KENNEBUNK RIVER

WATER QUALITY REPORT & WATERSHED STRESSOR GUIDE

FB Environmental Associates

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Cover photo taken by Amelie Jensen

I. PURPOSE

The goal of this document is to serve as a guide to stressor identification and restoration efforts in the Kennebunk River watershed and to present summarized historical water quality data. In the January 24, 2020 technical advisory committee (TAC) meeting, we discussed each tributary, proximate stressors that may be causing impairments to the biological community, and approaches for restoration that will address these proximate stressors. This document builds on that conversation by looking at the water quality history, survey results, and stressors in each sub-watershed. This assessment should be used in conjunction with the 2019 data summaries from the Wells National Estuarine Research Reserve (WNERR) and Maine Healthy Beaches (MHB) Monitoring Program. This document is part of the overall Watershed-Based Management Plan Development Project for the Kennebunk River watershed. This summary and stressor guide will be used as a tool to identify action items for Plan implementation.

II. METHODS

In 2019, the Maine Department of Environmental Protection (Maine DEP) published a *"Guide to Identifying NPS [Nonpoint Source] Stream Stressors"* (hereafter referred to as the "Stressor Guide"), to support environmental managers and professionals with analysis and restoration of urban waters in Maine. The purpose of this Stressor Guide is to identify a more dynamic and science-based approach to stream restoration that focuses on the proximate stressors in urban watersheds. Watershed management in urban watersheds has historically focused on impervious cover and typical stormwater pollutants (e.g. nutrients, metals, and hydrocarbons). However, the proximate-stressor approach focuses on identifying the primary environmental conditions (pollutants or habitat) that are causing the biological impairment that results in a state listing as an impaired stream.

In the 2019 Stressor Guide, Maine DEP outlines the proximate stressors to a stream's biological community as follows:

(1) Temperature
(2) Dissolved Oxygen
(3) Velocity
(4) Altered Physical Habitat
(5) Altered Food Source
(6) Low Recruitment Potential
(7) Toxicity (chloride, metals, hydrocarbons, and pesticides)

It is important to note that the 2019 Stressor Guide does not address bacteria impairments, such as the ones in the Kennebunk River and Duck Brook. However, we will have applied the outlined approach to our restoration plan for the bacteria impairments in the Kennebunk River watershed. At 59 sq. mi. and across six towns, the Kennebunk River watershed is large. Because of its size, we completed this stressor-based approach for each major tributary sub-watershed individually as well as the direct drainage of the Kennebunk River (see map on Figure 1, on the following page). The focus tributaries for this analysis were:

(1) Carlisle Brook
(2) Duck Brook and Duck Brook Tributary A
(3) Goff Mill Brook
(4) Lord's Brook
(5) Ward Brook

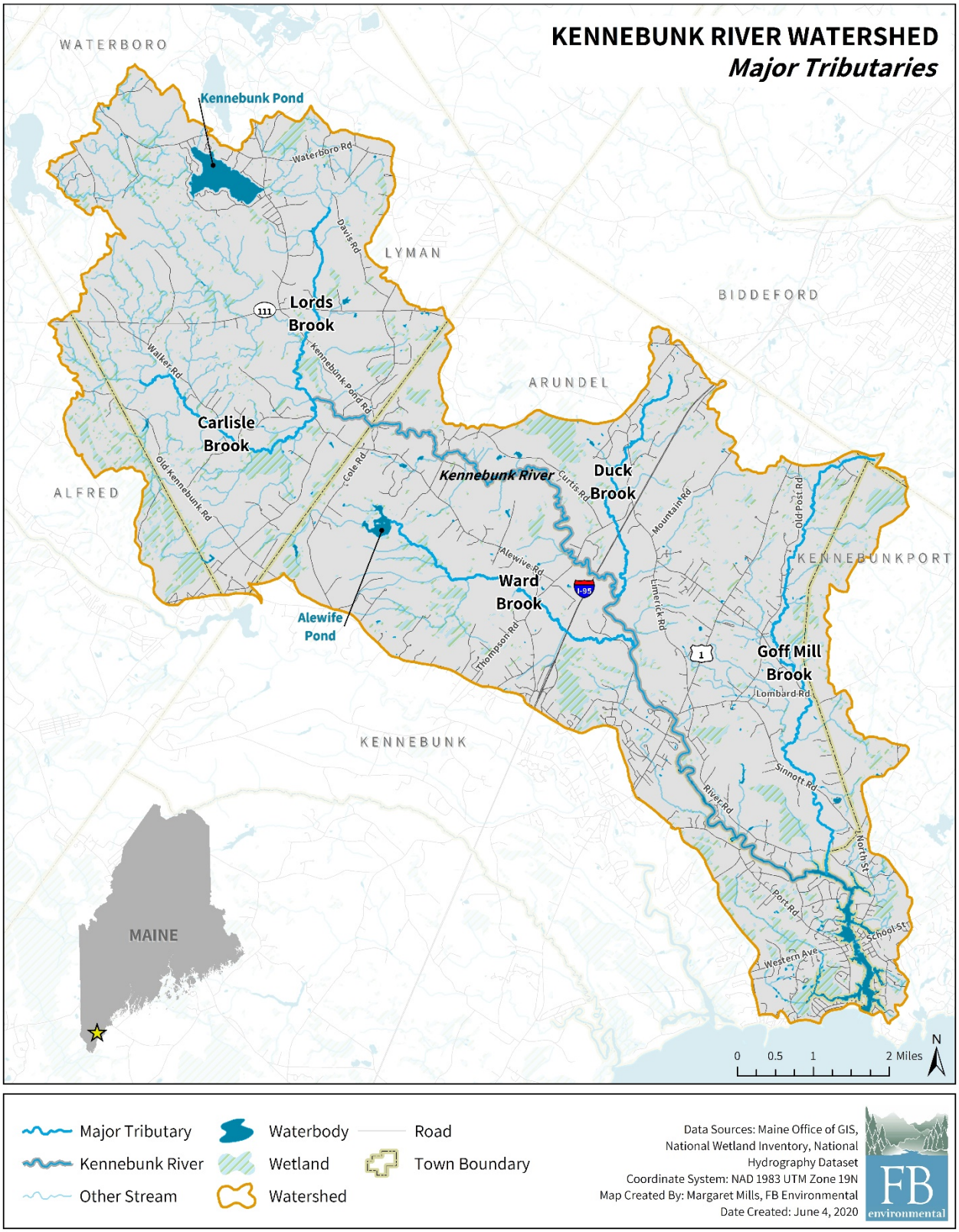


Figure 1. Major tributaries in the Kennebunk River watershed used for analysis in this guidance document.

IV. STRESSOR DEFINITIONS

Proximate stressors are those stressors that are directly responsible for the responses seen in a stream that cause an impairment. To summarize an example from page 2 of the Stressor Guide, … "If the response is die-off of sensitive organisms, the proximate stressor might be low dissolved oxygen." However, low dissolved oxygen is likely a result of other environmental stressors, defined as any other environmental condition (pollutants or habitat) that contributes to the biological impairment. Examples of environmental stressors are excess nutrients, high water velocity, no woody debris/habitat, chemical toxicity, etc. This pathway from initial cause to the proximate stressor is called the causal pathway. In this example, the causal pathway would go as follows: Runoff with Nutrients → Excessive Plant (Algae) Growth → Increased Respiration → Reduction in Dissolved Oxygen[1].

V. APPLICABLE WATER QUALITY CRITERIA

The freshwater portion of the Kennebunk River and its tributaries are categorized as Class B waters. Below head of tide, the Kennebunk River estuary is categorized as a Class SB water. Table 1, below, lists the Maine DEP and US EPA applicable criteria for the freshwater and estuarine portions of the Kennebunk River and its tributaries.

Table 1. Applicable state and federal thresholds for all parameters applicable to the Kennebunk River and its tributaries.

PARAMETER	TYPE	CLASSIFICATION	THRESHOLD JUSTIFICATION	THRESHOLD
E. coli *	Freshwater	Class A	Maine DEP	**236 CFU/100mL** (in more than 10% of samples in any 90-day interval); **64 CFU/100mL** (geometric mean over 90-day interval)
		Class B	Maine DEP	**236 CFU/100mL** (in more than 10% of samples in any 90-day interval); **64 CFU/100mL** (geometric mean over 90-day interval)
Enterococci *	Estuarine	Class SB	Maine DEP	**54 CFU/100mL** (in more than 10% of samples in any 90-day interval); **8 CFU/100mL** (geometric mean over 90-day interval) and **35 MPN/100mL** geometric mean for MHB program.
Dissolved Oxygen	Freshwater	Class A/B	Maine DEP	**7 ppm** and **75% saturation****
	Estuarine	Class SB	Maine DEP	**85% saturation**
Temperature	Freshwater	None	Maine DEP	Recommended instantaneous temperature of **<24°C** for fish survival and maximum weekly temperature of **19°C** ***

[1] Maine DEP. 2019. *Guide to Identifying NPS Stream Stressors*. Maine Department of Environmental Protection.

PARAMETER	TYPE	CLASSIFICATION	THRESHOLD JUSTIFICATION	THRESHOLD
Total Phosphorus	Freshwater	None	US EPA Ecoregion VIII Water Quality Criteria	12 ppb (threshold set at reference criteria for TP concentration)

** E. coli criteria only applicable seasonally (between April 15th and October 31st)*
***Except for Oct 1 – May 14 during spawning and egg incubation. 7-day mean dissolved oxygen not less than 9.5 ppm and 1-day minimum not less than 8.0 ppm in identified fish spawning areas.*
**** Temperature criteria found to be the limit for juvenile brook trout survival (Brungs, W.S. and B.R. Jones. 1977. Temperature Criteria for Freshwater Fish: Protocols and Procedures. EPA-600/3-77-061. Environ. Research Lab, Ecological Resources Service, U.S. Environmental Protection Agency, Office of Research and Development, Duluth, MN.*

Throughout this document, we use these criteria in Table 1 *as a guide* to assess the water quality conditions in each of the tributaries and will refer to these criteria as "State criteria" in our discussions. However, for consistency across sites, we are assessing the geometric mean of each parameter. When used for impairment designations, the criteria listed in Table 1 considers nuances in the data, such as sample count and interval of data collection, that are not considered in this analysis. The data presented in this document is truncated to include only sample points within the critical period (between April 15th and October 31st).

CURRENT STATE IMPAIRMENTS IN THE KENNEBUNK RIVER WATERSHED

KENNEBUNK RIVER MAIN STEM

In order to identify focus sub-watersheds for the stressor analysis, it is important to look at the current impairments. In the *2016 Integrated Water Quality Monitoring and Assessment Report*, the Kennebunk River is described as having 'insignificant data or information to determine if designated uses are attained'. However, recent data collected by Maine DEP for assessment indicates that this segment will likely be listed as impaired for aquatic life use (macroinvertebrates and algae bioassessments). In addition, the Kennebunk River is listed as impaired for *Escherichia coli (E. coli)* and was included in the *2009 Maine Statewide Bacteria TMDL*[2].

Duck Brook

In addition to the main stem of the Kennebunk River, a major tributary, Duck Brook, is listed as impaired for *E. coli* and was included in the *Maine Statewide Bacteria TMDL 2014 Freshwater Addendum*[3].

BIOLOGICAL MONITORING

Macroinvertebrate and Algae Monitoring

The Maine DEP Biomonitoring Unit uses macroinvertebrate (aquatic insects, crustaceans, mollusks, mites, leeches, and worms) and algae data to determine if waterbodies are attaining their statutory class and supporting aquatic life. The aquatic life (biological) narrative criteria for Class B waters in Maine (such as those in the Kennebunk River watershed) states *"Discharges may not cause adverse impact to aquatic life in that the receiving waters must be of sufficient quality to support all indigenous aquatic species without detrimental changes to the resident biological community*[4]*."*

Biological communities are great indicators of water quality because certain species are understood to be more "sensitive", requiring cold, clean water and natural habitats. The Maine DEP collects macroinvertebrate and algae data on rivers and streams and then analyzes the aquatic communities through a statistical model to determine if the river is meeting its statutory class and supporting aquatic life.

[2] https://www.maine.gov/dep/water/monitoring/tmdl/2009/bacteria_report.pdf
[3] https://www1.maine.gov/dep/water/monitoring/tmdl/2014-statewide-bacteria-tmdl-addendum/Appendix_A_Duck_Brook.pdf
[4] https://www.maine.gov/dep/water/monitoring/biomonitoring/materials/qapp2019.pdf (page 7).

In the Kennebunk River watershed, macroinvertebrate and algae sampling stations exist on the Kennebunk River main stem, Carlisle Brook, Lord's Brook, Ward Brook, and the East Outlet Tributary of Kennebunk Pond. Biomonitoring began in 1995 on the main stem (station S-270) and was most recently conducted in 2015. Given the available data, the first non-attainment occurred on the main stem (station S-270) in 2005. This site then met class in 2010 but not in 2015. Other stations not meeting class are sites S-863 and S-875 on Lord's Brook. Both stations did not meet class in 2008, and station S-863 did not meet class in 2010 (S-875 did meet class in 2010; see Table 2 for a summary of biomonitoring and attainment and Table 3 for a summary of algae monitoring and attainment in the Kennebunk River watershed).

Table 2. Summarized biomonitoring results from the Maine DEP in the Kennebunk River watershed.

STATION NUMBER	LOCATION	SAMPLE DATE	STATUTORY CLASS	ATTAINED CLASS	FINAL DETERMINATION
S-270	Kennebunk River above Route 1	08/22/1995	B	Y	B
		08/31/2000	B	Y	B
		08/15/2005	B	**N**	C
		08/31/2010	B	Y	B
		08/19/2015	B	**N**	C
S-469	Kennebunk River Main Stem at Alewive Road	08/31/2000	B	Y	B
		08/15/2005	B	Y	B
S-792	Carlisle Brook at Walker Road	08/31/2010	B	Y	A
S-863	Lord's Brook at Lords Lane	08/08/2008	B	**N**	C
		08/25/2010	B	**N**	C
S-867	East Outlet of Kennebunk Pond	08/08/2008	B	Y	A
S-875	Lord's Brook Upstream of East Outlet	08/08/2008	B	**N**	NA
		08/25/2015	B	Y	A
S-951	Ward Brook at Alewife Road	08/31/2010	B	I	I
		08/19/2015	B	Y	A

Table 3. Summarized algae monitoring results from the Maine DEP in the Kennebunk River watershed.

STATION NUMBER	LOCATION	SAMPLE DATE	STATUTORY CLASS	ATTAINED CLASS	FINAL DETERMINATION
S-792	Carlisle Brook at Walker Road	07/07/2005	B	Y	B
		07/19/2010	B	Y	B
S-862	Lord's Brook Downstream of East Outlet	07/08/2008	B	Y	B
		07/14/2015	B	**N**	C
S-863	Lord's Brook at Lords Lane	07/08/2008	B	Y	B

Bacteria

Indicator organisms (such as *Escherichia coli* or *E. coli*, Enterococci, and Fecal Coliform) are used to track a wide variety of potentially harmful pathogens such as viruses and bacteria found in mammalian fecal waste that would otherwise be too expensive to monitor comprehensively (Figure 2). Despite their widespread use, research suggests that these indicators have significant limitations and caution should be used in interpreting results of these indicators as a metric for risk management. Similar to other nonpoint source pollutants, addressing pathogen-impaired waters is challenging because fecal waste can come from a number of sources on the landscape (e.g., septic, pet waste, livestock, and wildlife/waterfowl). In addition to these more traditional nonpoint source pollutant challenges, pathogen impairments pose additional

challenges because of the limitations of selected fecal indicator bacteria (FIB) currently used to identify and track fecal contamination.

We have summarized below in bullets (1) through (4) the major reasons fecal contamination is one of the most difficult pollutants to remediate.

(1) It is a nonpoint source pollutant, meaning that it can come from many different locations on the landscape.

(2) Human health concerns are caused by potentially harmful pathogens such as viruses and bacteria, that are present within fecal matter. However, it would be too expensive to track and monitor each harmful virus and bacteria individually. Because of this, we use indicator organisms (such as *Escherichia coli* or *E. coli*, Enterococci, and Fecal Coliform). These indicator organisms are chosen based on similarities to pathogens in behavior and transport in the environment.

(3) Synchronicity in behavior between FIB and the pathogens-of-concern for public health risk (e.g., salmonella, campylobacter, rotavirus, giardia, norovirus, hepatitis, etc.) may break down under certain environmental conditions. Therefore, caution must be used when interpreting FIB data in the context of risk management decisions.

(4) Fecal contamination tracking is an evolving science, with new technologies consistently making their way to the market. We do our best to use the tools at our disposal while recognizing their limitations.

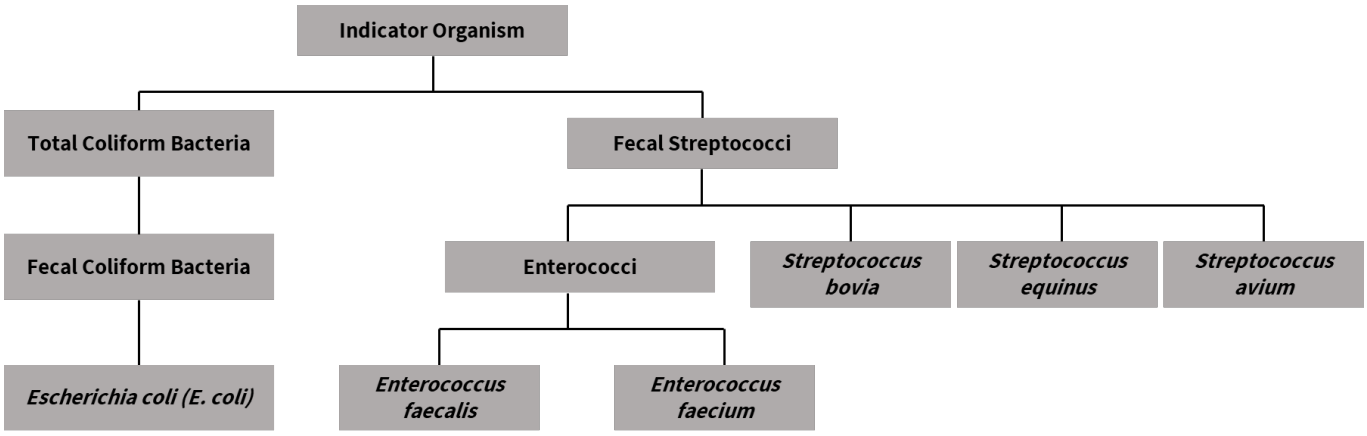


Figure 2. A classification tree of fecal indicator organisms commonly used to track pathogens.

Historical bacteria data is summarized individually by sub-watershed in Section VI, starting on the following page.

Optical Brighteners

Optical brighteners are commonly used for wastewater detection. Optical brighteners are not naturally occurring and are typically added to laundry soaps, detergents, cleaning agents, and toilet papers to aid in the brightening of fabrics and/or surfaces. A threshold of 100 µg/L is used a guide, consistent with Maine Healthy Beaches methodology.

In waterbodies where tea-colored water (an indicator of humic content) is common, the optical brightener 100 µg/L threshold may not be a good metric for identifying human-sourced pollution due to interference from humic substances (tannins and other dissolved organic compounds) that can artificially inflate optical brightener readings. This results in a "background level" contribution to observed optical brightener concentrations. When identifying contamination "hot-spots", examining how concentrations from a site deviate from the overall mean can help pull a meaningful signal, especially when most sites exhibit elevated bacteria levels and are suspected to be impacted by organic matter/interference. Sites with positive deviations for both bacteria and optical brightener values represent suspect locations with the potential for human sourced fecal pollution.

VI. SUB-WATERSHED WATER QUALITY AND STRESSORS

The following section summarizes the historical water quality data and stressor analysis for each of the major sub-watersheds in the Kennebunk River watershed. This includes Duck Brook (including Tributary A), Carlisle Brook, Goff Mill Brook, Lord's Brook, and Ward Brook. We have also included a section on the Kennebunk River main stem which includes sites on the main stem, as well as sites within the direct drainage (i.e. unnamed tributaries/drainages that directly enter the Kennebunk River). The review of each sub-watershed consists of two pages. The first page is a summary of the historical water quality data and information on biomonitoring stations. The second page is an overview of the land use as well as potential sources of nonpoint source pollution in the watershed including a breakdown of the proximate and environmental stressors on that tributary. We have also included a brief summary of the 2019 survey information on the second page for each sub-watershed. Additional tables and maps are included for the Kennebunk River direct drainage. Each sub-watershed has been assigned a different color to guide the reader that is shown on the map to the right (Figure 3a) and matches the colored box on the top right corner of each page.

All data presented is truncated to include only samples taken during the critical period (April 15 – October 31) and reflect **all** historical data from that sample site (i.e. all years available). Summarized data was limited to

Figure 3a. Sub-watersheds located in the Kennebunk River watershed, with assigned colors that will be used throughout the document to indicate a specific sub-watershed.

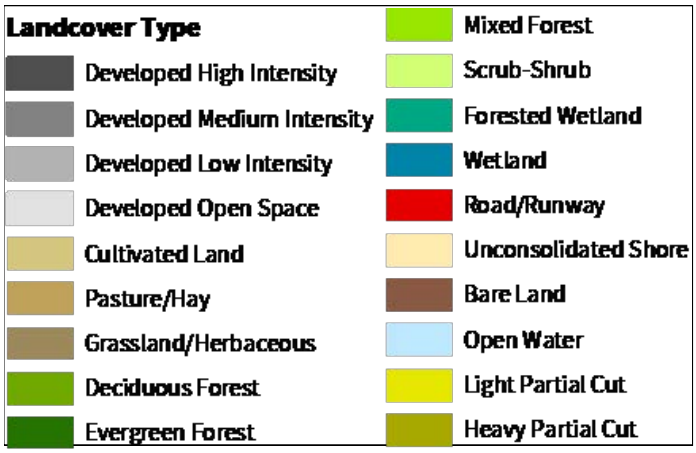


Figure 3b. Landuse color classifications used in the sub-watershed maps throughout this document.

normal environmental samples and excludes field and laboratory duplicates. Data are not summarized by condition (wet or dry) because of a limited dataset and resources, however, this should be considered for future analysis and sampling. It is important to note that synthesized historical data presented in this section does not show any change (e.g. improvements) in water quality in recent years and this analysis should be used in tandem with the data summaries from recent years provided by Maine DEP, MHB, and WNERR.

In addition to water quality data, we have included a brief summary for all relevant field surveying that occurred as part of this Watershed-Based Plan Development Project in 2019. Refer to the approved Sampling and Implementation Plan for details on survey methods and design.

Figure 3b shows the landuse types used as color-coding on all sub-watershed maps in this document.

KENNEBUNK RIVER DIRECT DRAINAGE

WATER QUALITY DATA SUMMARY

This section provides a brief overview of historical water quality data in the Kennebunk River direct drainage. The direct drainage represents the surrounding land that drains to the River without passing through a major tributary. This area is colored tan in Figure 3a on the previous page. Data presented in this section is limited to sites with 6 or greater datapoints for the listed parameter. This is because of substantially more sites within the Kennebunk River Direct Drainage area. All other sub-watersheds discussed include all data. All data discussed below can be found in Table 4 on the following page.

Dissolved Oxygen: Dissolved oxygen (DO) data are available for 26 sites in the Kennebunk River direct drainage. Of these 26 sites, six sites have six or more datapoints with the majority of sites having only one reading. These six sites are outlined in Table 4. Mean DO is above 7 ppm at all six sites, although five of the six sites have experienced minimums below 7 ppm. The lowest mean is 7.6 ppm at sites KB-02 and KB-04 and the minimum recorded DO is 3.9 ppm at KB-04. Also, important to note is that it is likely many of the times that measurements were taken were not early morning measurements when the DO would be lowest.

E. coli: In the Kennebunk River watershed, *E. coli* is used to track fecal contamination in the freshwater, and Enterococci is used in marine waters. Because of the variability in *E. coli* explained in section IV, the Maine DEP uses a geometric mean instead of an average. Geometric means are less sensitive to outliers, and therefore, present a more representative view of results.

E. coli data is available for 16 sites in the Kennebunk River direct drainage. Of these 16 sites, four had six or more datapoints with the majority of sites again having only one reading. These four sites are outlined in Table 4. Mean *E. coli* (geometric mean) is elevated at all three sites at 175.2, 213.5, 141.8, and 110.1 MPN/100mL for KB-03, KB-04, KB-05, and SKE09, respectively. However, all sites have a high standard deviation (>500) reflecting the extreme variability noted in *E. coli* samples. Maximum *E. coli* was greater than the detection limit (2,420 MPN/100mL) for three sites (KB-03, KB-04, and KB-05). All *E. coli* data within the Kennebunk River direct drainage is presented visually in the Figure 4 map (p.14), including sites with only one datapoint.

Enterococci (Entero): Entero data is available for 31 sites in the Kennebunk River direct drainage. Of these 31 sites, 10 sites have six or more than datapoints. All sites have significantly elevated mean (geometric mean) Entero with the lowest at 23.9 MPN/100mL at site KB-01 and the highest at site SD-03 at 200.3 MPN/100mL.

Optical Brighteners: Optical brightener data is available for 27 sites in the Kennebunk River direct drainage. Of these sites, one has six or more datapoints and optical brighteners were elevated at this site – KR-31 – at 304.1 µg/L.

Temperature: Temperature data is available for 31 sites in the Kennebunk River direct drainage. Of these 31 sites, 10 sites have six or more datapoints. Site 270 has >6,000 points because of a continuous monitoring device deployed at this site in 2005, 2010, and 2015. Mean (geometric mean) temperature is below 24°C (the recommended threshold for aquatic life) for all sites.

Total phosphorus: Total phosphorus data is available for one site in the Kennebunk River direct drainage. Site 270 has six total phosphorus samples with a geometric mean of 33 ppb.

Table 4. Summarized data for dissolved oxygen, *E. coli*, *Enterococci* (*Entero)*, temperature, optical brighteners, and total phosphorus in the Kennebunk River direct drainage. Sites were only included if they had greater than 6 historical datapoints to be consistent with Maine DEP methods to calculate geometric mean. Data was truncated to include only data taken in the summer season. Values that do not meet the applicable state and federal thresholds are in red. (DO was evaluated at 7 ppm; *E. coli* at 65 MPN/100mL; *Entero* at 35 MPN/100mL; Optical Brighteners at 100 µg/L; Temperature above 24C, and Total Phosphorus above 12 ppb).

	SITE	COUNT	GEOMETRIC MEAN	STANDARD DEVIATION	MEDIAN	MINIMUM	MAXIMUM
DISSOLVED OXYGEN (mg/L)	270	11	9.4	0.7	9.38	8.3	10.78
	KB-01	76	9.0	1.2	9.2	6.3	11.62
	KB-02	80	7.6	1.2	7.65	5.4	11.57
	KB-03/KR-06	75	9.1	1.1	9.05	5.6	12.3
	KB-04	81	7.6	1.3	7.8	3.9	12.1
	KB-05/KR-25	82	8.9	1.0	8.9	6	12.24
E. COLI (MPN/100mL)	KB-03/KR-06	74	175.2	539.3	147.5	10	2,420
	KB-04	76	213.5	530.2	192	15	2,420
	KB-05/KR-25	77	141.8	519.7	128	4	2,420
	SKE09	8	110.1	747.5	97	11	1,986
ENTERO (MPN/100mL)	KB-01	77	23.9	1,447.8	10	5	9,208
	KB-02	77	78.2	1,516.8	85	5	12,997
	KB-03/KR-06	56	50.6	357.4	41	5	1,500
	KB-05/KR-25	18	107.8	146.0	132.5	10	487
	KR-31	9	97.9	2,118.8	97	5	6,488
	KR-33	6	99.3	947.7	122	5	2,419.6
	KR-35	43	81.2	342.9	84	5	1,553
	KR-47	6	123.7	311.1	157	10	866.4
	KR-58	6	88.8	224.0	219.5	5	520
	SD-03	8	200.3	516.9	330	20	1,515
OPTICAL BRIGHTENER (µg/L)	KR-31	6	304.1	63.0	284	252	417
TEMPERATURE (°C)	270	6164	21.6	2.2	21.6	17.13	27.235
	KB-01	76	16.5	2.4	17.1	10.7	22.7

	SITE	COUNT	GEOMETRIC MEAN	STANDARD DEVIATION	MEDIAN	MINIMUM	MAXIMUM
	KB-02	80	19.1	3.1	19.9	7.7	25.4
	KB-03/KR-06	130	18.1	3.6	19	6.2	26.9
	KB-04	81	17.8	3.3	19	6	24.6
	KB-05/KR-25	99	17.3	3.0	18.5	7	23.3
	KR-31	7	17.9	3.1	17.7	14	22.75
	KR-35	43	16.6	3.9	18	7	23.6
	SD-03	6	17.3	3.9	16.4	14.3	24.8
	SKE09	7	20.7	1.7	21	18	23
TOTAL PHOSPHORUS (ppb)	270	6	**33.2**	3.3	34	29	38

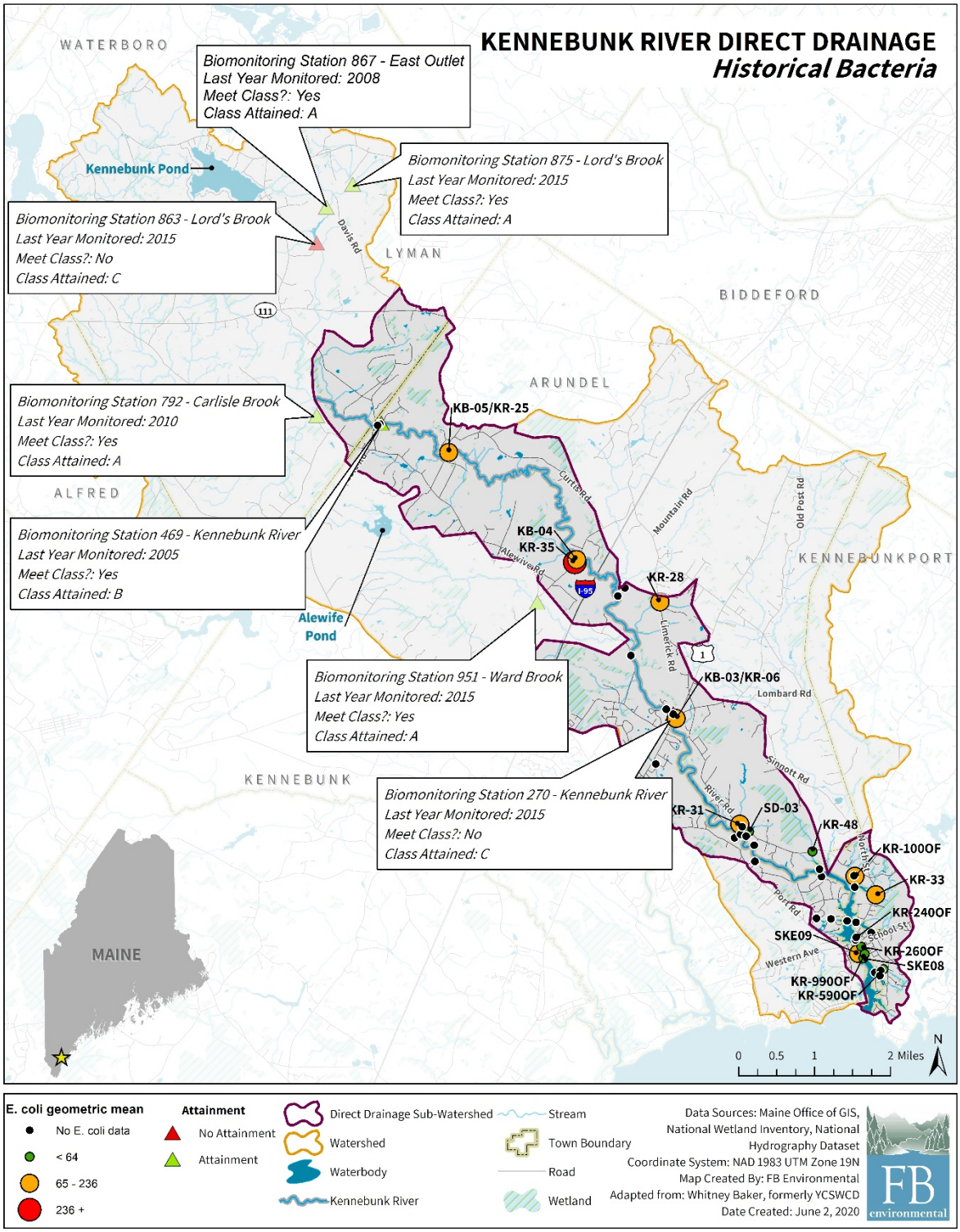


Figure 4. Geometric mean (MPN/100mL) for all sites with historical *E. coli* data within the direct drainage of the Kennebunk River. Represented data includes all years with data truncated to the summer season. Scaled/colored dots indicate the magnitude of the historical geomean and represent the Maine DEP geomean criteria (64 MPN/100mL) and tenth percentile (236 MPN/100mL). Sites with no *E. coli* data are represented as black circles.

LANDUSE

The Kennebunk River direct drainage sub-watershed is 16.6 sq. mi. and represents the entire length of the main stem of the river from its headwaters in Lyman to its intersection with the ocean in Kennebunkport. Land use in the direct drainage area is diverse, with significant tracks of forest along its length (Figure 5). The estuarine portion of the sub-watershed is heavily developed with residential and commercial development. (Developed land includes impervious surfaces such as roads, driveways, sidewalks, and roofs.) Pockets of agriculture (cultivated land and grazing land) exist along the northern portion of the river downstream of Perkins Lane. Other significant landuse include the Cape Arundel Golf Course along the northern banks of the river.

KEY FINDINGS FROM SURVEYING

A watershed survey[5] was conducted on the sections of the river along Alewive Rd and Curtis Rd between Cole Rd and the I-95 corridor. This area consists of significant agriculture with pastures used for grazing as well as row crops and dairy farms. From the roadways, it was difficult to identify any nonpoint source pollution threats to the Kennebunk River.

A stream corridor assessment[6] took place in the Kennebunk River main stem to provide a different perspective on nonpoint source pollution sites and in-stream conditions. This included a 1.9-mi segment above Route 1 and below biomonitoring station 270 as well as a 1.8-mi section downstream of Perkins Lane. Most notable in these surveys was the occurrence of exposed tree roots, large organic debris, and fallen or leaning trees and fence posts. Areas of significant bank erosion were visible along the channel. Several areas had soft sediment beds and high turbidity below the confluence with Ward Brook, which indicates mobile sediments. Water levels were generally low at the time of survey. Low water levels and high banks prevented observers from documenting the land use beyond the near riparian banks.

Proximate and environmental stressors are listed individually for each sub-watershed for the major tributaries. Because of mixing and dilution in the main stem of the Kennebunk River, it is difficult to identify the specific proximate stressors and causal pathways on the main stem. Observations from the stream corridor survey suggest that turbidity, velocity, and poor habitat are key stressors on the main stem for aquatic organisms. Elevated fecal indicator bacteria *(E. coli* and *Entero*) is a key environmental stressor on the main stem that is the cause of the bacteria impairment on the river.

Photos taken in the Kennebunk River. (Left) exposed tree roots with undercut banks, (middle) high turbidity along the main stem, and (right) a forested section of the Kennebunk River.

[5] A watershed inventory is a road survey that identifies possible sources of nonpoint source pollution and focused on development and land use throughout the watershed around hotspot areas.

[6] A stream corridor survey is an in-stream corridor assessment that provides information useful for the management of stream water quality, habitats, fisheries, and riparian lands by identifying streams, reaches or sites having high quality habitat; having moderately or highly degraded habitat; or significant pollution problems that are in need of more detailed follow-up survey or assessment work

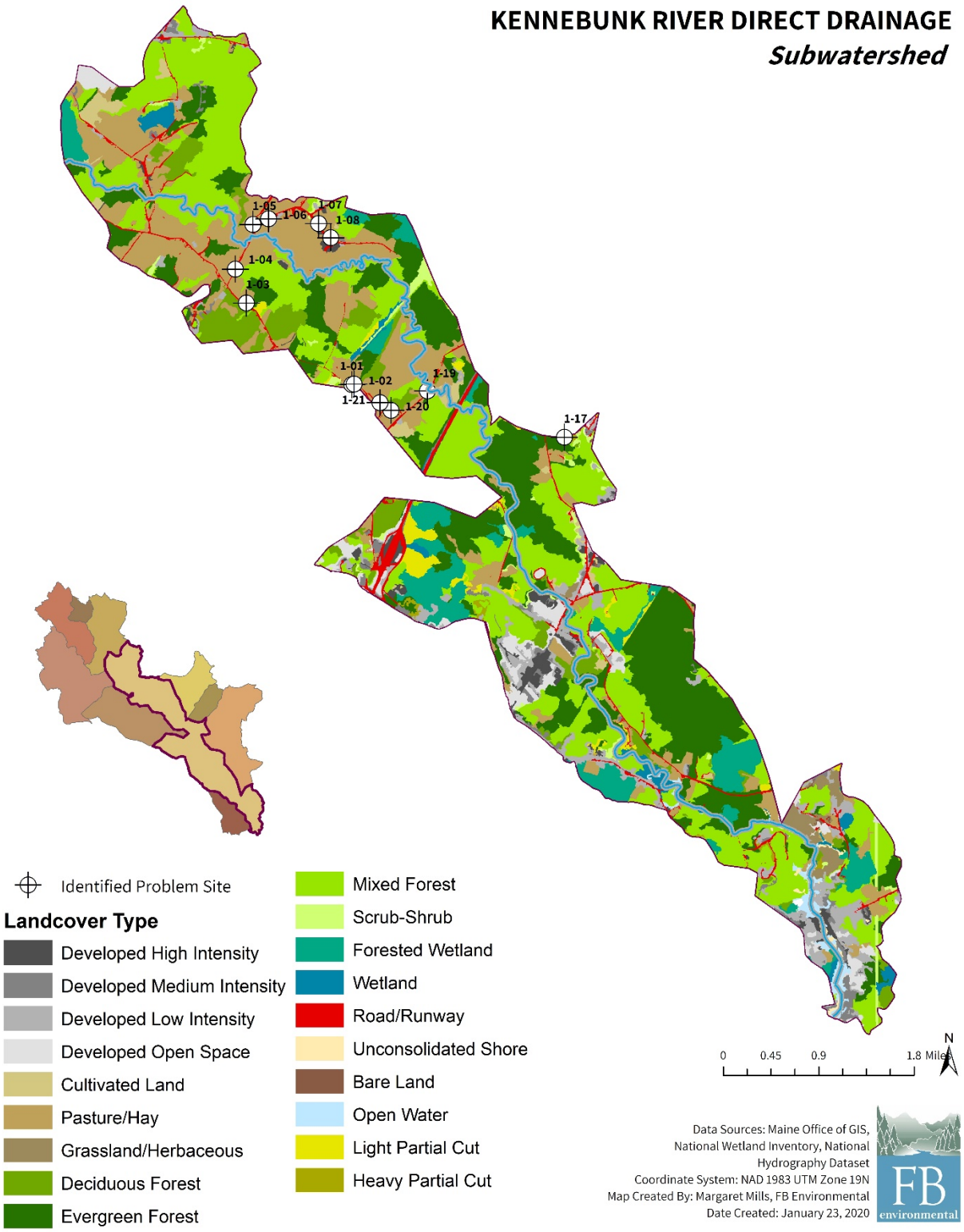


Figure 5. Land cover within the direct drainage of the Kennebunk River main stem.

CARLISLE BROOK

Biomonitoring stations: Site S-792 (Walker Road). Attained class in 2010 for biomonitoring data.

WATER QUALITY DATA SUMMARY

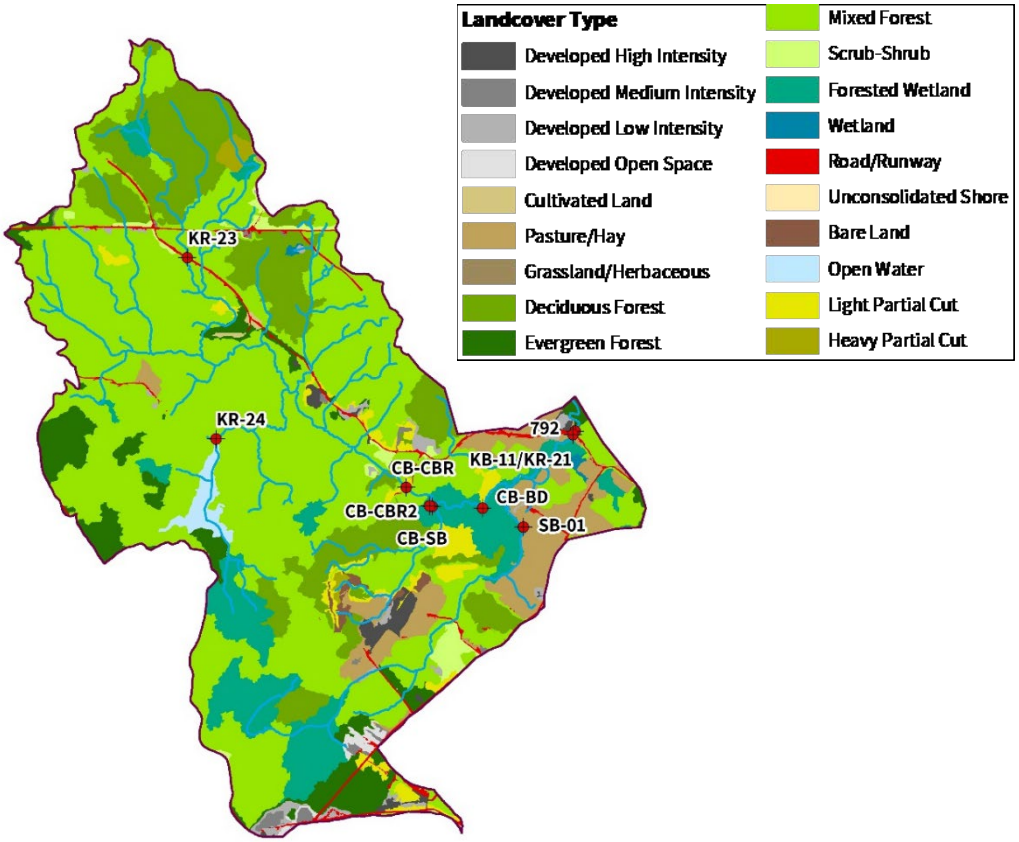
Dissolved Oxygen: Dissolved oxygen data is available for sites 792 (average 7.0 mg/L, n=5), CB-CBR (average 8.1 mg/L, n=4), KB-11/KR-21 (average 6.9 mg/L, n = 17), KB-23 (average 10.8 mg/L, n=1) and KR-24(average 11.5 mg/L, n=1; Figure 6a).

E. coli: A total of 47 samples have been collected for *E. coli* in the Carlisle Brook subwatershed across five sites. Three sites have geometric means exceeding the State criteria for Class B waterbodies (sites CB-SB, KB-11/KR-21, and SB-01), however, only one datapoint exists for CB-SB and three for SB-01 (see Figure 6b).

Optical Brighteners: A total of 32 samples have been collected for optical brighteners across seven sites. Optical brightener geometric means were slightly elevated above 100 µg/L at sites CB-CBR and KB-11/KR-21, at 108.4 µg/L and 113 µg/L, respectively (Figure 6c).

Temperature: Temperature data is available for sites 792 (mean 19.6°C,n=2,522), CB-CBR (2018 only, mean 15.7°C, n=7), KB-11/KR-21 (2017 and 2018, mean 16.6°C, n=20), KB-23 (mean 17.8°C, n=1) and KR-24 (mean 18.2°C, n=1). Mean (geometric) temperature was below the recommended threshold ofv24°C for aquatic organisms at all sites with a maximum recorded temperature of 24.5°C at site 792 (continuous logging data from 2010; Figure 6d).

Total phosphorus: Three samples at site 792 had a mean total phosphorus concentration of 35 ppb (Figure 6e).



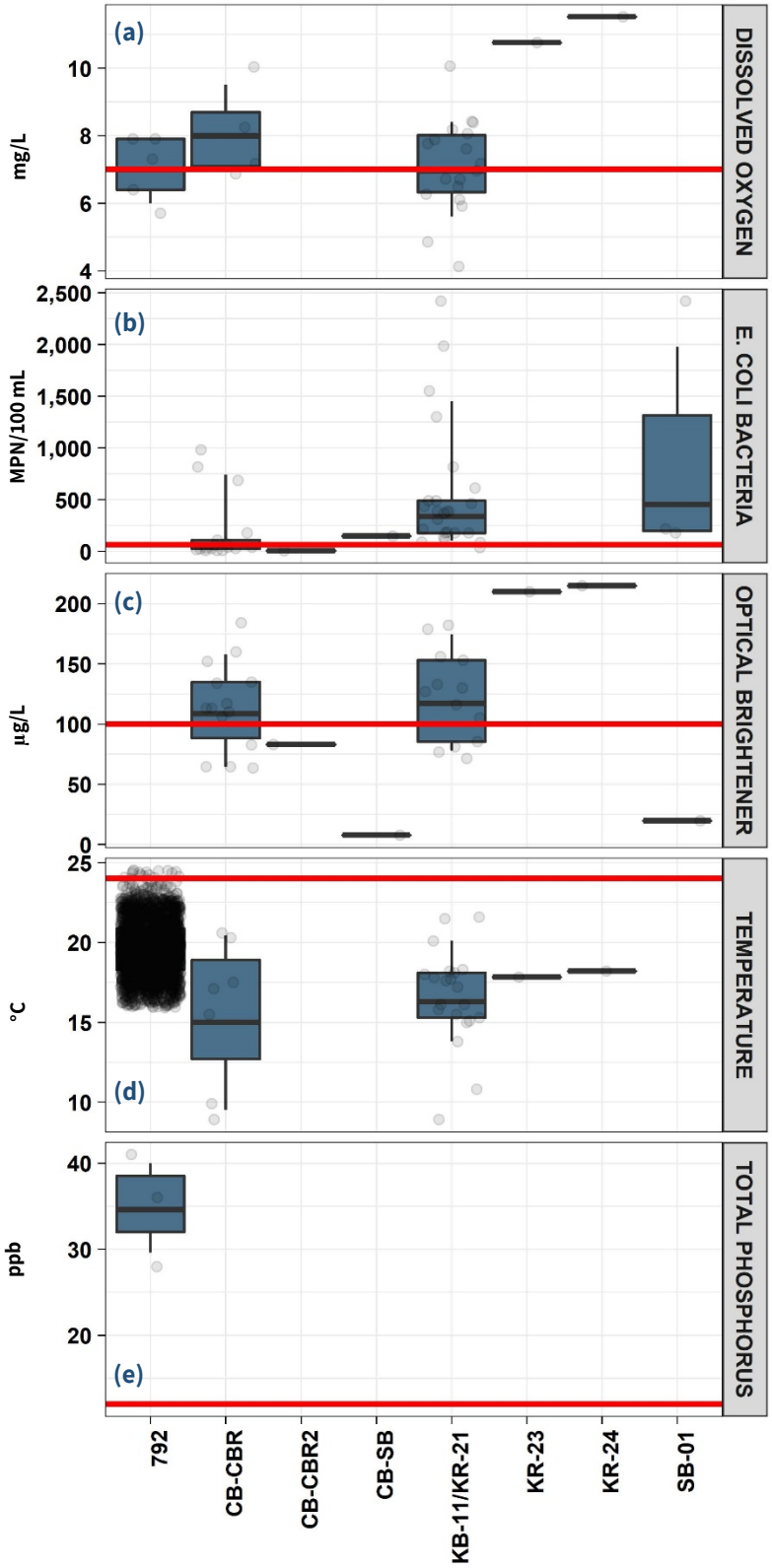


Figure 6. Boxplots showing the geometric mean, 25th, and 75th percentiles for (a) dissolved oxygen, (b) E. coli, (c) optical brighteners, (d) temperature, and (e) total phosphorus in the Carlisle Brook sub-watershed. Temperature at site 792 reflect a continuous monitoring device. *The red line indicates applicable state and federal thresholds for each parameter (refer to Table 1).*

LAND USE

The Carlisle Brook sub-watershed is 8.9 sq. mi. and is located at the headwaters of the Kennebunk River watershed. It is in the Towns of Lyman and Alfred. It has two main branches, one to the northwest and one to the southwest. It is predominantly forested (deciduous and mixed forest) with agriculture and cultivated land in the southeast corner before its intersection with the Kennebunk River.

KEY FINDINGS FROM SURVEYING

A stream corridor survey above Walker Road was attempted but beaver ponding limited access because of deep pools. The channel was wide and too deep for walking. Surveyors met with stakeholders from the Carlisle Academy for Integrative Therapy & Sports and were able to view the stream channel from this location at a later date. One aging culvert was causing a minor back-up of water into a field on Drown Road (a Town owned and maintained roadway). Otherwise, no notable threats were identified in the surveys outside of the potential impact from beaver, and livestock.

NONPOINT SOURCE STRESSORS

Proximate stressors: Data too limited to identify proximate stressors.

Environmental stressors: Elevated bacteria, ponding, and low water velocity.

Possible sources: Livestock farms, manure, beaver dams, logging, and excavation.



Photos taken in the Carlisle Brook watershed. (Left) ponding caused by a beaver upstream of Walker Road, (middle) fields at Carlisle Academy Integrative Therapy & Sports, and (right) ponding on a small tributary of Carlisle Brook. Numerous small tributaries feed into Carlisle Brook that have not been surveyed.

DUCK BROOK

Biomonitoring stations: None

WATER QUALITY DATA SUMMARY

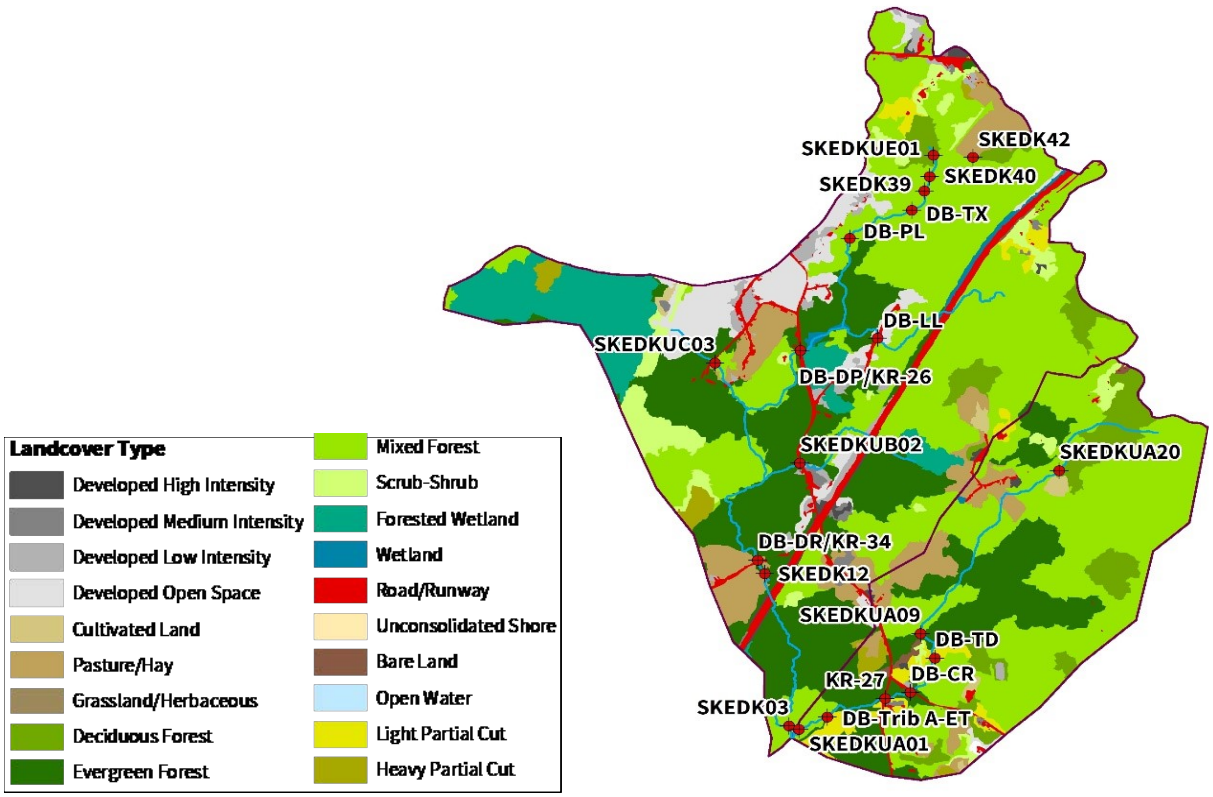
Dissolved Oxygen: A total of 88 samples have been collected for dissolved oxygen across 17 sites. Mean (geometric) dissolved oxygen concentration is above the water quality criteria for class B surface waters of 7 mg/L at only three sites (KR-27, SKEDK03, and SKEDKUA01; Figure 7a).

E. coli: A total of 302 samples have been collected for *E. coli* in the Duck Brook subwatershed across 22 sites. All sites have geometric means exceeding the State criteria for Class B waterbodies of 64 MPN/100 mL except sites SKEDK42 and SKEDKUC03 (Figure 7b).

Optical Brighteners: A total of 143 samples have been collected for Optical Brighteners across 17 sites. The only sites with optical brightener geometric means below 100 ug/L are SKEDKUA20 (96.6 µg/L) and SKEDKUC03 (97.6 µg/L; Figure 7c).

Temperature: Temperature data is available for 21 sites in the Duck Brook sub-watershed. Mean (geometric) temperature was below the recommended threshold of 24°C for aquatic organisms at all sites, however maximum recorded temperature at two sites was above the threshold (site DB-DP/KR-26 at 27.6°C and site SKEDK12 at 24.5°C, n= 22 and 11, respectively; Figure 7d).

Total phosphorus: No total phosphorus data is available within the Duck Brook sub-watershed.



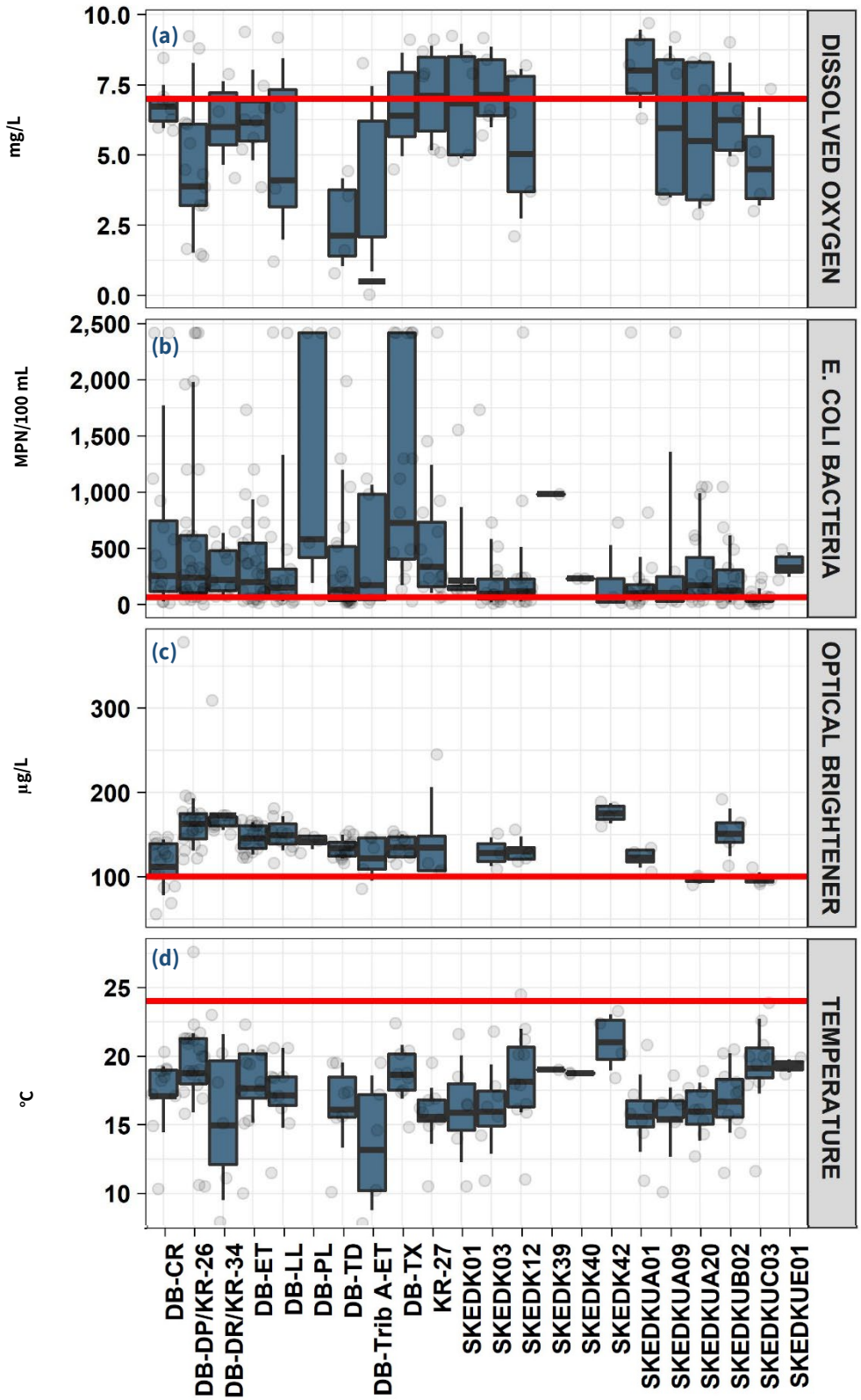


Figure 7. Boxplots showing the geometric mean, 25th, and 75th percentiles for (a) dissolved oxygen, (b) *E. coli*, (c) optical brighteners, and (d) temperature. *The red line indicates applicable state and federal thresholds for each parameter (refer to Table 1)*

LAND USE

Duck Brook and the Duck Brook Tributary A sub-watershed are 5.2 sq. mi. and are located in the central northern portion of the Kennebunk River watershed, in the Town of Arundel. Duck Brook and Duck Brook Tributary A each have one main branch running north to south before joining the Kennebunk River main stem. The sub-watersheds are predominantly forested (deciduous and evergreen) with agriculture and cultivated land present in both. The Duck Brook watershed also contains some low intensity residential development.

KEY FINDINGS FROM SURVEYING

In 2019, a stream corridor assessment was performed on a 0.8-mile segment of Duck Brook Tributary A (from the confluence with Duck Brook up to the Talbot Road crossing). An unusual conditions assessment[7] was performed on this segment with the following key observations:

- Bank erosion and slumping across multiple sections with steep banks.
- A small drainage with a mucky, oily sheen and bright green algae located just upstream of the Limerick Rd crossing.

In addition, the Duck Brook sub-watershed was targeted for the watershed survey. Key findings from this survey included:

- Livestock and improper manure storage (not located directly in a waterbody).
- Unstable construction sites.

NONPOINT SOURCE STRESSORS

Proximate stressors: Low water velocity.

Environmental stressors: Elevated bacteria, stagnant, low gradient stream.

Possible sources: Agriculture, high residential development pressure.

Photos taken in the Duck Brook watershed. (Left) a drainage entering the tributary above, (middle) bank erosion, (right) outlet of the Duck Brook Tributary A at the eastern trail. Small tributaries feeding into Duck Brook Tributary A were not surveyed.

[7] An unusual conditions assessment included walking the full reach and identifying anything 'unusual' that could be a cause for concern. Note that the observers did not always know if it was a concern (e.g. a pipe discharge) but rather marked the site for follow-up.

GOFF MILL BROOK

Biomonitoring stations: none

WATER QUALITY DATA SUMMARY

Significant sampling at Goff Mill Brook occurred for the first time in 2019, with the exception of only a few datapoints at sites KR-29, KB-15/KR-61, KR-36, KR-56, and KR-62.

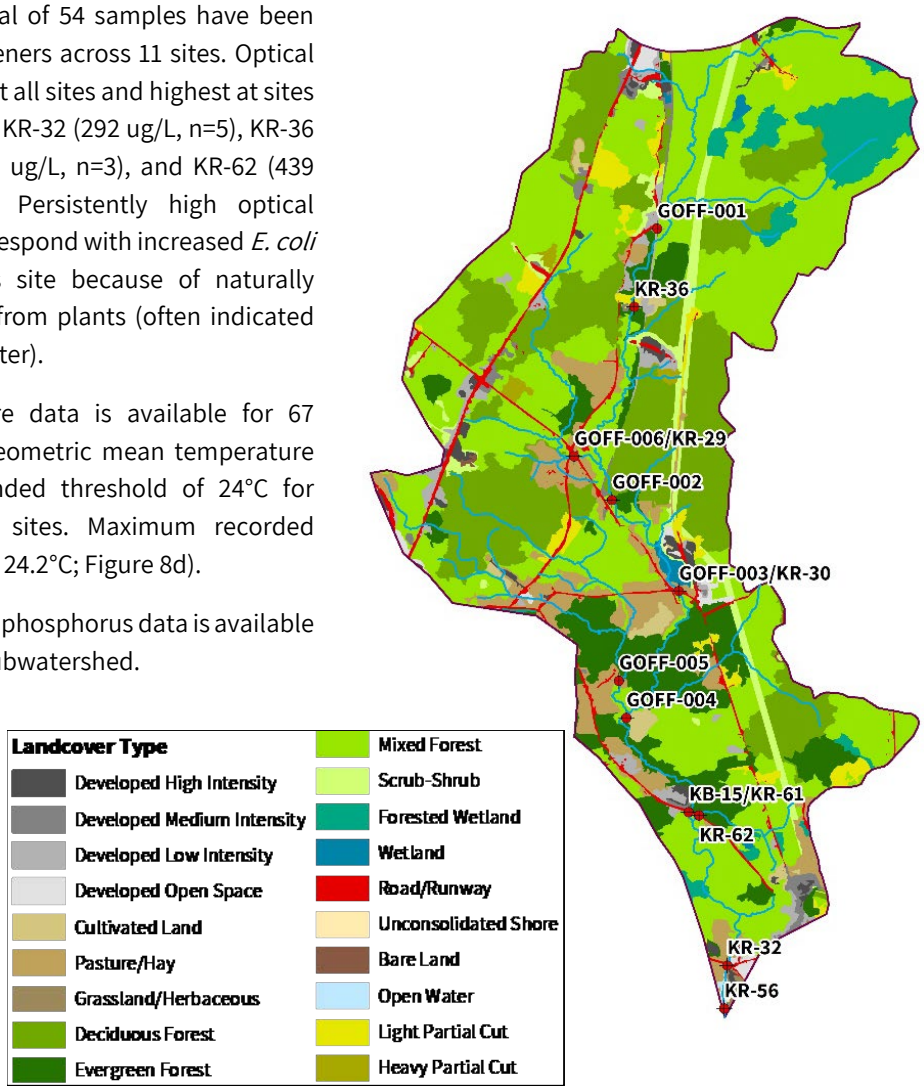
Dissolved Oxygen: A total of 64 samples have been collected for dissolved oxygen in the Goff Mill Brook sub-watershed across 11 sites. Mean (geometric) dissolved oxygen was lowest at site GOFF-001 at 5.7 mg/L, and is below the Maine water quality criteria for Class B surface waters of 7 ppm at 4 sites (GOFF-001, GOFF-003/KR-30, GOFF-006/KR-29, AND KB-15/KR-61) (Figure 8a).

E. coli: A total of 57 samples have been collected for *E. coli* in the Goff Mill Brook tributary across nine sites. All nine sites have geometric means exceeding the State criteria for Class B waterbodies. GOFF-002 and GOFF-006/KR-29 are the highest at 298.9 MPN/100 mL and 460.7 MPN/100 mL, respectively (Figure 8b).

Optical Brighteners: A total of 54 samples have been collected for optical brighteners across 11 sites. Optical brighteners were elevated at all sites and highest at sites GOFF-005 (178.4 ug/L, n=5), KR-32 (292 ug/L, n=5), KR-36 (297 ug/L, n=1), KR-56 (226 ug/L, n=3), and KR-62 (439 ug/L, n=1) (Figure 8c). Persistently high optical brighteners that do not correspond with increased *E. coli* could be elevated at this site because of naturally occurring tannins leached from plants (often indicated by brown coloring in the water).

Temperature: Temperature data is available for 67 samples across 11 sites. Geometric mean temperature was below the recommended threshold of 24°C for aquatic organisms at all sites. Maximum recorded temperature at site KR-56 is 24.2°C; Figure 8d).

Total phosphorus: No total phosphorus data is available within the Goff Mill Brook subwatershed.



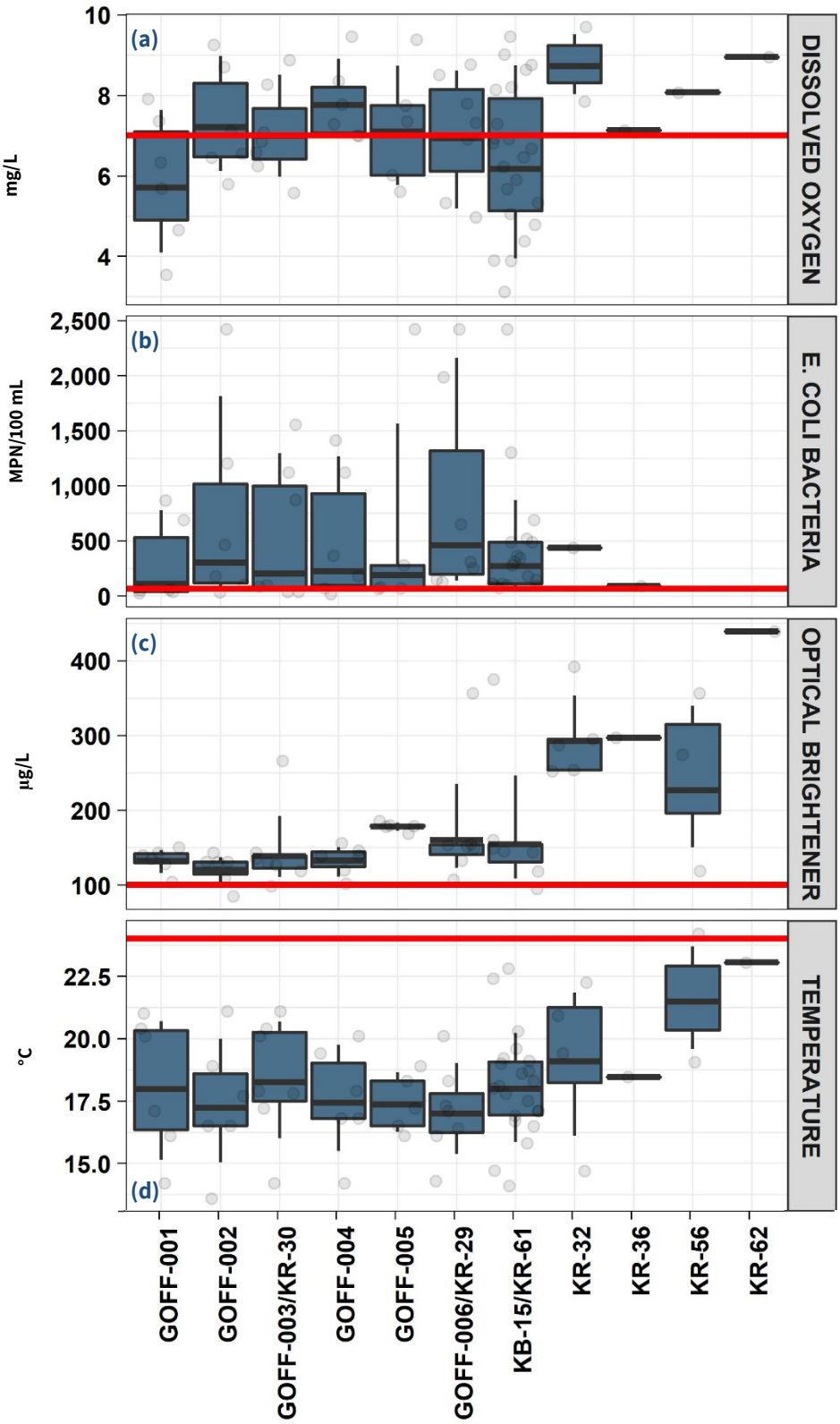


Figure 8. Boxplots showing the geometric mean, 25th, and 75th percentiles for (a) dissolved oxygen, (b) *E. coli*, (c) optical brighteners, and (d) temperature in the Goff Mill Brook sub-watershed. *The red line indicates applicable state and federal thresholds for each parameter (refer to Table 1)*

LAND USE

The Goff Mill Brook sub-watershed is 8.1 sq. mi. and is located at the eastern edge of Kennebunk River watershed. It is in the Towns of Arundel, Kennebunkport, and a small portion of Biddeford. It has one main branch, running north to south with several tributaries that enter it, including a major forked tributary entering from the west. It is predominantly forested (deciduous and mixed forest) in the northern portion with agriculture and cultivated land present in the central and southern sub-watershed.

KEY FINDINGS FROM SURVEYING

No surveying was completed in the Goff Mill Brook watershed in 2019 for the Watershed-Based Management Plan development.

NONPOINT SOURCE STRESSORS

Proximate stressors: Low dissolved oxygen, high temperature, low water velocity.

Environmental stressors: Elevated bacteria.

Possible sources: Low gradient stream, yard waste in stream, undersized culverts, undercut riparian banks, livestock.

Photos taken in the Goff Mill Brook watershed during water quality sampling. (Left) ponding upstream of Log Cabin Road, (middle) site GOFF-04 near Sinnot Road and (right) Wells National Estuarine Research Reserve WNERR) intern Jacob Watson collecting water at GOFF-003. Photo credit: Jake Aman, WNERR.

LORDS BROOK

Biomonitoring stations: S-863 did not attain class in 2008 or 2010. S-875 did not attain class in 2008 and attained class A in 2015. S-862 did not attain class in 2015.

WATER QUALITY DATA SUMMARY

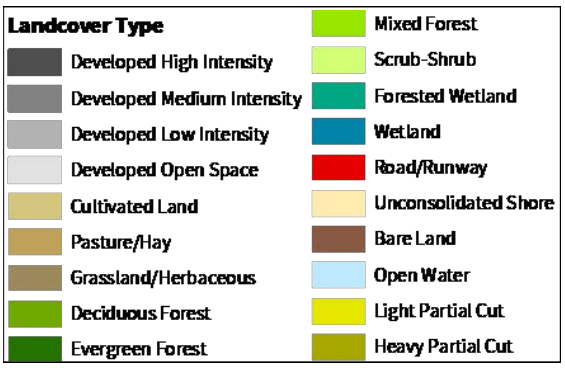
Dissolved Oxygen: A total of 44 samples have been collected for dissolved oxygen across 11 sites. Mean (geometric) dissolved oxygen concentration is above the water quality criteria for class B surface waters of 7 mg/L at all sites except for 875, KR-13, and KR-16 (note that n=1 for KR-13 and KR-16; Figure 9a).

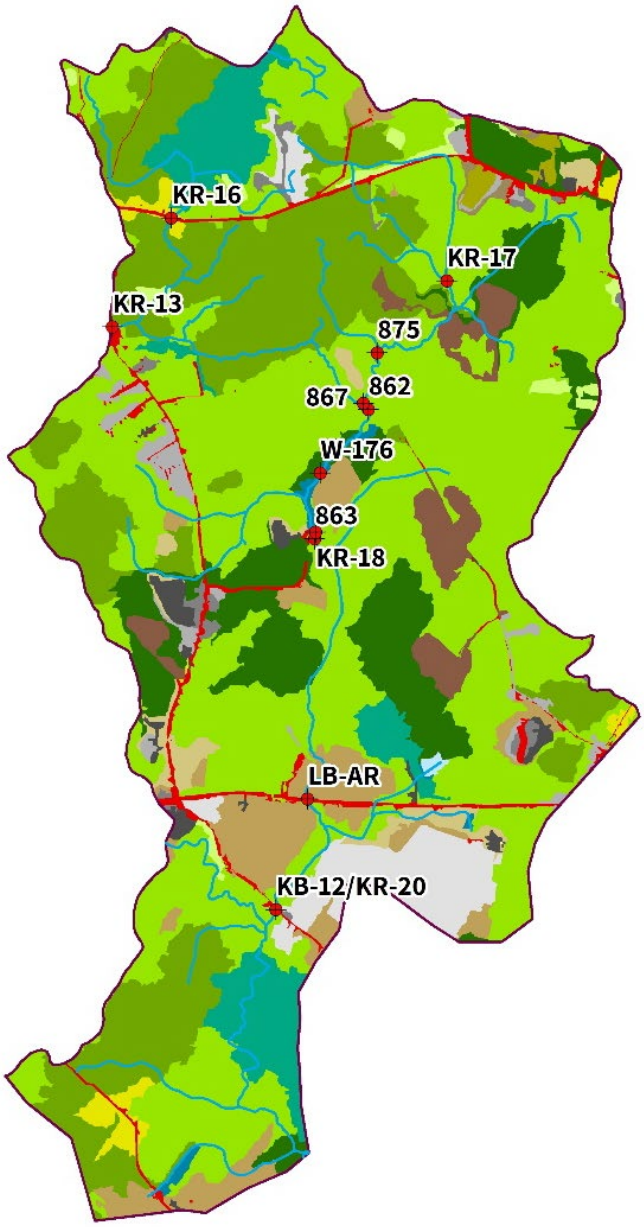
E. coli: A total of 22 samples have been collected for *E. coli* in the Lords Brook subwatershed across two sites (KB-12/KR-20, and LB-AR). Both sites have geometric means exceeding the State criteria for Class B waterbodies of 64 MPN/100 mL (309.5 MPN/100mL and 184.9 MPN/100mL, respectively; Figure 9b).

Optical Brighteners: A total of 15 samples have been collected for Optical Brighteners at six sites. All sites are above 100ug/L except KR-13, and LB-AR). Only one datapoint exists at all sites except for LB-AR with 10 points; Figure 9c).

Temperature: Temperature data is available for 11 sites and has been collected on a continuous monitoring device for sites 863, 867, and 875. Mean temperature was highest at site KR-13 (mean of 22.5°C, n=15; Figure 9d).

Total phosphorus: Total phosphorus data is available at five site and is elevated significantly at all recorded sites; Figure 9e).





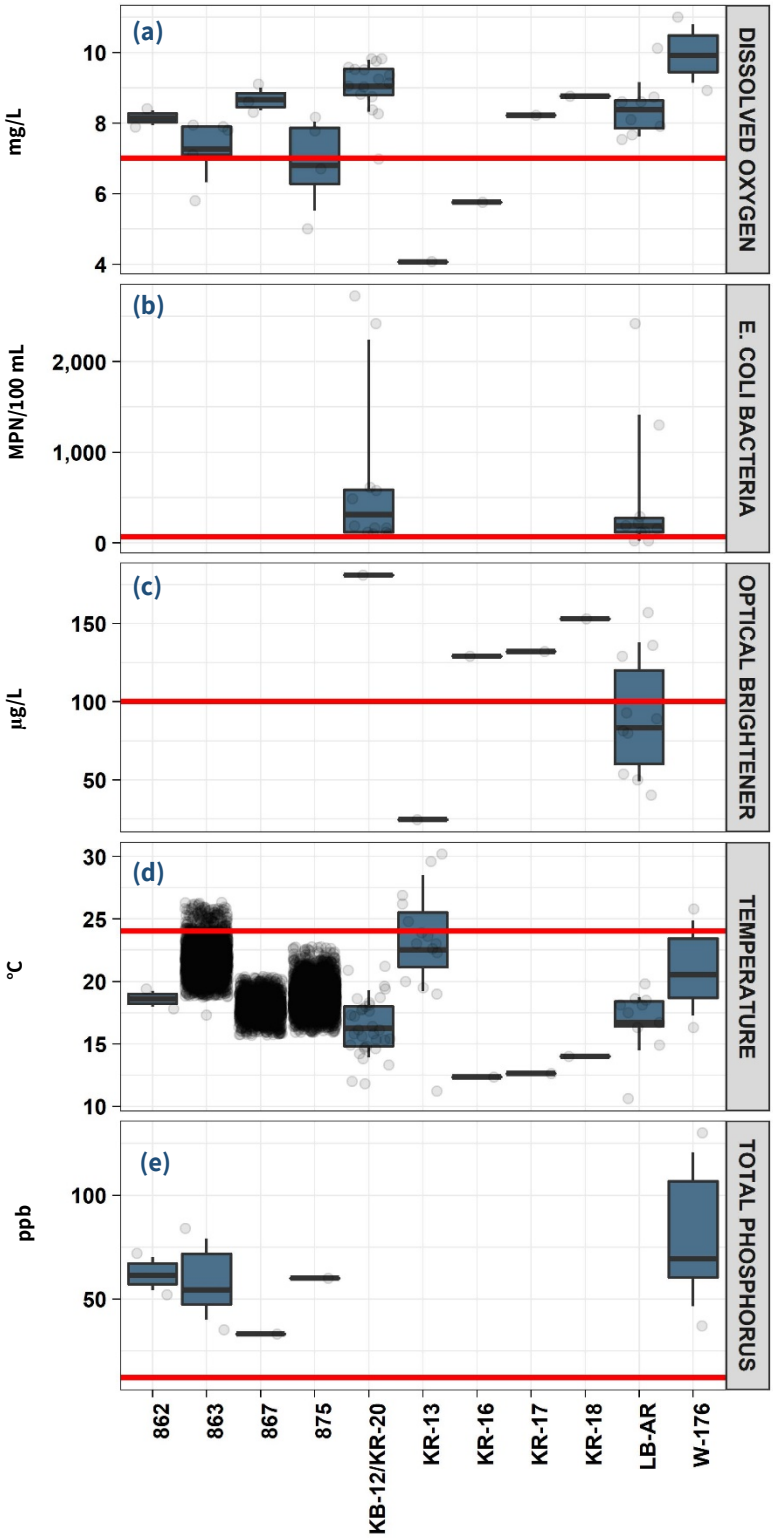


Figure 9. Boxplots showing the geometric mean, 25th, and 75th percentiles for (a) dissolved oxygen, (b) *E. coli*, (c) optical brighteners, and (d) temperature, and (e) total phosphorus in the Lord's Brook sub-watershed. Temperature at site 863, 867, and 875 reflect a continuous monitoring device. *The red line indicates applicable state and federal thresholds for each parameter (refer to Table 1)*

LAND USE

The Lords Brook sub-watershed is 5.3 sq. mi. and is located in the northern portion of the Kennebunk River watershed at the Kennebunk River headwaters. It is in the Town of Lyman. Lords Brook has one main branch running north to south with multiple tributaries joining it. The sub-watershed is predominantly forested (deciduous, mixed, and evergreen) with agriculture and cultivated land present throughout the area and developed land present in the southern portion of the subwatershed.

KEY FINDINGS FROM SURVEYING

A watershed survey was conducted on the public roads in the Lord's Brook sub-watershed in July and was followed by a survey of some private roads (residents were provided advanced notice) in August 2019.

Survey results from the public and private roads in this sub-watershed identified many gravel roads with road surface, shoulder, and ditch erosion. Additionally, roads had cross-drainage culverts that were undersized and had unstable inlet and outlet banks. In one area, algae mats were visible in the stream (from the roadway) and it was clearly a waterfowl and wildlife gathering area. Multiple areas were experiencing the smell of manure and had uncovered manure piles.

NONPOINT SOURCE STRESSORS

Proximate stressors: Data too limited to identify proximate stressors.

Environmental stressors: Elevated bacteria.

Possible sources: Road erosion, agriculture/manure storage, logging, and impoundments and wildlife/waterfowl gathering.

Photos taken in the Lord's Brook sub-watershed. (Left) an unstable culvert bank on Kennebunk Pond Rd, (middle) mobile sediment alongside a bridge crossing Lord's Brook on Lords Road, (right) algae mats in a wetland area alongside the roadway on Waterboro Road near the intersection with Winterwood Rd.

WARD BROOK

Biomonitoring stations: S-951 attained Class A in 2015.

WATER QUALITY DATA SUMMARY

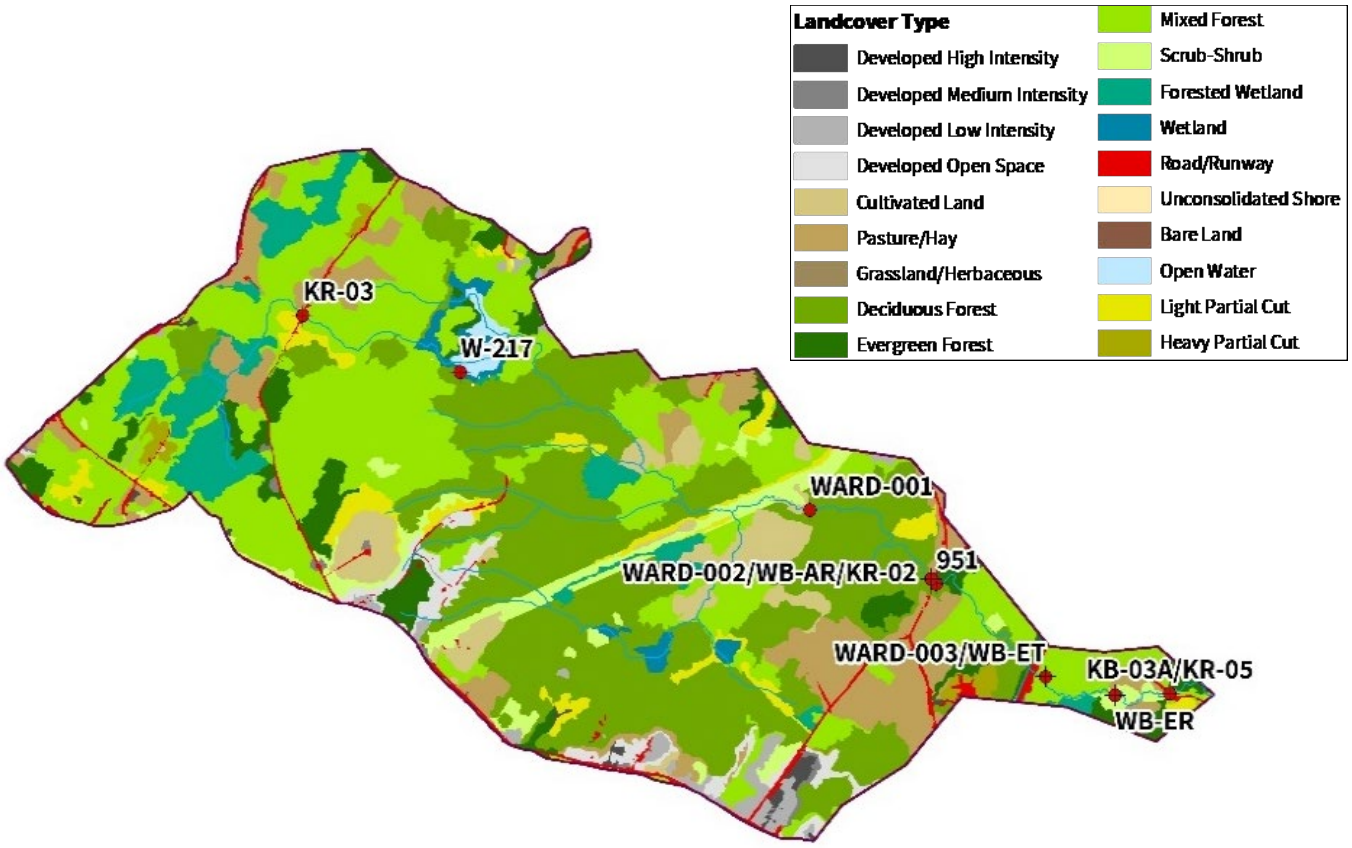
Dissolved Oxygen: A total of 100 samples have been collected for dissolved oxygen across eight sites. Mean (geometric) dissolved oxygen concentration is below the water quality criteria for class B surface waters of 7 mg/L at sites WARD-001 and WB-ER, at 6.4 mg/L and 6.9 mg/L, respectively (also note that n = 1 for KR-03; Figure 10a).

E. coli: A total of 97 samples have been collected for *E. coli* in the Ward Brook subwatershed across five sites. All sites have geometric means exceeding the State criteria for Class B waterbodies of 64 MPN/100 mL. Sites WARD-003/WB-ET has the highest geomean at 190.8 MPN/100 mL and site WARD-002/WB-AR/KR-02 has the lowest geomean at 85.9 MPN/100 mL (Figure 10b).

Optical Brighteners: A total of 38 samples have been collected for Optical Brighteners across six sites. Optical brightener geometric means was elevated at site KR-03 at 237 ug/L, but only one sample has been taken (Figure 10c).

Temperature: Temperature data is available for ten sites. Mean (geometric) temperature was below the recommended threshold of 24°C at all sites with the maximum mean temperature at site W-217 (geomean of 22.7°C, n=2; Figure 10d).

Total phosphorus: Total phosphorus data exists at two sites. One sampling point at site 951 at 31 ppb and two at site W-217 with a mean of 18 ppb, both of which are above the threshold of 12 ppb (Figure 10e).



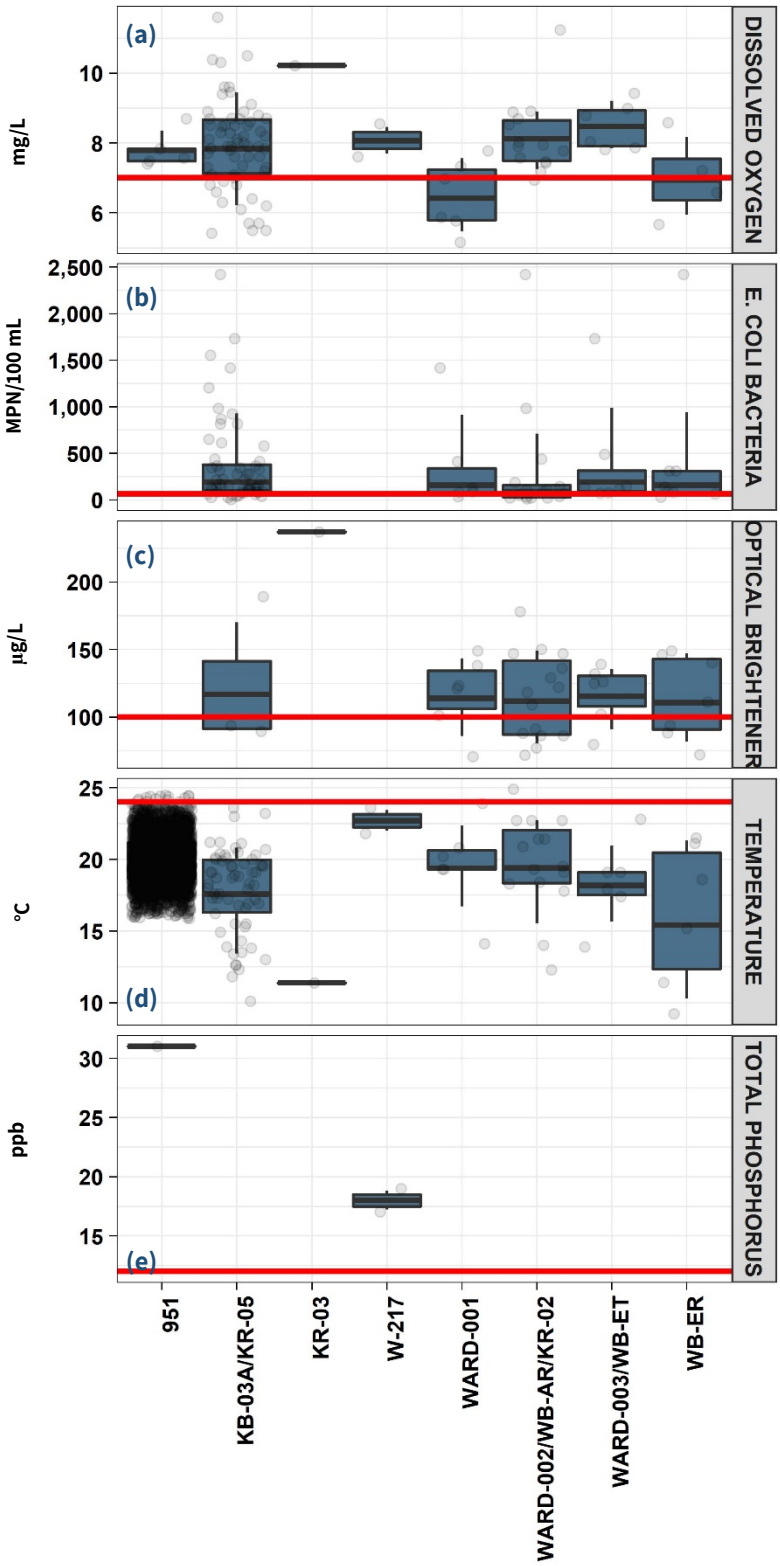


Figure 10. Boxplots showing the geometric mean, 25th, and 75th percentiles for (a) dissolved oxygen, (b) *E. coli*, (c) optical brighteners, and (d) temperature in the Ward Brook sub-watershed. Temperature at site 951 represents a continuous monitoring device. *The red line indicates applicable state and federal thresholds for each parameter (refer to Table 1)*

LAND USE

The Ward Brook sub-watershed is 6.8 sq. mi. and is located in the central southern portion of the Kennebunk River watershed. It is in the Towns of Lyman and Kennebunk. It has one main branch running northwest to southeast with several tributaries joining from the south before joining with the Kennebunk River main stem. The sub-watershed is predominantly forested (deciduous and mixed) with agriculture and cultivated land present mostly in the southeastern end.

KEY FINDINGS FROM SURVEYING

A stream corridor survey was conducted on a 1.4-mile segment of Ward Brook above its confluence with the Kennebunk River. Unusual conditions were noted at three locations in the stream segment and represented the following:

- a horse and chicken farm with a drainage ditch entering the stream
- a stream-side structure and bonfire area with no bathroom facilities
- a crossing of Ward Brook by the Eastern Trail. The Eastern Trail provides recreational access to a significant number of users and represents a threat from dog or horse waste.

NONPOINT SOURCE STRESSORS

Proximate stressors: High water temperature, elevated baseflow.

Environmental stressors: Elevated bacteria at downstream sites.

Possible sources: Beaver dams, undersized culverts, human and dog waste (from recreational trail users).

Photos taken in the Ward Brook sub-watershed. (Left and right) Ward Brook crossing at the eastern trail.

VII. SUMMARY AND RECOMMENDATIONS FOR NEXT STEPS

WATER QUALITY SUMMARY

Compiling historical data showed long term trends of elevated bacteria (*E. coli*, and/or Enterococci) in the Kennebunk River and its tributaries, with notably very high bacteria in Lord's Brook and Carlisle Brook and high bacteria in Duck Brook, Goff Mill Brook and Ward Brook as well as the mid to lower main stem of the Kennebunk River (Table 5). Carlisle Brook, Duck Brook, Goff Mill Brook, Ward Brook, and the mid main stem by Downing Road and lower main stem by Durrell's bridge have also historically experienced low dissolved oxygen. Water temperatures are warm at the mid main stem by Route 1. Total phosphorus is elevated in Lords Brook, Carlisle Brook, Ward Brook, data at the mid main stem by Route 1, indicating potential nutrient enrichment and should be investigated. These data are a reflection of all historical monitoring data, and therefore, should be paired with more recent analyses by the Maine Healthy Beaches Program and Maine DEP to monitor changes and improvements.

Table 5. Summarized stressors in the Kennebunk River and its tributaries, used to help determine priority stressors by subwatershed. Sites were analyzed based on the criteria presented in Table 6. All historical data between April 15 and October 31 was included. *Table created by K. Feindel, Maine DEP.*

Subwatershed	Site #	Dissolved Oxygen	Chloride and SPC	Bacteria	Temperature	Total Phosphorus	Biological Monitoring
Lords Brook	KB-12	Adequate	Good	**Very High**	Good	**High**	**Mixed** (several stations and results)
Carlisle Brook	KB-11	**Poor**	Good	**Very High**	Good	**High**	2010 – Class A
Upper Main Stem – Perkins Ln	KB-05	Good*	Good	Moderately High	Good	-	2000 – Class B 2005 – Class B
Mid Main Stem – Downing Rd	KB-04	**Poor**	Good	**High**	Good	-	-
Duck Brook	DB-ET	**Poor**	Slightly High	**High**	Good	-	-
Ward Brook	KB-03A	**Poor**	Slightly High	**High**	Good	**High**	2015 – Class A
Mid Main Stem – Route 1	KB-03	Good	Good	**High**	**Warm**	**High**	**2015 – Non-attaining** 2010 – Class B **2005 – Non-attaining**
Lower Main Stem – Durrell's Bridge	KB-02	**Poor**	-	**High**	Moderately Warm	-	-
Goff Mill Brook	KB-15	**Poor**	Slightly High	**High**	Good	-	-
Estuary Main Stem – Dock Square	KB-01	Adequate	-	Moderately High	Good	-	-

Table 6. Water quality criteria indicators used to determine overall water quality summary used to help determine priority stressors by subwatershed. These are not criteria for listing purposes. *Table created by K. Feindel, Maine DEP.*

Parameter	Very Poor/ Very High/ Very Warm	Poor/ High/ Warm	Adequate/ Slightly High/ Moderately Warm	Good
Dissolved Oxygen	More than 25% < 5 mg/l **OR** 3 or more < 4 mg/l	More than 25% < 7 mg/l, but ≥ 5 mg/l **OR** 3 or more ≤ 6 mg/l, but ≥ 4 mg/l	25% or less < 7 mg/l, but ≥ 6 mg/l	2 or less < 7 mg/l, but ≥ 6 mg/l
Specific Conductance	Maximum ≥ 900 µs/cm	Maximum 450 to 899 µs/cm	Maximum 200 to 449 µs/cm	Maximum < 200 µs/cm
Bacteria – E. Coli	Geomean ≥ 300 MPN	Geomean 150 to 299 MPN	Geomean 65 to 149 MPN	Geomean ≤ 64 MPN
Bacteria – Enterococcus	Geomean ≥ 105 MPN	Geomean 36 to 104 MPN	Geomean 9 to 35 MPN	Geomean ≤ 8 MPN
Temperature	Max > 28˚C Mean > 24˚C	Max 27 to 28˚C Mean 23 to 24˚C	Max 25 to 26˚C Mean 20 to 22˚C	Max ≤ 24˚C Mean ≤ 19˚C

RECOMMENDATIONS FOR NEXT STEPS

The purpose of this water quality summary and stressor analysis document is to provide guidance to the steering committee and the technical advisory committee in shaping the action plan in the final Watershed-Based Management Plan for the Kennebunk River. This action plan will outline executable steps to address water quality impairments in the main stem of the Kennebunk River and its tributaries. Additionally, it will outline protection measures for waterways with declining water quality. This action plan should focus on both structural and non-structural action items. Structural action items are those that use the construction of stormwater control devices to reduce stormwater nonpoint source pollution (e.g. bioretention basins, vegetated buffers, underground storage). Non-structural action items hold equal importance in an effective Watershed-Based Management Plan and contain actions such as changes to regulatory policy (e.g. ordinances), maintenance, and education and outreach. We recommend that structural and non-structural action items should be tailored to each sub-watershed and community, as outlined in this stressor guide. A draft action plan should be presented to the public for their input and feedback prior to finalizing the Plan.

KEY RECOMMENDATIONS

1. **Create** an action plan for the Kennebunk River Watershed-Based Management Plan using this guidance document.
2. **Address** both structural and non-structural action items.
3. **Organize** action plan by tributary and by community.
4. **Design** an enhanced baseline monitoring program that allows for inter-annual comparisons at representative sites.

In addition to action items built upon current monitoring data, we recommend that the final Plan include an organized monitoring plan for the Kennebunk River and its tributaries. Investigative monitoring from various organizations limits the ability to synthesize changes at specific sites and tributaries over-time. We suggest a unified monitoring approach across organizations to establish baseline conditions at a sub-set of sites. Any investigative monitoring would occur above and

beyond these baseline conditions. This could build upon the volunteer river monitoring program (VRMP) work that is already established and should address the tributaries where we have insufficient data to assess proximate and environmental stressors. We recommend that future monitoring efforts be linked to antecedent moisture conditions and precipitation to identify patterns in the indicator parameters discussed in this document.