, some sites were variable, and some were lighter. It does seem, however, that darker colors were prevalent during summer months, and particularly associated with lower flows.

Habitat Observations

Each month monitors recorded wildlife and habitat observations. Often, the level of observation depended on monitor knowledge of birds, macroinvertebrates, fish, and other wildlife. Lists of birds and other wildlife seen are below.

Birds
baltimore oriole
Bank swallow
Barn swallow
Black duck
blue jays
Broad winged hawk
Canada geese
cat bird
cedar waxwing
chickadee
chimney swift
common yellowthroat
Coopers hawk
cormorant
crows
downy woodpecker
Eastern wood pee-wee
flicker
goldfinch
grackles
great blue heron
great crested flycatcher
herring gull
kingbird

kingfisher
Little green heron
mallard
mockingbird
mourning doves
ovenbird
Palm warbler
phoebe
red-bellied woodpecker
red-tailed hawk
red-winged blackbird
robins
Rose breasted grossbeak
Rough winged swallow
ruby-throated hummingbird
Spotted sandpiper
song sparrow
swamp sparrow
Tree swallow
tufted titmouse
warbling vireo
willow flycatcher
wood ducks
Wood thrush
Yellow warbler

Reptiles and Amphibians
bullfrog
painted turtle
Mammals
Beaver activity evident
chipmunk
Opossum
Fish
minnows
Plants
asters
Button bush
cattails
Cardinal flower
Pickerelweed
purple loosestrife
Raspberries
Winterberry
Invertebrates
Caddisflies
bumblebee
dragonfly
Water bugs

Other Notable Observations

Site ID	Date(s)	Observation
MMB	7/29/18	River is brown but not as dark as IP00. In the bucket the color appears deep yellow with a vague metallic odor.
MMB	8/28/18	River looks good! Cardil flower still blooming, smartweed in flower, very little duckweed
IP00	6/24/18	River looks low and slow. Odor slightly metallic. Lots of birdsong!

3.2 Quality Assurance/Quality Control

Quality Assurance Project Plan (QAPP)

A formal Quality Assurance Project Plan (QAPP) for 2016-2018 was updated and approved in 2016 for the RiverWatch Program by the Department of Environmental Protection (DEP) and the Office of Coastal Zone Management (CZM). No significant changes were made to the QUAPP for the 2016-2018 monitoring years.

As part of the Quality Assurance Project Plan, temperature, dissolved oxygen and specific conductivity are evaluated for quality control purposes. Volunteers must attend an annual training and calibrate new chemicals for testing dissolved oxygen and conductivity meter. Also, monitors undergo an annual site audit by the Program Coordinator from IRWA where values for dissolved oxygen, temperature and specific conductivity obtained by the program manager are compared to the values obtained by the monitor. Monitors also perform a duplicate test for dissolved oxygen once each year. Dissolved oxygen and temperature values must be within +/- 1 mg/L or 1°C and < 20% relative percent difference (RPD) for DO and specific conductivity and 10% RPD for temperature. All conductivity meters are calibrated with a known standard of 450 µS/cm prior to each measurement, at the training and during field testing.

Table 7 shows results for dissolved oxygen, temperature and specific conductivity calibration values at the annual training with 22 out of 32 sites in attendance. The dissolved oxygen meter with temperature was calibrated at air saturation and used to generate the calibration standard values for dissolved oxygen and temperature whereas the volunteers use Winkler Titration kits and field thermometers. Chemicals for dissolved oxygen kits are replaced annually and thermometers are replaced on an as-needed basis. Volunteers tested a sample of river water from a source bucket with one designated for dissolved oxygen and another for temperature and conductivity. The titration procedure was reviewed where there was an inconsistency. All but 5 temperature readings were within quality control standards. Thermometers for these 5 sites were checked and replaced.

Comparison of program manager site audit DO, temperature and conductivity readings are presented in table 8. This type of field duplicate is performed by first calibrating the dissolved oxygen meter at air saturation and taking a reading from either the bucket grab sample or stream depending on where the volunteer fills the sample bottle for the Winkler Titration procedure. For 2018, 26 out of 32 sites were audited. 83% of field duplicates for temperature and 91% of field duplicates for dissolved oxygen met quality control standards. Where exceedances were observed, recommendations were made, in particular, making sure to eliminate air bubbles in the titrator syringe or to avoid air bubbles when filling the sample bottle. Volunteers perform one field duplicate per year on their own in July and these results are presented in table 9. All of the field duplicates met quality standards, indicating that volunteer data are within quality assurance limits.

Table 7. Volunteer training dissolved oxygen, temperature and specific conductivity calibration comparisons.

		RiverWatch Training Calibrations											
		Temperature				Dissolved Oxygen				Conductivity			
Site	**Date**	Monitor Calibration Temp. (°C)	Program Calibration Temp. (°C)	Difference Monitor, Calibration Temp. (°C)	Relative Percent Difference	Monitor Calibration DO (mg/L)	Program Calibration DO (mg/L)	Difference Monitor, Calibration DO (mg/L)	Relative Percent Difference	Monitor Calibration Conductivity (µS/cm)	Program Calibration Conductivity (µS/cm)	Difference Monitor, Auditor Conductivity (µS/cm)	Relative Percent Difference
LB	3/10/2018	10	10.5	0.5	5	11.4	11.3	0.1	1	590	590	0	0
MMB	3/10/2018	10	10.5	0.5	5	10.6	11.3	0.7	6				
IP00	3/10/2018	10	10.5	0.5	5	10.6	11.3	0.7	6	530	590	60	11
IP00.5	3/10/2018	10	10.5	0.5	5	9.6	11.3	1.7	16	590	590	0	0
IP01	3/10/2018	10	10.5	0.5	5	10.9	11.3	0.4	4	580	590	10	2
IP02	3/10/2018	9	10.5	1.5	15	10.3	11.3	1	9				
MB62	3/20/2019					13.2	13.6	0.4	3				
MBPS	3/10/2018	10	10.5	0.5	5	11	11.3	0.3	3				
IP03	3/10/2018	10	10.5	0.5	5	11	11.3	0.3	3	550	590	40	7
IP04	3/10/2018	10.1	10.5	0.4	4	10.4	11.3	0.9	8	551	590	39	7
IP06	3/10/2018	11.5	10.5	1	9	10.8	11.3	0.5	5	590	590	0	0
IP08	3/10/2018												
IP10	3/10/2018	10	10.5	0.5	5	10.4	11.3	0.9	8	560	590	30	5
IP11	3/22/2018	16	16.5	0.5	3	5.6	6.4	0.8	13				
IP12	3/10/2018												
FB-MI	3/10/2018	12	10.5	1.5	13	10	11.3	1.3	12	560	590	30	5
FB-RI	3/10/2018												
IP13	3/10/2018	9	10.5	1.5	15	10.9	11.3	0.4	4				
IP14	3/10/2018	14.5	14.5	0	0	6.7	6.7	0	0				
IP16	3/10/2018	10	10.5	0.5	5	11	11.3	0.3	3	590	590	0	0
HB	3/10/2018	13	10.5	2.5	21	11.2	11.3	0.1	1	550	590	40	7
IP18	3/10/2018	10	10.5	0.5	5	10.3	11.3	1	9	570	590	20	3
GB	3/10/2018												
IP19A	3/10/2018	9	10.5	1.5	15	10	11.3	1.3	12				
IP19	3/10/2018	9	10.5	1.5	15	10	11.3	1.3	12				
IP20	3/10/2018												
IP22	3/10/2018												
MR-1A	3/10/2018	11	10.5	0.5	5	11.2	11.3	0.1	1	550	590	40	7
IP24	3/10/2018												
ER1A	3/10/2018	10	10.5	0.5	5	12.2	11.3	0.9	8	560	590	30	5
IP25	3/10/2018												
IP26	3/10/2018	10	10.5	0.5	5	11.4	11.3	0.1	1				

Table 8. Program manager site audit comparisons for dissolved oxygen and temperature readings.

RiverWatch Site Audits													
		Temperature				Dissolved Oxygen				Specific Conductivity			
Site	Date	Monitor	Audit	Difference Monitor, Auditor Temp. (°C)	Relative Percent Difference	Monitor	Audit	Difference Monitor, Auditor DO (mg/L)	Relative Percent Difference	Monitor Audited Conductivity (µS/cm)	Program Auditor Conductivity (µS/cm)	Difference Monitor, Auditor Conductivity (µS/cm)	Relative Percent Difference
LB	6/24/2018	19	18	1	5	4.6	4.0	0.6	14	760	770	10	1
MMB	5/20/2018	16.5	17.5	1	6	3	2.0	1	40	650	670	20	3
IP00													
IP00.5	12/16/2018	0.5	0.5	0	0	5.8	6.2	0.4	7				
IP01	12/16/2018	0.5	1.2	0.7	82	9	9.1	0.1	1				
IP02	9/30/2018	14	14.3	0.3	2	3.5	3.3	0.2	6				
MB62	6/24/2018	18	19	1	5	4.6	3.8	0.8	19				
MBPS	5/20/2018												
IP03													
IP04	11/18/2018	10	11	1	10	1.9	2.8	0.9	38	390	370	20	5
IP06	8/26/2018	20.5	20.9	0.4	2	2.3	2.0	0.3	14				
IP08	8/26/2018	20	20	0	0	2	2.3	0.3	14				
IP10	5/20/2018	18	18	0	0	3.6	4.7	1.1	27	610	600	10	2
IP11	8/26/2018	21	20	1	5	1.7	1.7	0	0				
IP12													
FB-MI	11/18/2018	2	3.3	1.3	49	10	11.9	1.9	17	230	190	40	19
FB-RI	11/18/2018												
IP13	5/20/2018	17	17.6	0.6	3	5	6.1	1.1	20				
IP14	5/20/2018	17	17.3	0.3	2	6.6	6.3	0.3	5	520	500	20	4
IP16	12/16/2018	4	2.4	1.6	50	8	11.0	3	32				
HB	10/28/2018	8	8.5	0.5	6	7.9	8.0	0.1	1				
IP18	11/18/2018	2.9	1.8	1.1	47	10	10.6	0.6	6				
GB	7/29/2018	23.6	22	1.6	7	6.4	5.2	1.2	21				
IP19A	10/28/2018	8	9	1	12	6.2	6.4	0.2	3				
IP19													
IP20	5/20/2018	17	17.1	0.1	1	5.9	6.8	0.9	14				
IP22	10/28/2018	8	7.7	0.3	4	10	10.1	0.1	1				
MR-1A	4/29/2018	14	14.1	0.1	1	6	5.1	0.94	17	360	400	40	11
IP24	7/29/2018	26	26	0	0	5.3	4.1	1.2	26				
ER1A	7/29/2018	24.6	24	0.6	2	5.2	3.2	2	48				
IP25	12/16/2018	2	3.1	1.1	43	12	13.0	1	8				
IP26	12/16/2018	2	2.5	0.5	22	12	13.6	1.6	13				

Table 9. Monitor field duplicate dissolved oxygen measurements.

RiverWatch Site Duplicate DO				
Site	**July DO**	**July Duplicate DO**	**Difference**	Relative Percent Difference
LB	4	4.8	0.8	18
MMB				
IP00				
IP00.5	1.6	1.7	0.1	6
IP01	3.6	3.4	0.2	6
IP02	2	2.1	0.1	5
MB62	2.9	2.9	0	0
MBPS	3	2.8	0.2	7
IP03				
IP04	3.6	3.8	0.2	5
IP06	5.5	2.8	2.7	65
IP08	2.1	1.5	0.6	33
IP10	1.4	2.8	1.4	67
IP11	2.6	3	0.4	14
IP12				
FB-MI	5.2	5.2	0	0
FB-RI				
IP13	4	4.6	0.6	14
IP14	3.8	3.8	0	0
IP16				
HB				
IP18	2.2	2	0.2	10
GB				
IP19A	4.1	3.9	0.2	5
IP19	3.5	3.1	0.4	12
IP20	5	4.8	0.2	4
IP22				
MR-1A	2	1.25	0.75	46
IP24	4.1	4.1	0	0
ER1A	3.2	3	0.2	6
IP25				
IP26	6.5	6.6	0.1	2

Volunteer Qualifications

Volunteer quality assurance is maintained in the following ways:
Volunteers attend one training annually, led by the Monitoring Coordinator. The training includes a review of all procedures in the RiverWatch Monitoring Manual and a discussion of any changes. In addition, the previous year's data are presented, calibrations conducted, and QA/QC standards discussed.

Monitors are audited at their sampling site once per year.

Volunteers take duplicate samples at their site once per year, and equipment, data analysis and data control are held to QA/QC standards to the maximum extent possible.

Completeness

Table 10, below, summarizes the completeness of data collection for the 18-year period through 2015. Completeness is calculated as the number of samples taken in a year divided by the maximum number of samples it was possible to collect during that year. Our goal is to collect at least 80% of the total number of samples possible, and that goal was met for every year except 2003 and 2010. However, there is excellent completeness for all other years of monitoring, indicating the strength of volunteer commitment. In 2009, the bridge at site IP18 was out for construction, so monitoring was not possible at that site for six months.

Table 10: Percent of Samples Collected per year, 1997 - 2015.

Year	Completeness	Year	Completeness
1997	86%	2008	83%
1998	90%	2009	78%
1999	92%	2010	73%
2000	89%	2011	85%
2001	83%	2012	87%
2002	89%	2013	82%
2003	76%	2014	87%
2004	81%	2015	86%
2005	88%	2016	88%
2006	91%	2017	91%
2007	82%	2018	92%

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RiverWatch Data Appendices and Quality Assurance Project Plan (QAPP) available at: http://www.ipswichriver.org/our-work/library/research/