IPSWICH RIVER WATERSHED ASSOCIATION

Connecting Communities from Source to Sea

RiverWatch Water Quality Volunteer Monitoring Program

The Ipswich River Watershed serves as the voice of the Ipswich River. Through outreach, education, monitoring, and advocacy, we seek to connect the people, unities, and ecosystems integral to a healthy watershed.

2011 Annual Results Report

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December, 2012

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Executive Summary

In 1997 the Ipswich River was listed as one of the 20 most threatened rivers in America; and in 2003 its level of threat was heightened 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.

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. In 2011, monitors took measurements at 31 sites throughout the watershed: 9 sites are on major tributaries and 21 sites are on the mainstem of the Ipswich River.

Results:

The Ipswich River and many of its tributaries continue to show impairment for dissolved oxygen. 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.

Low DO conditions have been widespread and frequent during the past 15 years of monitoring. In 2011, 22% of samples did not meet the state standard for dissolved oxygen concentration of 5 mg/L. Figure 1 illustrates average summer dissolved oxygen concentration values at all sites. Sites located in the upper section of watershed continue to show a higher degree of impairment for dissolved oxygen than sites elsewhere.

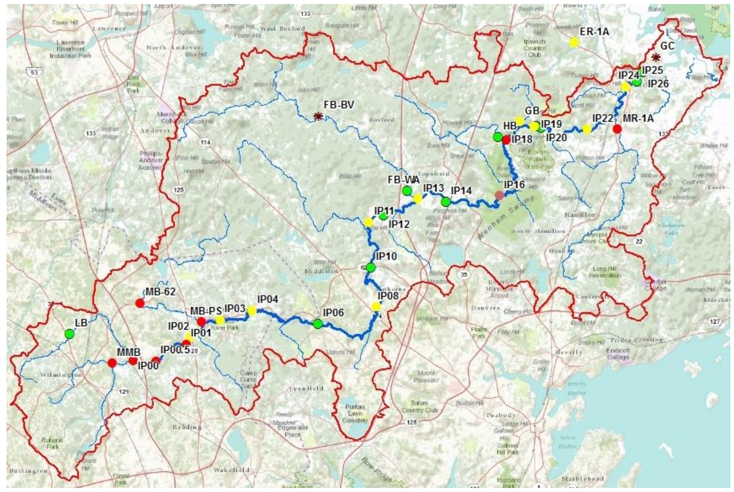


Figure 1. Average summer dissolved oxygen levels for 2011. Sites in red (< 3mg/L) represent a highly stressed environment for fish and other aquatic organisms.

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. 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 experienced significant periods of extreme low flow during the past 15 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). While it might be expected that low flows occur seasonally, the low flows observed in the Ipswich River are about 1/10th of what might be considered "natural." 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 gauges maintained by the United States Geological Survey (USGS) have recorded regular episodes of extended extreme low flow events over the past 15 years. "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).

Conclusion

The upper watershed continues to experience low dissolved oxygen levels despite higher precipitation in 2011 and the low flow conditions in 2008 and 2009 and 2010 not being as severe as in 2007. Water has remained in the river year-round since 2006 when Reading discontinued using wells adjacent to the Ipswich River. This shows that reductions in water withdrawals and water restrictions by towns can have a beneficial effect on the Ipswich River.

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!

View of the Ipswich River looking downstream from Boston St. in Middleton.

Section 1: An Introduction to the Ipswich River

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. 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: Beverly, Danvers, Hamilton, Ipswich, Lynn, Lynnfield, Middleton, North Reading, Peabody, Salem, Topsfield, Wenham, and Wilmington.

Under the Massachusetts Surface Water Quality Standards (MA DEP 1996), 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. 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 Dam 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 1 details the water quality standards associated with these classifications:

Table 1. Massachusetts Department of Environmental Protection water quality standards (2007).

	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 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.

1314 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.

2314 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.

In 1997 and again in 2003, American Rivers, a national nonprofit, recognized the Ipswich River as one of the most threatened or endangered rivers in America, primarily due to severe low flow problems (American Rivers 1997, 2003, IRWA 2003, Zarriello and Reis 2000). 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. Major fish kills were documented in 1995, 1997, 1999, 2002, and 2005.

In early 2000, the United States Geological Survey (USGS) completed development of a hydrologic model of the Ipswich River watershed that linked water withdrawals and low-flows in the River. The USGS found that groundwater withdrawals, especially in the upper reaches of the watershed, are the main factor responsible for reducing summer river flows (Zarriello and Reis 2000). Additionally, the diversion of wastewater to treatment plants outside the watershed also significantly reduces flow (Ibid). A recent USGS study shows that 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).

A companion study by USGS and the Massachusetts Division of Fisheries and Wildlife (MADFW) found that the Ipswich River's fisheries have been degraded by low-flow problems and the River has experienced a decrease in biodiversity due to the loss of river dependent fish species (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).

A recent USGS study shows that 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).

Under section 303d of the Clean Water Act, the Massachusetts Department of Environmental Protection (MA DEP, 2012) lists all sections of the Ipswich River as impaired. Sections include, the beginning of the river at the confluence of Maple Meadow Brook and Lubbers Brook at Woburn St. in Wilmington to the Salem Beverly waterway canal in Topsfield, the canal to the Ipswich Dam (formerly known as the Sylvania Dam) and from the dam to the mouth of the river at Ipswich Bay. Types of impairments include low dissolved oxygen, mercury in fish tissue, fish bioassessments and flow alterations.

Section 2: Goals and Description of the RiverWatch Monitoring Program

2.1 Goals

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 RiverWatch program, in operation since 1997, 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 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. An EPA-approved Quality Assurance Project Plan (QAPP) was finalized in 1999 and most recently updated in 2009.

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 over the range of annual conditions in both mainstem and tributary locations.
- Defining the range of water temperature over the range of annual conditions in both mainstem and tributary sites.
- Defining the range of conductivity of the over the range of annual conditions at selected 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.

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. In 2011, volunteers monitored 31 sites on the Ipswich River and its tributaries.

The purpose of this report is to summarize data collected in 2011 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.)

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!

2.2 Program Description and Monitoring Methods

As stated earlier, IRWA has conducted informal monitoring from 1988-1996. The RiverWatch program took its current form in 1997 and has been continuously monitoring the Ipswich River Watershed since this time. In order to best use our resources to gain an accurate picture of the Ipswich River, 9 tributary sites and 21 sites along the mainstem of the River from Wilmington to Ipswich, have been identified for monitoring once a month from March through December. Both Fish Brook at Brookview Farm Rd. (FB-BV) and Greenwood Creek (GC) were discontinued in 2001. In 2011 we added Gravelly Brook in the Willowdale State, Forest, Ipswich and Martins Brook on route 62, Wilmington as two additional tributary sites. We also added the Egypt River on Rt. 1A, a site located just outside the watershed in Ipswich. The Egypt River forms the confluence of Dow Brook and Bull Brook, which is an important sub-watershed for drinking water supply in the town of Ipswich. This was also once an important smelt run and probably river herring. A map of monitoring sites and a list of site descriptions and monitoring parameters are included in figure 2 and table 2.

Figure 2. RiverWatch Monitoring Sites

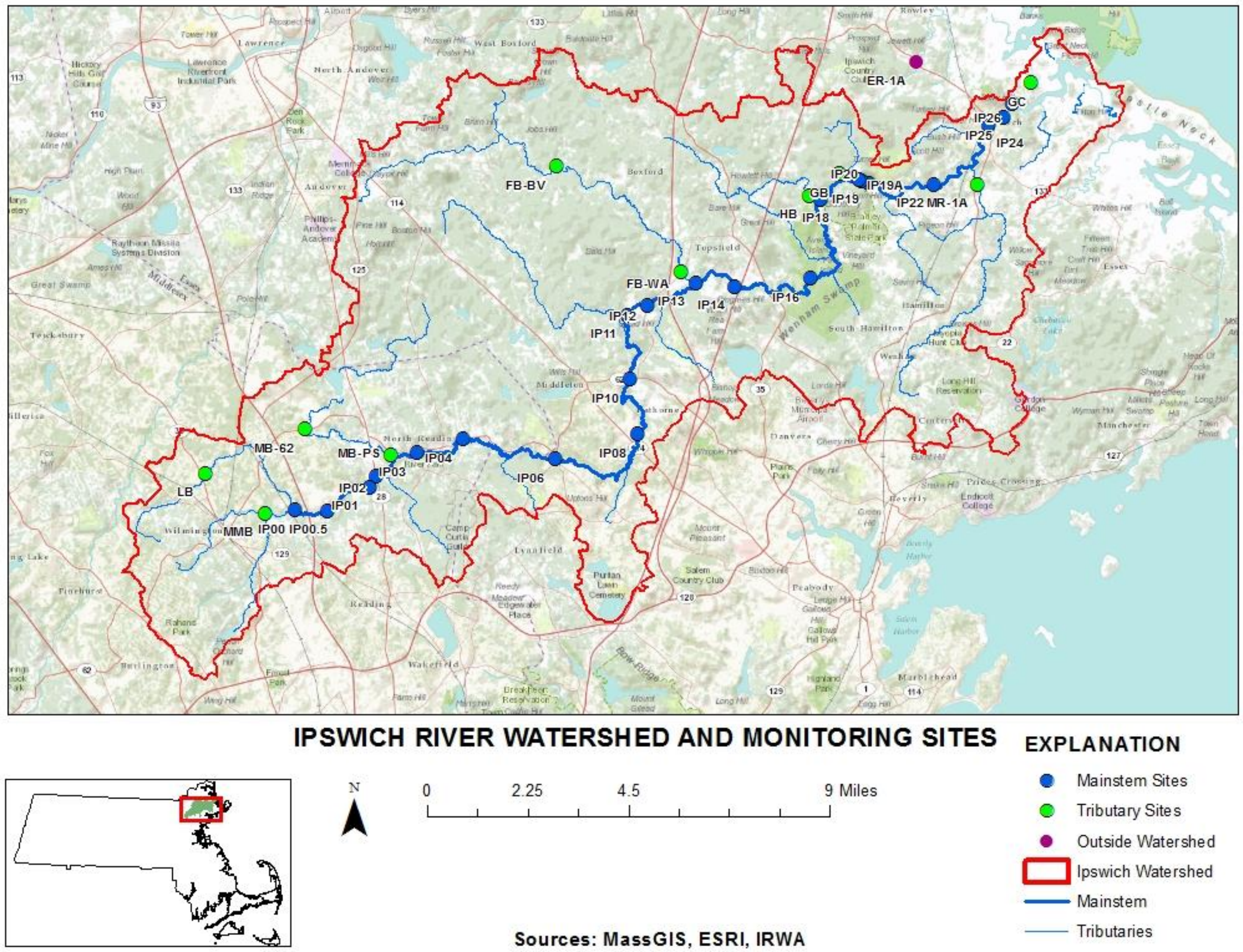


Table 2. RiverWatch monitoring sites.

Site	Location	Town	Dissolved Oxygen	Temperature	Depth	Velocity	Cross Section	Conductivity
MMB	Maple Meadow Brook at Wildwood Street	Wilmington	✓	✓	✓	✓		✓
LB	Lubbers Brook @ Glen Rd.	Wilmington	✓	✓	✓	✓	✓	
IP00	Woburn St.	Wilmington	✓	✓	✓	✓	✓	✓
IP00.5	Reading Town Forest	Reading	✓	✓	✓	✓		✓
IP01	Mill St.	Reading	✓	✓	✓	✓		
IP02	Route 28	Reading	✓	✓	✓	✓	✓	
MB-62	Martins Brook at Rt. 62	Wilmington	✓	✓	✓	✓		✓
MB-PS	Martin's Brook at Park Street	North Reading	✓	✓	✓	✓	✓	✓
IP03	Central St.	North Reading	✓	✓	✓	✓	✓	
IP04	Route 62	North Reading	✓	✓	✓	✓	✓	✓
IP06	South Middleton Gage	Middleton	✓	✓	✓	✓	✓	
IP08	Log Bridge Road	Middleton	✓	✓	✓	✓		
IP10	Route 62	Middleton	✓	✓	✓	✓	✓	
IP11	Peabody St.	Middleton	✓	✓	✓	✓	✓	
IP12	Thunder Bridge	Middleton	✓	✓	✓	✓	✓	
FB-BV*	Brookview Farm Rd.	Boxford						
FB-MI	Fish Brook at Middleton Rd.	Boxford	✓	✓	✓	✓	✓	
FB-WA	Fish Brook at Washington St.	Boxford	✓	✓	✓	✓	✓	✓
IP13	Rowley Bridge Road	Topsfield	✓	✓	✓	✓	✓	
IP14	Salem Road	Topsfield	✓	✓	✓	✓	✓	✓
IP16	IRWS - Boat Launch	Topsfield	✓	✓	✓			
HB .	Howlett Brook at Topsfield Rd	Ipswich	✓	✓	✓	✓		✓
IP18	Asbury Road	Topsfield	✓	✓				
GB	Gravelly Brook, Willowdale State Forest	Ipswich	✓	✓	✓	✓	✓	✓
IP19	Willowdale Dam	Ipswich	✓	✓	✓	✓		
IP20	Winthrop Street	Ipswich	✓	✓	✓	✓	✓	
IP22	Mill Road	Ipswich	✓	✓	✓	✓		
IP24	Sylvania Dam	Ipswich	✓	✓	✓	✓		
MR-1A	Miles River at 1A	Ipswich	✓	✓	✓	✓		
ER-1A	Egypt River at 1A	Ipswich	✓	✓	✓			
GC*	Greenwood Creek	Ipswich						
IP25	Green Street	Ipswich	✓	✓	✓	✓		
IP26	Town Landing	Ipswich	✓	✓				

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. If there is a conflict, 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 and odor are made. Color is recorded as a range of pre-determined colors from Clear to Dark Tea. The color and odor of the river are used only as indicators of other pollution issues if abnormalities are noticed.

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. Results from DO kits were compared 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 measure DO concentration. In addition, duplicate DO samples were 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).

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 bridges. Monitors take depths at two to five foot increments across the channel. Monitors try to take 20 measurements across the bed of the channel. On the cross section data sheet, volunteers indicate at what location they measure depth each month.

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.

Conductivity is measured at selected sites to determine the influence of runoff from stormwater. This is done using an Oakton ® ECTestr conductivity meter. The meter is first rinsed with deionized or distilled water. The meter is calibrated using 447 µSiemens/cm conductivity standard. The meter is rinsed and placed in the sampling bucket to record the conductivity of the water.

In 2011 Monitoring was cancelled on the August 28th and October 30th testing dates due to poor weather and road conditions. Summer averages reported here reflect June and July readings only.

Section 3: Results by Parameter

3.1 Temperature

In 2011, 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 3 is a comparison of average annual and maximum water temperature. The temperature limit is indicated by the dashed line. Figure 4 is a similar comparison of average annual and average summer water temperature. Summer averages include values recorded in June, July and August. Both graphs indicate all values were within the state standard.

Table 3: Annual temperature statistics for all sites.

Water Quality Parameter	Year	# Samples	Range	Average	Summer Average	Winter Average	#Samples Outside Class B/SA Standard
Water Temp (degrees C)	1997	201	-4 - 26	9.8	21.4	2.3	0
	1998	264	-1 - 32	12.7	21.4	6.6	1
	1999	315	-0.5 - 28	12.1	22.9	5.2	0
	2000	295	-5.6 - 25	11.3	20.4	4.2	0
	2001	265	-1 - 25.3	11.0	20.4	3.9	0
	2002	291	-2 - 25.5	10.0	20.2	3.7	0
	2003	237	0 - 29	12.3	21.5	5.7	1
	2004	247	-2 - 25	11.4	20.2	5.1	0
	2005	264	-2.5 - 34	11.0	21.3	2.9	2
	2006	268	-0.5 - 28	11.1	21.1	5.2	0
	2007	230	-1 - 26	12.8	21.7	5.8	0
	2008	225	-1 - 29	12.2	20.7	4.1	1
	2009	209	0-24	13.8	18.8	7.4	0
	2010	235	-1 - 27.5	13.7	22.1	5.5	0
	2011	228	0.1-26	12.6	20.0	12.6	0
	Entire Record	3774	-5.6 - 34	11.9	20.9	5.3	5

Figure 3: Maximum and Average Water Temperatures, by Site, 2011. The dashed line indicates the maximum temperature for class B (28.5°C) and Class SA waters (29.4°C).

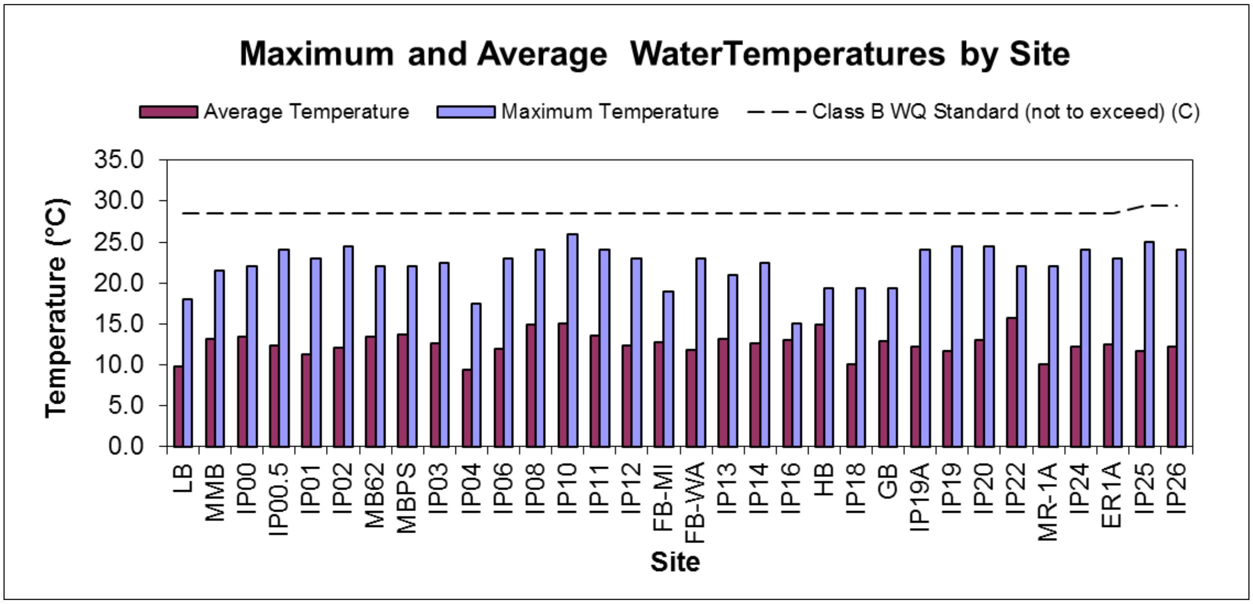
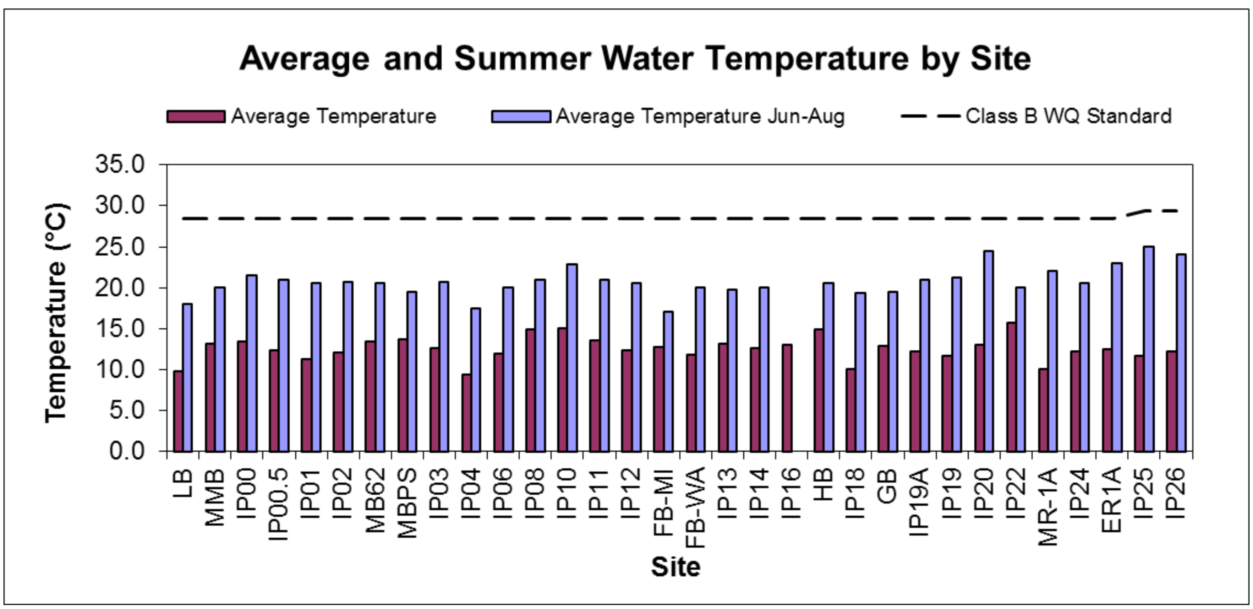


Figure 4. Comparison of average annual and summer water temperatures by site, 2011.



General Findings

Water temperature readings met state standards throughout 2011 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.

3.2 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, 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 monitor according to this figure.

Annual Statistics

Table 5 presents annual statistics for DO concentration and percent saturation for all sites monitored.

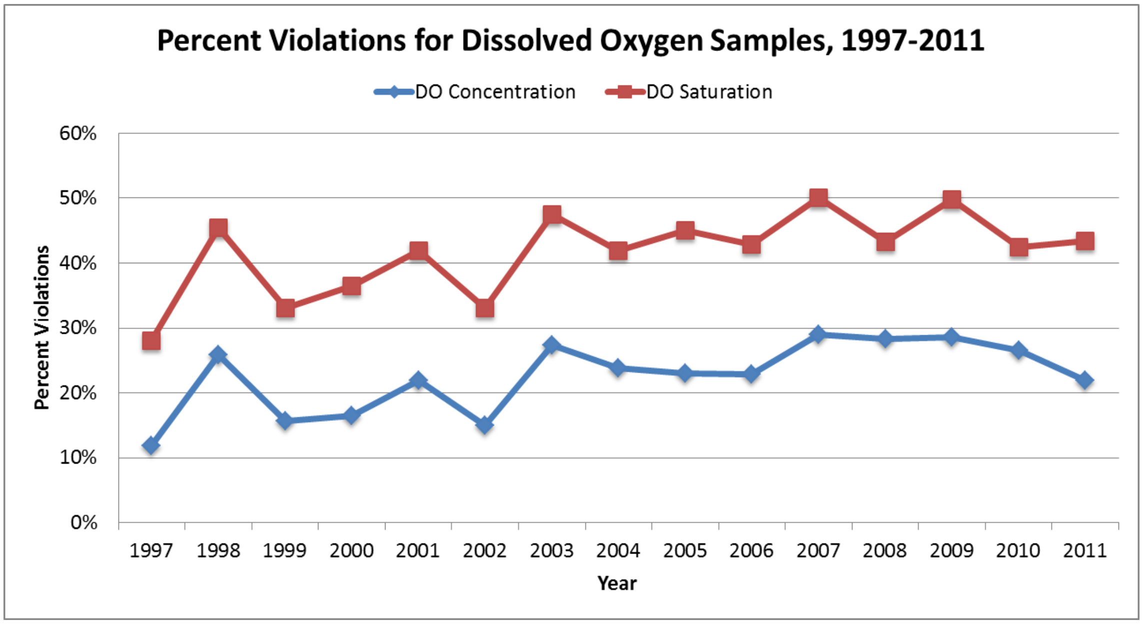
Table 5: Annual statistics for dissolved oxygen concentration and percent saturation for All Sites.

Water Quality Parameter	Year	# Samples	Range	Average	Summer Average	Winter Average	#Samples Outside Class B/SA Standard	% Violations (% of samples not meeting Standard)
Dissolved Oxygen	1997	110	1 - 14.4	7.9		9.1	13	12%
(mg/L)	1998	267	0 - 13	6.6	3.9	8.4	69	26%
	1999	318	0.4 - 14.8	7.5	5.0	9.1	50	16%
	2000	309	1 - 15.5	7.6	5.1	9.4	51	17%
	2001	278	0.2 - 16	7.3	4.6	9.1	61	22%
	2002	288	0.2 - 14.4	7.8	5.3	9.6	43	15%
	2003	234	0.1 - 12.4	6.5	3.8	8.2	64	27%
	2004	252	0 - 12.4	6.8	4.3	8.8	60	24%
	2005	270	0 - 13.2	6.9	4.4	8.8	62	23%
	2006	271	0.2 - 13.8	7.2	4.2	9.0	62	23%
	2007	231	0.6 - 16.2	6.4	4.9	7.8	67	29%
	2008	223	0.6 - 13.9	6.8	4.0	9.4	63	28%
	2009	210	0.8 - 12.7	6.2	4.4	8.0	60	29%
	2010	237	0-13.2	6.6	4.5	8.7	63	27%
	2011	210	0.6-12.6	7.2	5.0	7.2	46	22%
	Entire Record	3708	0 - 16.2	7.0	4.5	8.7	834	22%
DO % Saturation	1997	107	7.8 - 113.9	66.8		66.6	30	28%
(%)	1998	260	0 - 111.3	59.1	44.5	67.0	118	45%
	1999	308	4.4 - 101.7	67.3	57.9	71.5	102	33%
	2000	291	11.7 - 115.2	65.7	56.1	71.9	106	36%
	2001	258	2.1 - 116.3	62.6	51.7	67.8	108	42%
	2002	284	2.1 - 119.7	66.3	58.6	72.3	94	33%
	2003	232	0.7 - 99.2	58.4	43.1	65.5	110	47%
	2004	246	0-97.4	59.7	47.6	68.4	103	42%
	2005	264	6.7 - 115.9	59.7	50.2	65.3	119	45%
	2006	268	2.4 - 117.9	61.6	45.9	69.4	115	43%
	2007	224	6.2 - 123.6	58.7	54.6	60.5	112	50%
	2008	222	0 - 113.2	59.8	44.9	70.2	96*	43%
	2009	207	0 - 112.5	57.8	47.7	64.8	103*	50%
	2010	233	0-95.4	60.5	51.1	68.2	99*	42%
	2011	228	0-115	58.6	43.0	58.6	100*	43%
	Entire Record	3632	0 - 123.6	61.5	49.8	67.2	1117	31%

* In 2008, the State eliminated standards pertaining to DO % saturation. Number is based on previous standard of a minimum of 60% DO saturation and presented for comparison with previous years.

In 2011, 22 percent of all samples taken by volunteers did not meet the state standard of 5 mg/L for class B waters (46 of 210 samples). When calculating percent saturation of dissolved oxygen, 43% of these same samples fall below 60% saturation. This indicates the water should have more dissolved oxygen than is present. Figure 5 shows the percent violations for DO concentration and percent saturation for the entire monitoring record (1997-2011).

Figure 5. Percent violations of Massachusetts water quality standards for dissolved oxygen concentration and percent of saturation for the entire record of monitoring, 1997-2011.



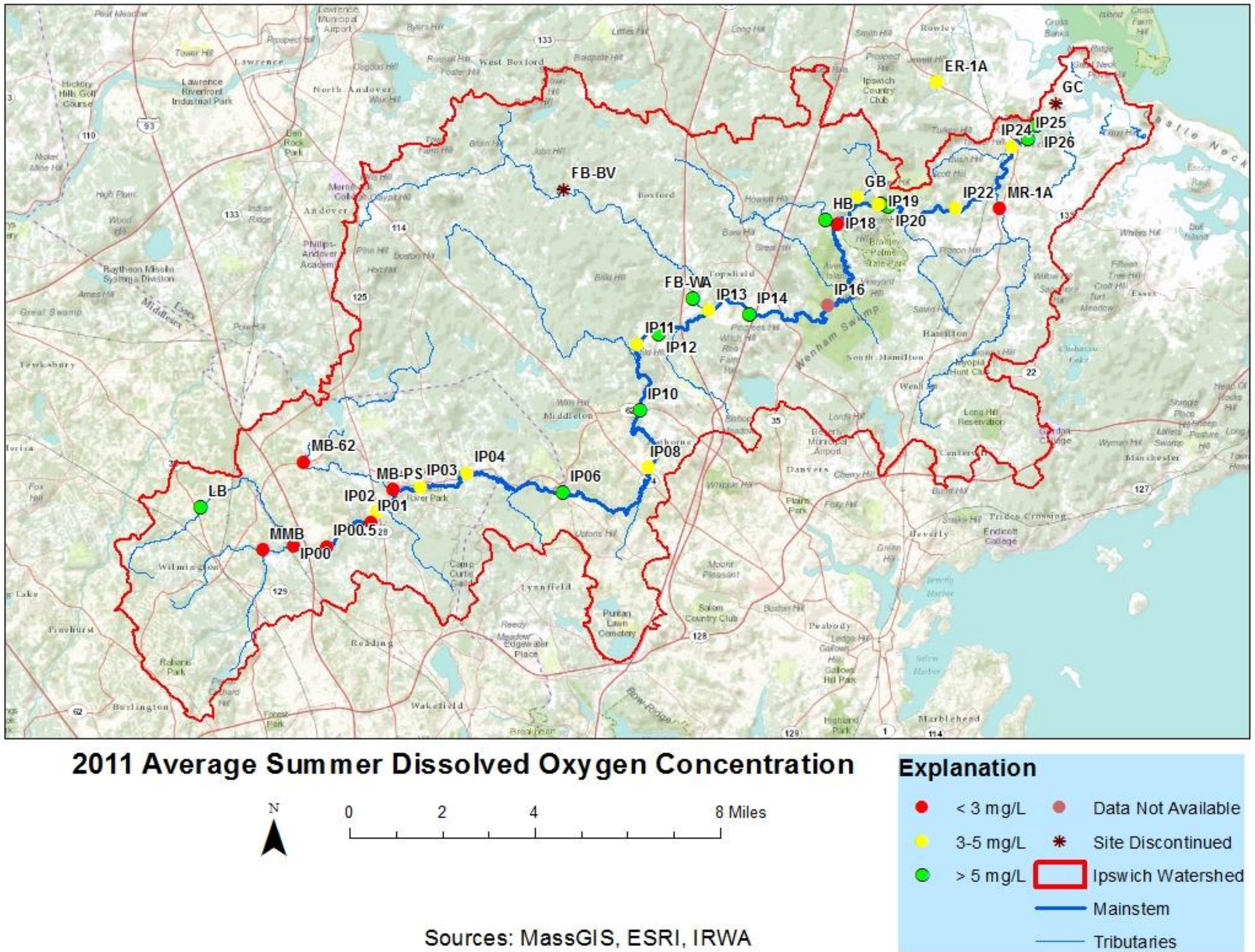
The fact that DO levels were very low consistently over the past decade represents a significant impaired condition on the river, and indicates that many aquatic organisms are under high stress conditions. Many organisms may not likely survive during most summers.

Site Statistics

Low DO conditions have been widespread and frequent during the past 15 years of monitoring. In 2011:

- Summer averages for 19 sites (out of 31) were less than 5.0 mg/L DO concentration. Eight sites had summer DO averages below 3.0 mg/L (figure 6).
- Year averages for 2 (out of 31) sites were less than 5.0 mg/L DO concentration.
- Twelve sites out of 31 had a minimum DO concentration below 5.0 mg/L DO. Only 6 sites had minimum values above 5.0 mg/L.
- Both tidally influenced sites had summer average, annual average and minimum values above 6mg/L.
- 22% of the 210 samples for dissolved oxygen were below the standard for concentration (5 mg/L).

Figure 6. Average summer dissolved oxygen levels for 2011 and relative river health.



■ **> 5mg/L (Class B), > 6mg/L (Class SA): Supports aquatic organisms.**

■ **3-5 mg/L: organisms may become stressed.**

■ **< 3mg/L: Mobile organisms will move to areas of higher DO and immobile organisms may die.**
<0.5 mg/L Cannot support most aquatic life.

Figures 7 and 8 compare average annual and summer dissolved oxygen concentration for mainstem and tributary sites respectively. Sites IP00 to IP04 all have summer dissolved oxygen levels below 5mg/L.

Figure 7. Comparison of average annual and summer dissolved oxygen concentration for mainstem and tidal sites. The dashed line represents the minimum level for class B waters (5mg/L) and class SA waters (6mg/L).

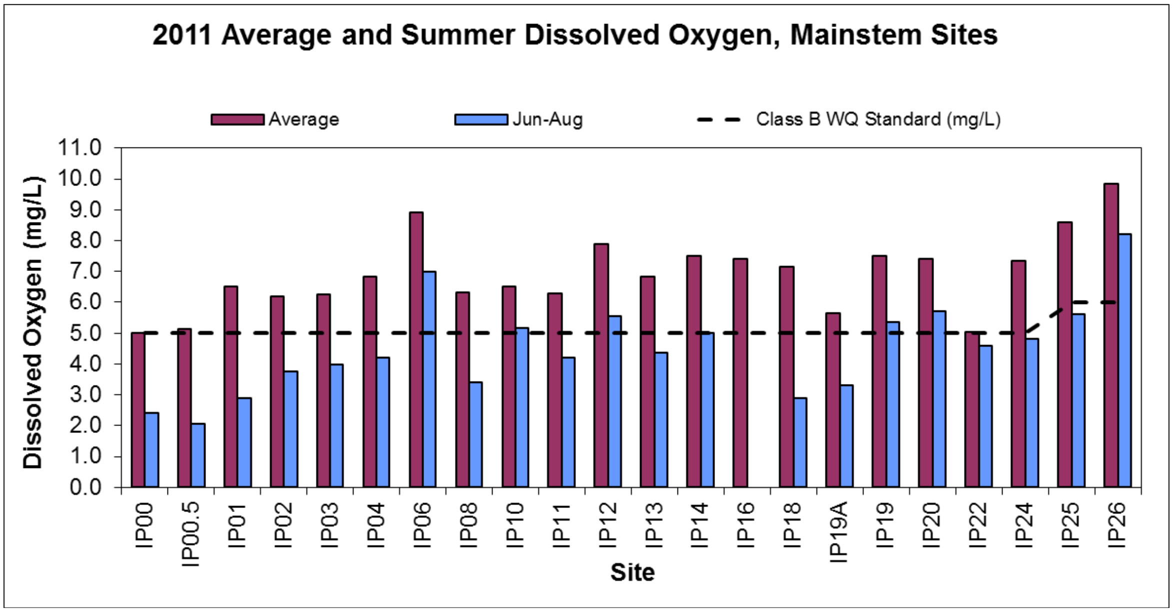
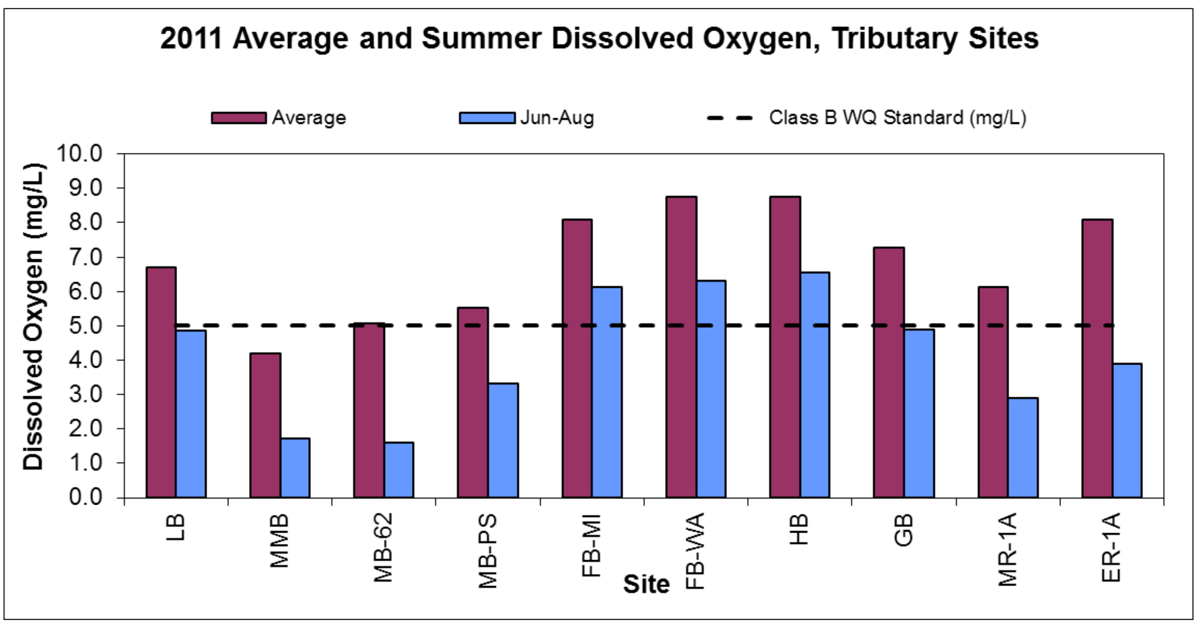
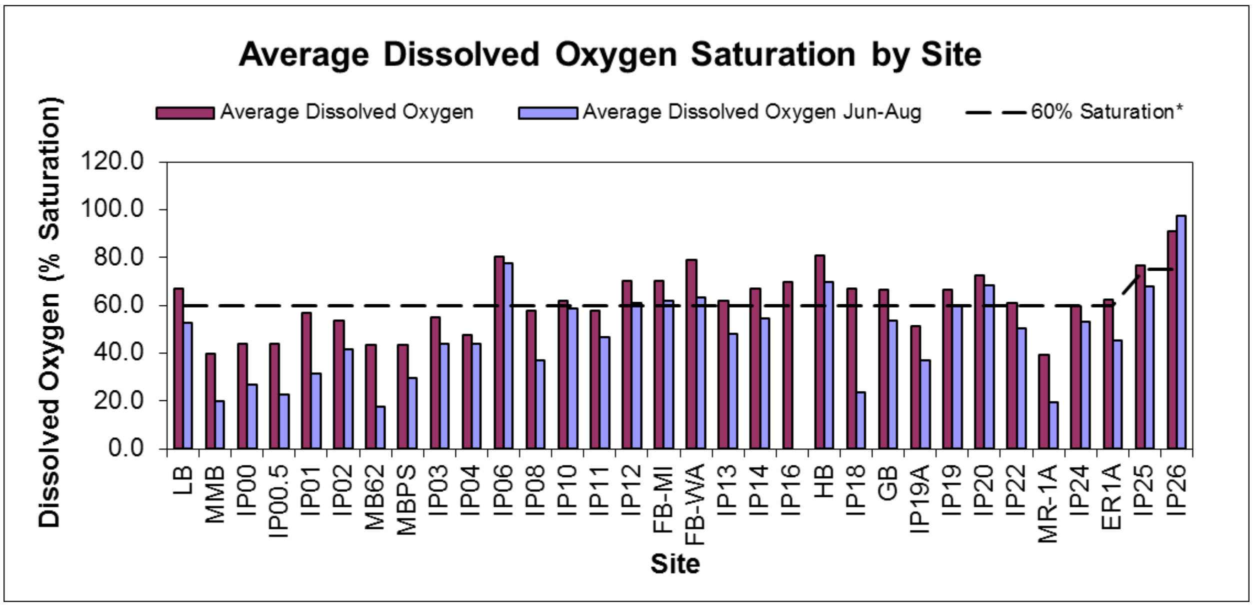


Figure 8. Comparison of average annual and summer dissolved oxygen concentration for tributary sites.



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 state 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% saturation can be used to confirm water oxygen depletion in the upper watershed. Most sites in the upper watershed did not achieve this level 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 figure 9.

Figure 9: Average Dissolved Oxygen Percent Saturation Statistics.* 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 7 and 9). 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 a first step 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?

3.3 Depth, Velocity, Streamflow

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 the flooding event in May of 2006 and March 2010. Conversely, velocity is a conservative indicator, since volunteers insert the floatable only where there is noticeable current. Immeasurable velocities cannot be quantified.

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.

Site Statistics

In 2011, most sites recorded water depths consistent between seasons (figure 10). Average summer depth was not drastically lower; in fact, average summer depth was nearly equal to and in some cases, greater than average annual or spring water levels. This was due to precipitation being at or above normal most months of the year. August was especially wet, with 303% the normal rainfall recorded in the northeast region of Massachusetts (Table 6).

Figure 10: Comparison of average annual, spring and summer water depths by site.

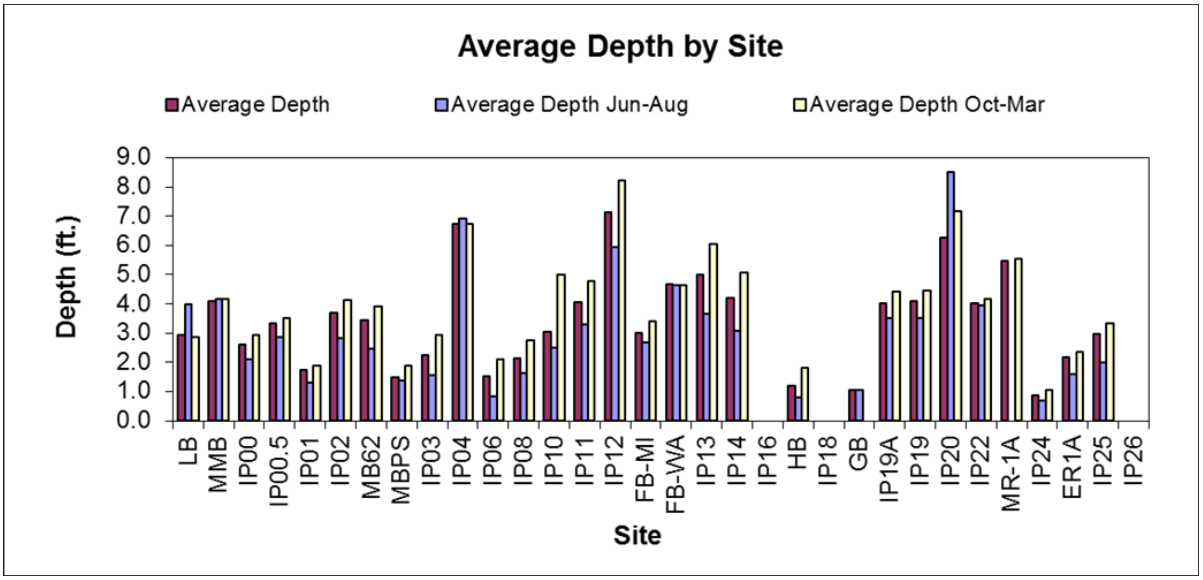
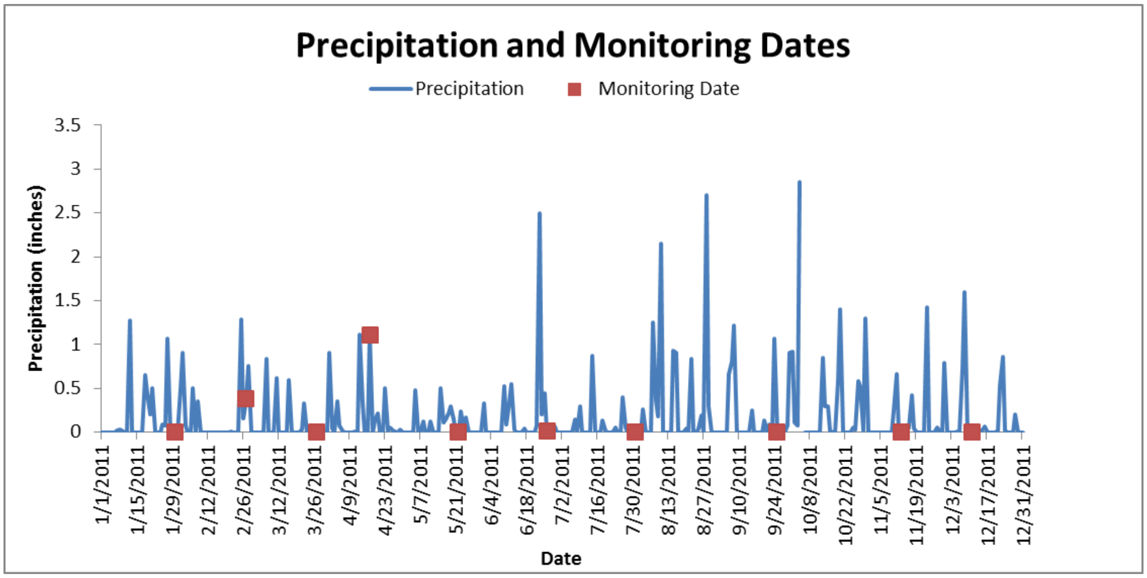


Table 6. Percent normal monthly rainfall for 2011. Source: Mass. Dept. of Conservation and Recreation Rainfall Program).

Month	Rainfall (% Normal)	Month	Rainfall (% Normal)
January	106	July	79
February	146	August	303
March	74	September	171
April	114	October	225
May	81	November	96
June	144	December	98

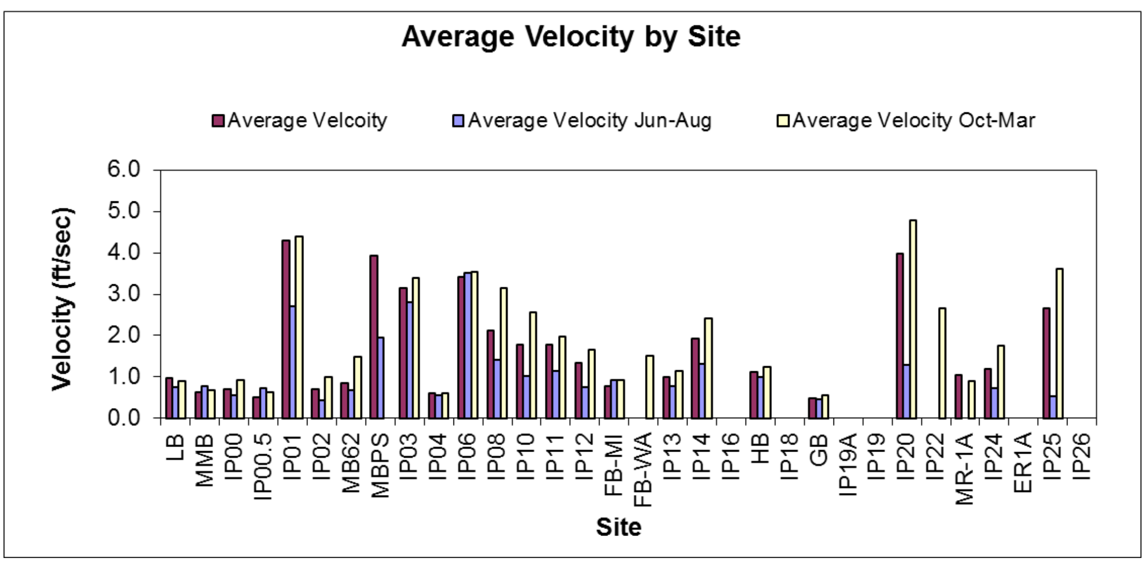
Figure 11 illustrates daily precipitation and the occurrence of water monitoring events. August 28th 2011 monitoring would have occurred on the same day that Tropical Storm Irene reached New England. Due to the potential for hazardous conditions, monitoring was cancelled for this day. As a result, average summer values in this report reflect June and July results only. Monitoring was also cancelled on October 30th due to the unexpected snowstorm that caused widespread damage and power outages. Average fall results that are reported only reflect September and November data.

Figure 11. 2011 daily precipitation levels from Middleton MA and monitoring dates. Source: National Weather Service.



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. At many sites, velocity was consistent between seasons due to high precipitation levels throughout the year. Water velocity is typically lowest in the upper watershed where there is a low gradient to the river and tributaries and surrounding wetlands (figure 12). Sites IP01 and IP03 are located at bridges where the channel width narrows, increasing water velocity beyond what would be expected naturally.

Figure 14: Comparison of average annual, summer and winter water velocity by site.

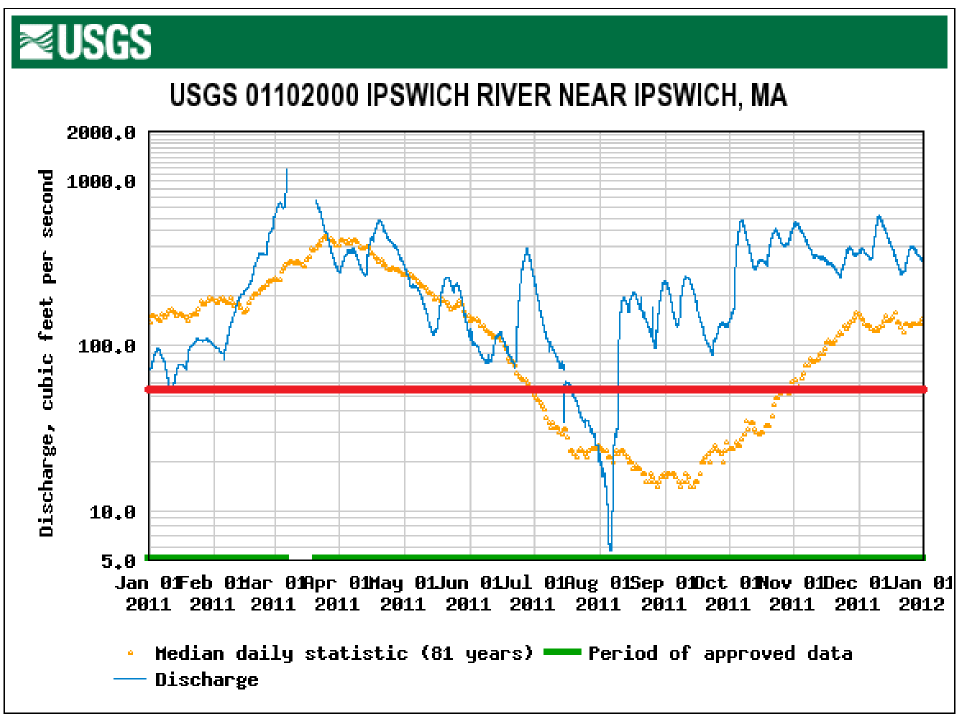


The United States Geological Survey (USGS) maintains two real-time streamflow gauges on the Ipswich River. One is located near Boston St. in South Middleton and the other is located off Topsfield Rd., near Winthrop St. in Ipswich. Water depth or stage height is recorded and compared to a rating curve of flow measurements taken over time at high and low water levels. The result is a flow volume measured in cubic feet per second (CFS). The South Middleton and Ipswich gauges have been recording streamflow data since 1938 and 1930, respectively.

These gauges have recorded regular episodes of extended extreme low flow events over the past 15 years. “Extreme low flow” is defined by the USGS as a minimum summer “ecological protection flow” (Horsley and Witten 2002). This “ecological protection flow” is the flow that “provides adequate habitat for the protection of fisheries” (Ibid).

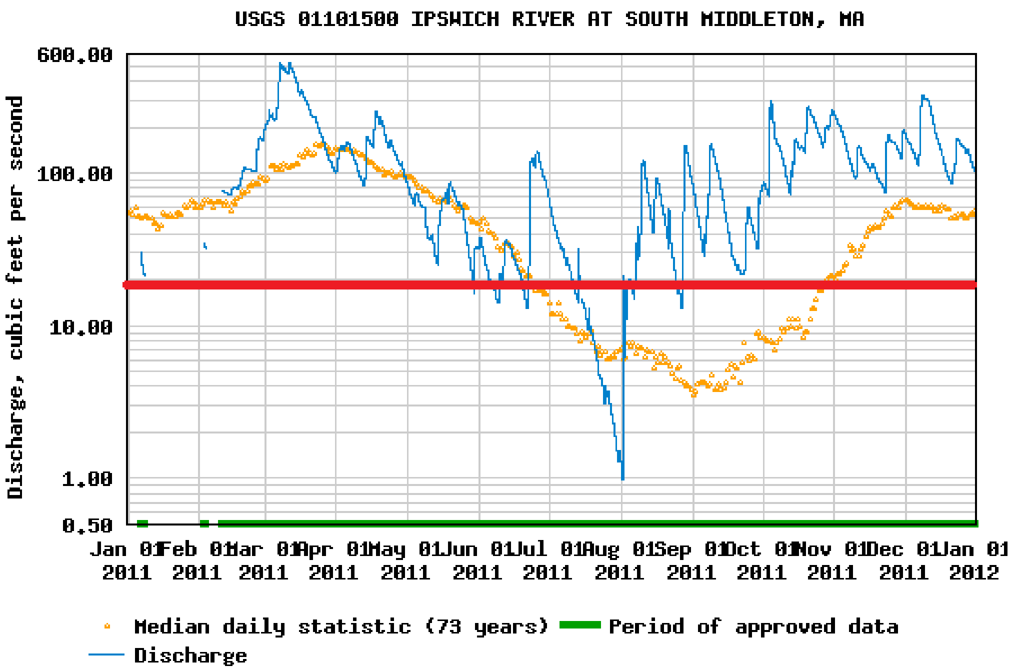
Summer low flows at the Ipswich gauge are defined as flows lower than 52.5 cfs (calculated as 0.42 cfsm multiplied by the drainage area of 125 square miles). At the Ipswich gauge low flows were recorded July 20 to August 9 or 5% of the year (figure 15).

Figure 15: 2011 Daily Mean Flow at the USGS streamflow gauge in Ipswich MA. The red line indicates the minimum ecological protection flow. Flows were below this level for 5% of 2011 Source: USGS



Summer low flows at the South Middleton gauge are defined as flows falling below 18.6 cfs (calculated as above, with a drainage area of 44.5 square miles). The South Middleton gauge low flows were recorded: January 9-11, June 6-9, June 20-22, July 12-August 4, August 6 and August 25-27 or 7% of the year (figure 16).

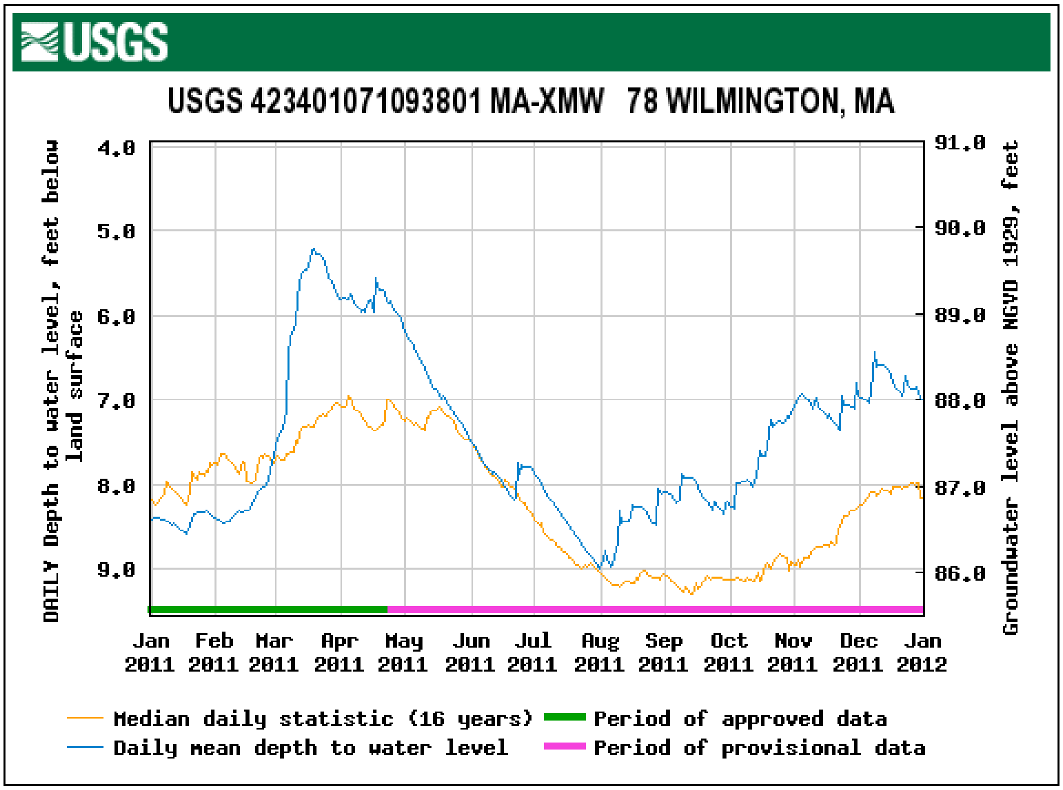
Figure 16: 2011 daily mean flow at the USGS streamflow gauge in South Middleton MA. The red line indicates the minimum ecological protection flow. Flows were below this value for 7% of 2011 Source: USGS



Summer flows were above the historical discharge at the South Middleton and Ipswich Gauges in 2011.

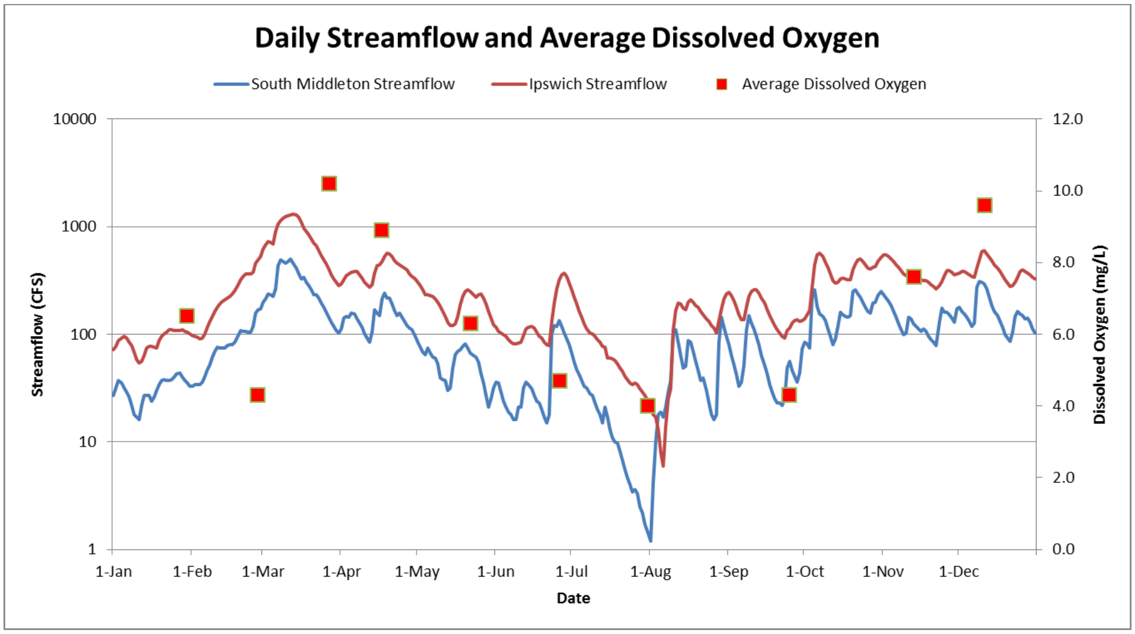
Groundwater is important to maintaining base flows in rivers and streams. Zariello and Ries (2000) linked groundwater withdrawals in the Ipswich River basin with low flow events. The USGS maintains a real-time groundwater monitoring station in on Middlesex Ave. in Wilmington near the headwaters of the Ipswich River. In Figure 16, groundwater levels are shown to be near or above the 16 year median for most of 2011and, particularly in the summer months. This monitoring station is located in the Martins Brook sub-basin which is the site of water withdrawals for the towns of Wilmington and North Reading. We now maintain a monitoring station on this section of Martins Brook at Rt. 62 in Wilmington as well as the existing site on Park St. in North Reading. We look forward to collecting new data in this sub-basin which is one of the largest and most impacted in the watershed.

Figure 16. Real-Time groundwater measurements from well located on Middlesex Ave. in Wilmington MA. Source: USGS.



Dissolved oxygen measurements can be compared to daily streamflow readings to observe how the two variables change over the course of the year. Average dissolved oxygen concentration levels for all monitoring sites were plotted against daily streamflow for 2011 (figure 17). Dissolved oxygen levels are highest in March, decline through the summer months and increase again during the fall. A few readings were taken in January and February when ice cover tends to depress dissolved oxygen levels. We cannot provide the level of analysis in this report needed to address the causes of low dissolved oxygen; however, we can highlight trends such as this that may warrant further investigation

Figure 17. 2011 Comparison of average monthly dissolved oxygen for all sites and daily streamflow for South Middleton and Ipswich gauges. Monitoring did not occur in August or October.



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 a 10th 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.

3.4 Conductivity

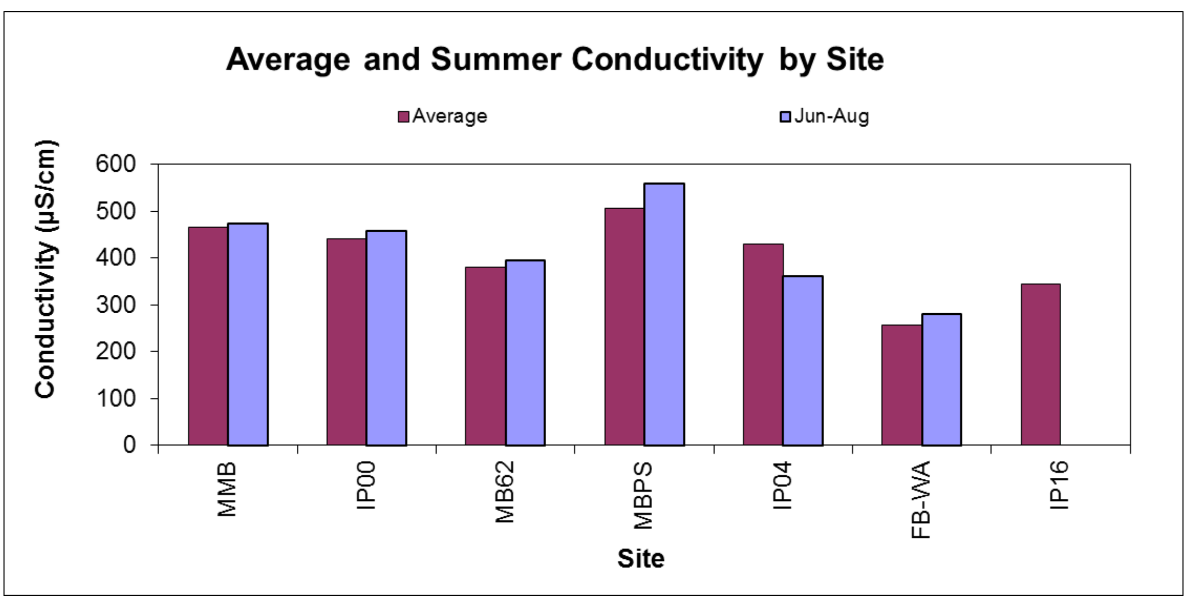
Conductivity measures the ability of water to pass an electrical current resulting from the presence of dissolved solids (or salts) such as chloride, sulfate, sodium and calcium, among others. Many factors can affect conductivity including local geology, rainfall, low flows and salt water concentrations 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 7 sites in 2011. Table 7 shows statistics of conductivity collected from 2007 through 2011. Figure 18 shows a comparison of average annual and summer conductivity for the sites monitored. Most sites show higher readings in the summer months. This may be due to lower flows resulting in higher concentrations of salts in the water. Martins Brook at Park St. shows values at or exceeding those that can support a healthy fishery. This is also higher than the site located upstream on Rt. 62, indicating a possible discharge source somewhere in between.

Table 8: Statistics for Conductivity 2007-2011.

Water Quality Parameter	Year	Site	Range	Average	Summer Average	Winter Average
Conductivity	2007	MMB	267 - 557	437		414
(µS/cm)		IP00	277 - 557	446	494	403
		IP04	297 - 607	487	472	537
		FB-MI	147 - 217	190		
	2008	MMB	197 - 517	376	354	340
		IP00	257 - 507	421	370	449
		IP04	47 - 447	343	440	292
		FB-MI	150 - 220	201	193	
	2009	MMB	420-480	447	430	
		IP00	280-480	404	400	
		IP04	320-510	428	410	495
	2010	IP04	250-641	486	583	284
	2011	MMB	330-540	465	475	468
		IP00	338-580	441	459	441
		MB-62	330-430	380	395	380
		MB-PS	440-560	507	560	480
		IP04	362-476	430	362	453
		FB-WA	180-380	256	280	256
		IP16	340-350	345		345

Figure 18 Annual and summer average conductivity by site. The normal range for conductivity is 150-500 µS/cm (micro Siemens per centimeter).



3.5 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 1 through 5: 1 (Clear), 2 (Very Light Tea), 3 (Light Tea), 4 (Tea), and 5 (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) 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.

3.6 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.

Beaver activity was noted at sites IP01 and IP13. Fish activity was noted at IP10 and FB-MI.

Birds

Woodpeckers
Chickadees
Crows
Cardinals
Robins
Red-Winged Blackbirds
Mallards
Red-Tailed Hawk
Canada Geese
Grackles
Song Sparrow
Tree Swallow
Great Blue Herron
Cormorants
Tufted Titmouse
Yellow Warbler
Common Yellowthroat
Mourning Dove
Downey Woodpecker
Ring-Necked Duck
Catbird
Warbling Vireo
Baltimore Oriole
Goldfinch
Tree Swallow
Coot
Wood Duck
Phoebe
Great-Crested Flycatcher
Red-Bellied Woodpecker
Flicker
Kingfisher
Pigeons

<u>Other Wildlife</u>
Mammals: Beavers, Muskrat, River Otter, Red Squirrel
Reptiles and Amphibians: Frogs, Painted Turtle, Water Snake
Insects: Dragonflies

<u>Plants</u>
Loosestrife, duckweed, bittersweet, lily pads

<u>Other Observations</u>
Beaver dam at IP01
Beaver activity at IP13
Fishermen
Pollen on water surface
Debris in water

Section 4: Quality Assurance/Quality Control

4.1 Quality Assurance Project Plan (QAPP)

A formal Quality Assurance Project Plan (QAPP) was updated and approved in November of 2009 for the RiverWatch Program by the Office of Coastal Zone Management (CZM) and the Department of Environmental Protection (DEP).

As part of the Quality Assurance Project Plan (QAPP), both temperature and dissolved oxygen are evaluated for quality control purposes. Volunteers must attend an annual training and undergo an annual site audit by the Program Coordinator from IRWA. Also for quality control, volunteers perform a duplicate test for dissolved oxygen once each year.

Comparison of field duplicate and audit DO readings are presented in figures 19 and 20.Only 3 samples exceeded the 1 mg/L DO concentration difference level specified in the 2009 QAPP. Field duplicates met quality standards as defined in the 2009 QAPP, indicating that volunteer data are within quality assurance limits.

Figure 19: Difference between duplicate field DO samples by site. 2011

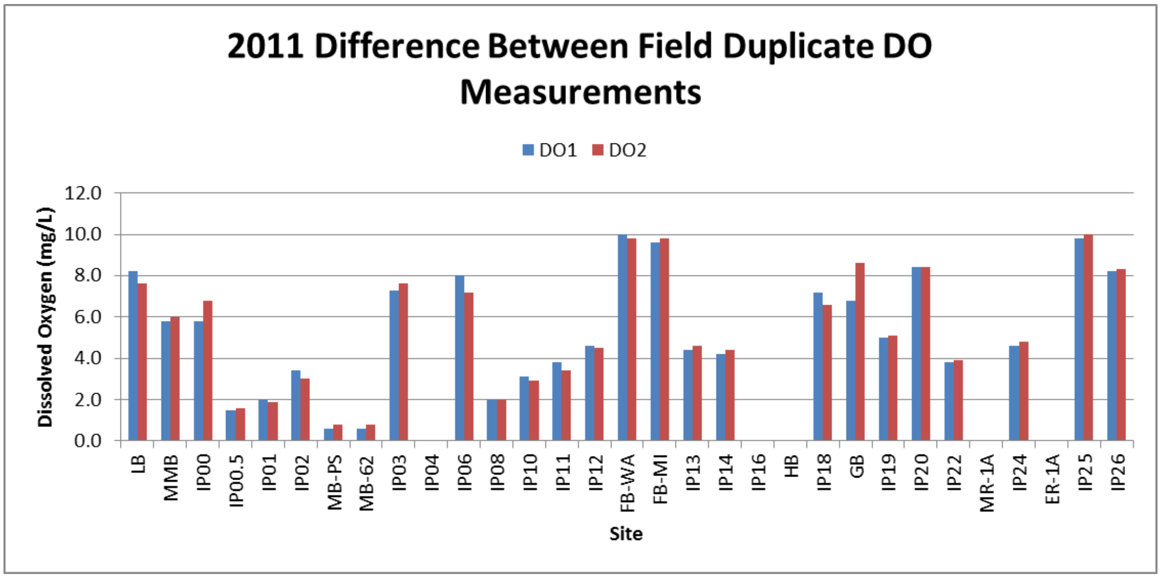
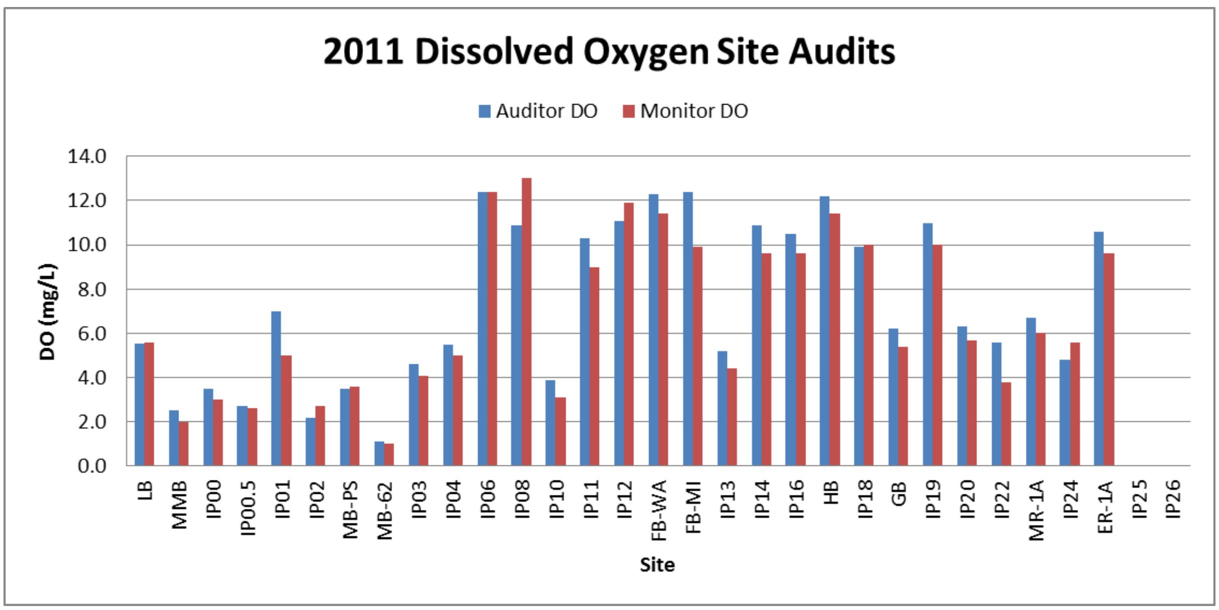


Figure 21: Difference between site audit dissolved oxygen readings.



4.2 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.

4.3 Completeness

Table 10, below, summarizes the completeness of data collection for the 15-year period. 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 for six months.

Table 9: Percent of Samples Collected per year, 1997 - 2011.

Year	Completeness
1997	86%
1998	90%
1999	92%
2000	89%
2001	83%
2002	89%
2003	76%
2004	81%
2005	88%
2006	91%
2007	82%
2008	83%
2009	78%
2010	73%
2011	85%

Section 5: Acknowledgements

The Ipswich River Watershed Association would like to thank:

The people and organizations that provided funding for IRWA's monitoring program including: New England Biolabs Foundation, and all IRWA members.

The people and organizations that supported our program with field and laboratory support, technical advice, program oversight and general helpfulness:

Wayne Castonguay, TTOR
John Clarkeson, EOEEA
Cindy DelPapa, Riverways
Chuck Hopkinson, MBL
Jim MacDougall, IRWA
Jerry Schoen, MWWP
Gina Snyder, EPA
Richard Tomczyk, EOEEA
Wil Wolheim, UNH

Most of all, we would like to thank all of our dedicated volunteers:

Loring Bradlee
Katharine Brown
Jeff Becker
Donnan Barnes
Cheryl Clapp
Chris Cummings
Judy Donovan
Michael and Susan DeAmario
Renee Dunn
Jack Elsey
Joan Flynn
Will Finch
Paul and Susan Fritz
Gayle Gleichauf
Karen Hartel
Curtis Hermann
Kim Honetschlager
Art Howe
Ingrid Johnson
Alex Kane
Mary Kane
John Kastrinos
Bob Koenig
Mark Lovejoy
Wayne Mackey
Bill McDavitt
Judy Mansfield
Larry McTiernan
Ben Mendelson
Francis Masse
David Merrill
Pike Messenger
Catie Moore
Peter and Alicia Moore
Tim Nawrocki
Deborah Nelson
Pamela Newport
Beth O'Connor
Robert O'Donnell
Barbara Ostberg
Bill Reed
Rick Rogers
Ruth Ryan
Carol Sandberg
Karl Seibert
Gina Snyder
Ava Steenstrup
Martha Stevenson
Janet Stone
Lee Story
Suzanne Sullivan
Katie Szymaszek
Joe, Bernadine Tragert
Jim, Siobhan and Gavin Ugone
David Williams
Nancy and Michael Wolfe

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RiverWatch Data Appendices and Quality Assurance Project Plan (QAPP) available at:

http://ipswich-river.org/resources/monitoring-data/
http://ipswichriver.org/our-work/science-monitoring/