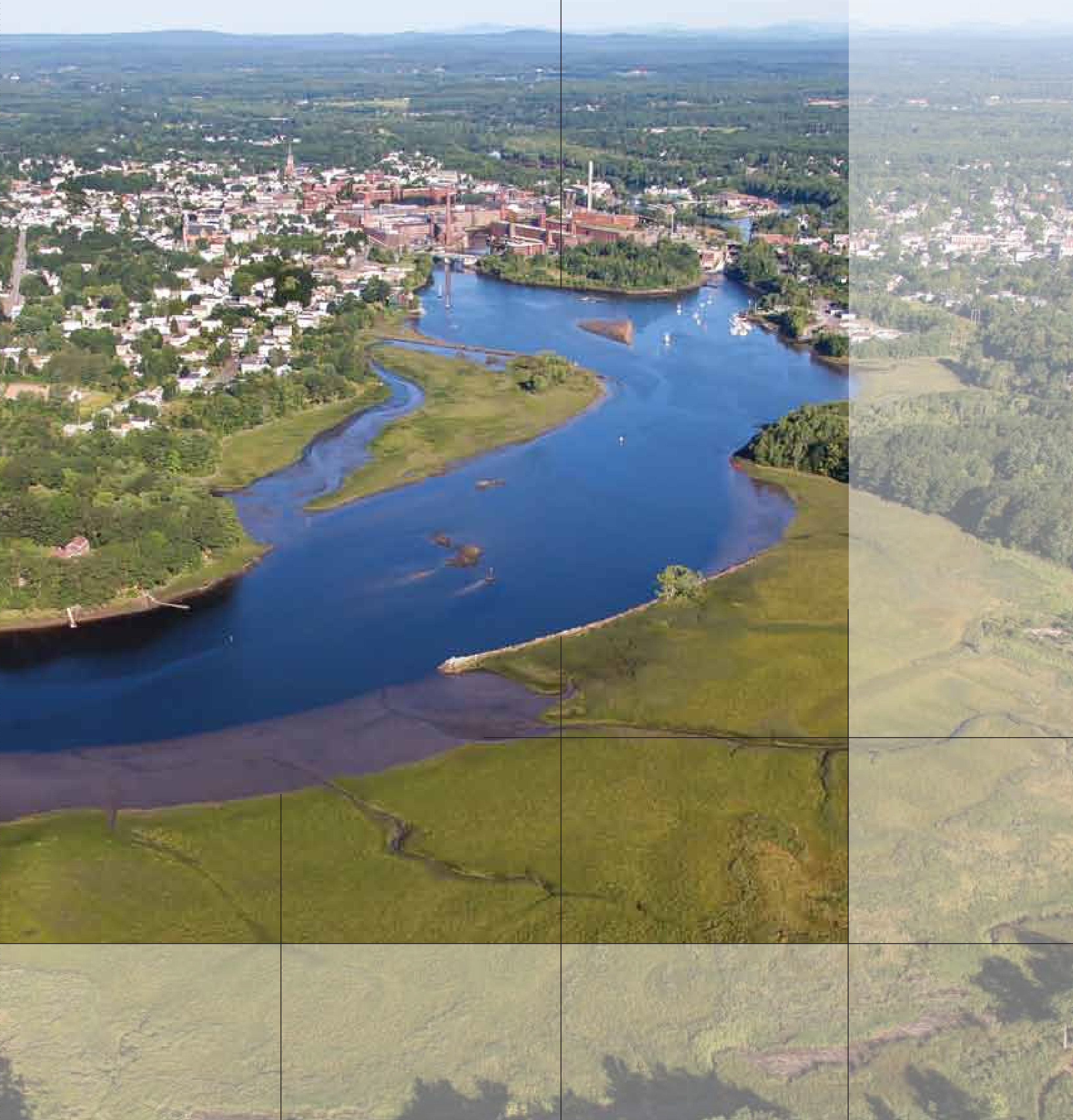
Sustaining the Saco estuary

final report 2015



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Report Editing and Design: Waterview Consulting

CONTENTS

Saco River Corridor Commission · Biddeford-Saco Chamber of Commerce and Industry

About the Stewardship Network

Many people care for the Saco Estuary. Together they form a Stewardship Network protecting water, wildlife and habitats. Residents, visitors and businesses benefit from the efforts of the Stewardship Network. The surprisingly diverse collection of plants, birds and fish discovered by UNE and Wells Reserve researchers is a consequence of the cumulative actions taken by these people to sustain the Saco Estuary and the values most important to the people who live work and play in the region.

360 Acres of Tidal Marsh

Three types of tidal marshes --salt, brackish, and freshwater-- occur here. These marshes improve water quality and provide habitat for many kinds of wildlife.

10 Rare Plants

A surprising diversity of plants live in these marshes, including ten species that are rare in Maine and/or nationally.

MollyMaps 2014

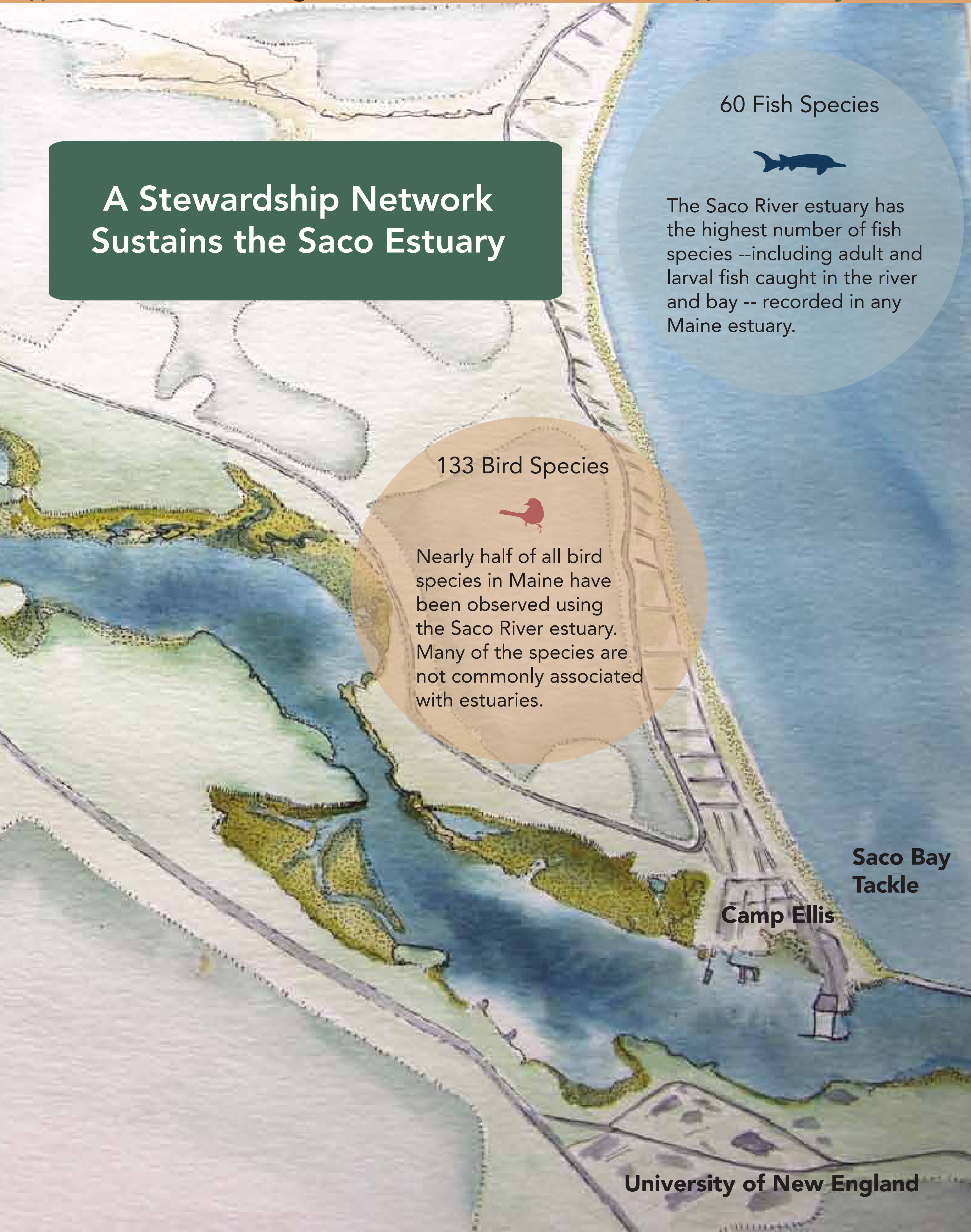
This research is part of Maine's Sustainability Solutions Initiative, a program of the Senator George J. Mitchell Center, which is supported by National Science Foundation award EPS-0904155 to Maine EPSCoR at the University of Maine.

State of Maine: DEP, DMR, DIFW · Wells National Estuarine Research Reserve

Town of Biddeford: Planning Board, Open Space Committee, Conservation Commission, Shellfish Conservation Committee

Town of Saco: Planning Board, Conservation Commission · Saco Valley Land Trust

A Stewardship Network Sustains the Saco Estuary



60 Fish Species

The Saco River estuary has the highest number of fish species --including adult and larval fish caught in the river and bay -- recorded in any Maine estuary.

133 Bird Species

Nearly half of all bird species in Maine have been observed using the Saco River estuary. Many of the species are not commonly associated with estuaries.

Saco River Salmon Club · Biddeford Saco Water · Coastal Waters Commission · Biddeford Pool Land Trust

Rachel Carson National Wildlife Refuge · Friends of Wood Island Lighthouse

CHAPTER 10

WATER QUALITY IN THE SACO RIVER

BY STEPHAN I. ZEEMAN AND TYLER SPILLANE

INTRODUCTION

What does water quality mean? Water quality means different things to different people, but it basically comes down to, how good is the water for living things in and around it? From a scientific standpoint we can measure water chemistry (what are its chemical components), biology (what organisms inhabit the water), or physics (what is its temperature, or is it stratified into temperature layers). From a human perspective we are often interested in aesthetic questions: does it look good, does it taste good, and does it smell good? Water quality is important because it impacts the health of humans and other living creatures that come in contact with it.

STUDY OBJECTIVES—WATER QUALITY

Our objectives for the water quality study were to answer these questions:

1. What are the levels of fecal indicator bacteria, nutrients, chlorophyll, and dissolved oxygen? Are any issues or parameters that should be monitored?
2. What do indicators of water quality tell us about the state of the Saco River?

RESEARCH DESIGN AND METHODS

Sampling

A total of 18 sites along the Saco River watershed from Crawford Notch, NH, to Biddeford, ME, were monitored for indicator bacteria. Sample collection occurred monthly from December 2010 to November 2012, with some additional data collected later. Fourteen sites were directly along the Saco River, while sites 3, 8, and 9 were small tributaries that feed into the river. Sites 15, 16, and 17 were in the estuarine portion of the river with variable salinity levels. Site 18 was at Biddeford Beach adjacent to the river in the Gulf of Maine. Sampling the entire length of the river throughout the year posed its challenges as can be seen in Figure 1.

FIGURE 1 Contrasting sample collections. Top left: Tyler Spillane sampling a partially ice-covered river in Conway, NH. Bottom left: sampling during spring flood at Limington Rapids. Right: sample collection during relatively normal river stage on Little Ossipee River near Limington, ME.

Fecal Indicator Bacteria

Total coliform bacteria and *E. coli* were determined with Colilert-18© and enterococci with Enterolert©, both from IDEXX laboratories. These methods are US EPA approved (Meyers et al. 2007). Samples were collected in sterile 120-ml bottles and volume adjusted to 100 ml. The bottles were kept on ice and in the dark until they reached the laboratory. Reagents were added to each

100-ml sample, thoroughly mixed, and poured into a Quanti-Tray®/2000, which are then heat sealed and incubated. The trays were incubated at 35±0.5°C for 18-22 hours for Colilert-18© and 24 hours or Enterolert©. Most Probable Number (MPN) is calculated from the number of cells that turn yellow (total coliform) or turn yellow and fluoresce under UV light (*E. coli* and enterococci).

Nutrients

Samples were collected in 200-ml polyethylene bottles, stored on ice for transport, and frozen until analyzed. Concentrations of phosphate (PO_4), nitrate + nitrite (NO_3+NO2), ammonia, and silicate (Si) were measured spectrophotometrically using prepackaged Hach chemicals (Hach Company, Loveland CO). For nitrogen compounds in this study, we report only nitrate plus nitrite. In most of our samples, ammonia was not detectable by our analysis techniques.

Chlorophyll

Chlorophyll *a* samples were collected in 200-ml polyethylene bottles and stored on ice for transport to the laboratory. Aliquots of 50-100 ml were then vacuum filtered at < 8 inches Hg onto Whatman GF/F glass fiber filters. The filters were ground with a Ten Broeck tissue grinder, transferred to conical centrifuge tubes, and extracted with 10 ml of 90% acetone for 24 hours in a freezer. The centrifuge tubes were then spun at 3,500 rpm for 10 minutes. The samples were analyzed with a Turner TD-700 fluorometer.

Temperature and Dissolved Oxygen

Water temperature and dissolved oxygen were measured in the field with a YSI ProODO meter (YSI Inc., Yellow Springs, OH).

Rainfall and River Discharge

Rain data were accessed from the Community Collaborative Rain, Hail, and Snow Network (CoCoRaHS) for sites 2, 15, 16, and 17. Discharge data for sites 2 and 7 were accessed from the US Geological Survey (USGS).

Land Cover

Land cover data was acquired from the National Land Cover Database through the Multi-resolution Land Characteristics Consortium (http://www.mrlc.gov/finddata.php). Future land cover was modeled using the IDRISI Land Change Modeler from Clark Labs (http://www.clarklabs.org/)

RESULTS AND DISCUSSION

What are the levels of fecal indicator bacteria, nutrients, chlorophyll, and dissolved oxygen? Are any issues or parameters that should be monitored?

Indicator Bacteria

Geographical distribution

Overall the Saco River met water quality standards for indicator bacteria. The geometric mean from each site was far below the required levels set by the US EPA criterion of 126 (Figure 2). The geometric means for *E. coli* numbers across 2 years show a high amount of variability as indicated by the large error bars. The figure shows overall higher levels of *E. coli* at sites 15,16, and 17 (which are all in the estuarine portion of the river and located close to the population centers of Biddeford and Saco) and then a return to lower values at site 18 (the beach site). The greatest variability also is found at these sites, and the results also show that a sample from site 15 exceeded the

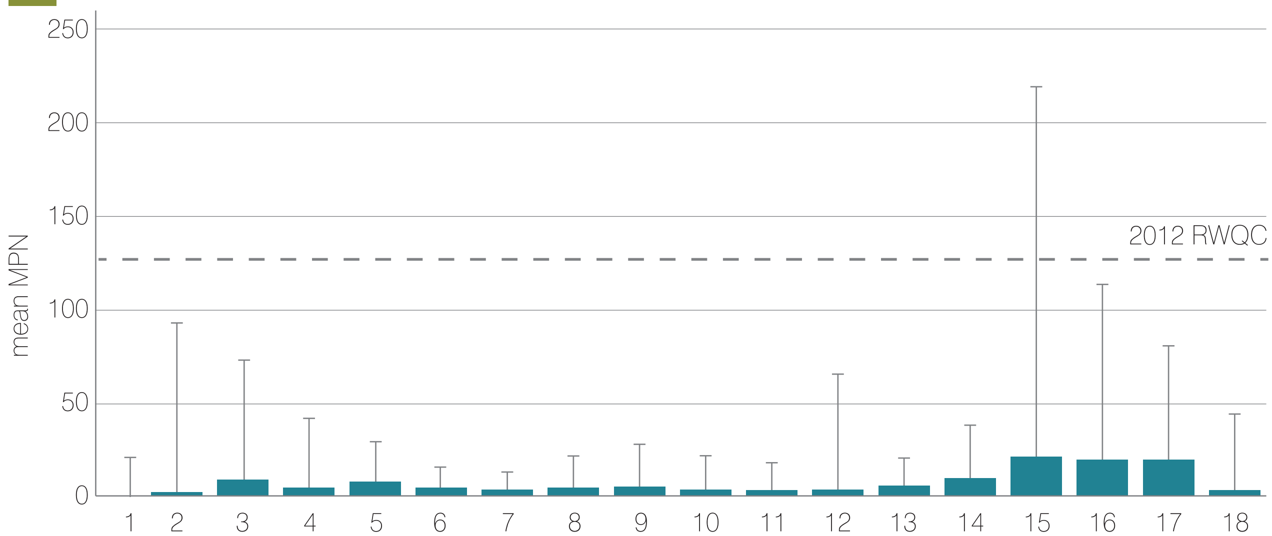


FIGURE 2 Geometric mean of MPN of *E. coli* at each station across 2 years of monthly sampling. Bars indicate standard deviation.

recommended US EPA levels. Similar results were obtained for total coliform numbers, where the data showed an overall increase in MPN for sites 15, 16, and 17, and a subsequent decrease again at 18. Total coliform and *E. coli* data are highly correlated as shown in Figure 3. Total coliform data is not discussed further in this report for two reasons: (1) the relationship shown in Figure 1 means that no new information would be gleaned from the total coliform numbers and (2) these bacteria are potentially from additional sources. In other words, they are not as specific an indicator as are *E. coli* of fecal contamination. Indeed, total coliforms include bacteria in soils and plants as well as those from the intestines of warm- and cold-blooded animals.

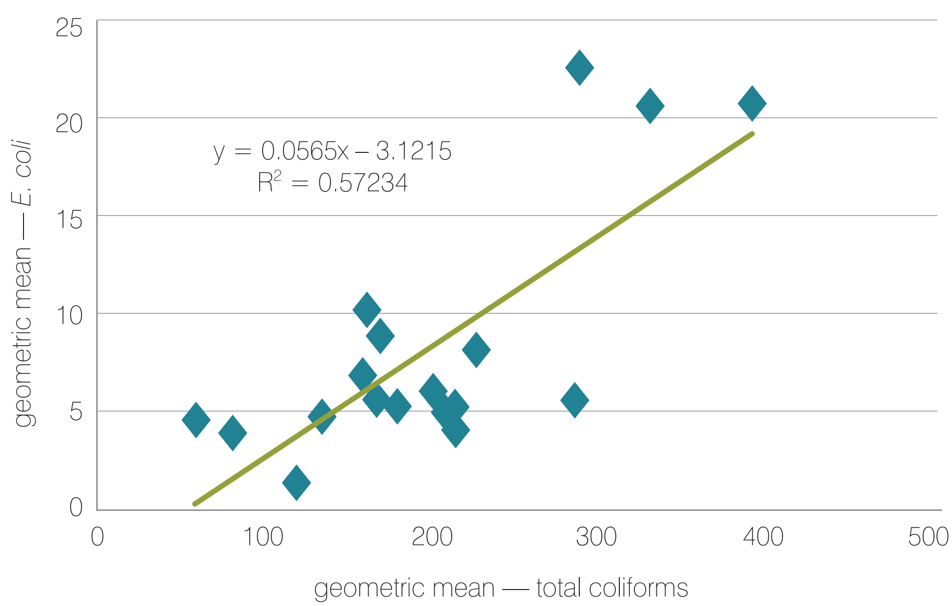


FIGURE 3 Correlation of MPN of Total Coliforms and *E. coli*. The regression equation and R^2 are also shown.

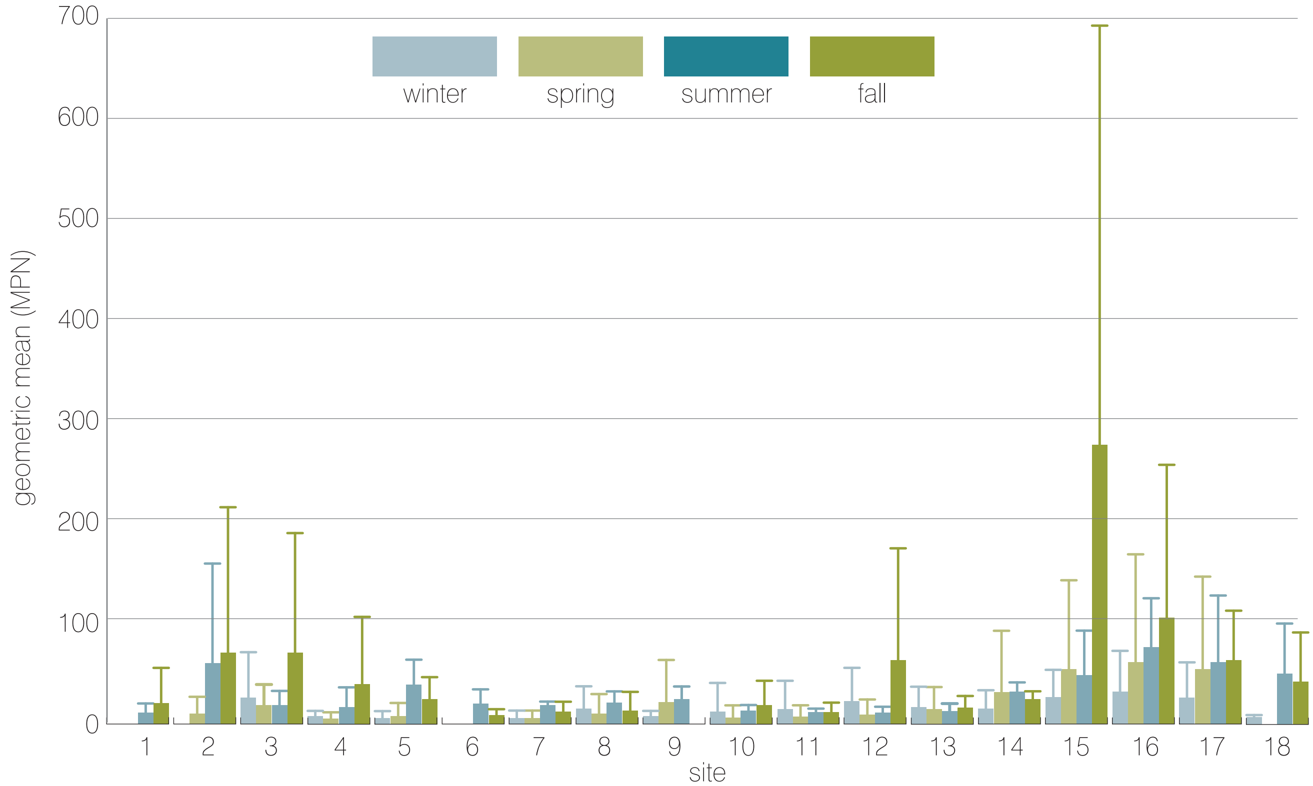


FIGURE 4 Winter, spring, summer, and fall (DJF, MAM, JJA, SON) geometric mean *E. coli* MPN at sites along the Saco River. Bars indicate standard deviation.

Seasonal change

The amount of indicator bacteria in the water changes with the season (Figure 4). As might be expected, winter (Dec/Jan/Feb) and spring (Mar/Apr/May) have the lowest values. While fall and summer (June/July/Aug) have the highest levels of *E. coli*, there is no significant difference between the two ($p=0.21$). Levels of *E. coli* in the summer and spring are significantly different ($p<0.1$), as are levels in summer and winter ($p<0.00$). Spring and winter levels are not significantly different ($p=0.33$). The level in fall (Sept/Oct/Nov) is significantly higher than both winter ($p<0.05$) and spring ($p=0.05$) values. That fall had the highest *E. coli* numbers is perhaps somewhat surprising.

Population density

We attempted to look at relationship of indicator bacteria to population by aggregating sites near the upper end of the river (low population, but commercialized), middle reach (low population, mostly agriculture), and lower end of the river (higher population, and more urbanized).The indicator bacteria levels at the upper end (sites: 1-5) and middle reach (6-12) of the river are not significantly different from each other ($p=0.71$). However, the values at the lower reach sites (13-18) are significantly higher than both the upper ($p<0.05$) and middle ($p<0.05$) reach sites. The population size in the lower reach is approximately 40,000 people, the middle reach is about 11,000 people,

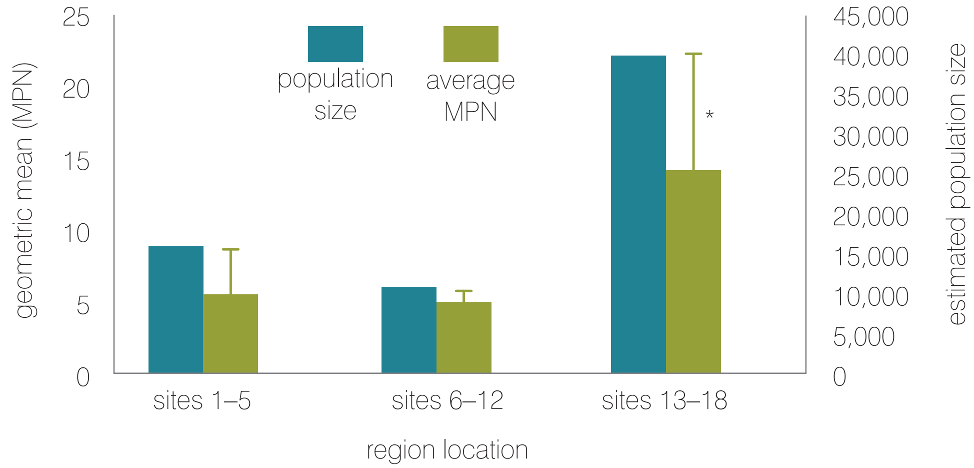


FIGURE 5 Relationship between population size and MPN of *E. coli* at grouped sites. Bars for the MPN are the standard deviation.

and around the high reach about 16,000 people (Figure 5). The figure shows that areas with high *E. coli* also had a higher population, and low MPN areas had a lower surrounding population.

Rainfall

Regression analysis was performed between *E. coli* (MPN) and precipitation (cm) at each available site with no lag in time, and with rainfall occurring at lag times of 1,2, or 3 days before sampling. Rainfall data analysis produced no significant results. Regression analysis of precipitation (cm) against *E. coli* at site 2 for no lag period produced an R^2 of 0.14, similar results were found with a 1-day ($R^2 = 0.10$), 2-day ($R^2 = 0.02$), and 3-day ($R^2 = 0.01$) lag period after precipitation. These results indicate that precipitation alone was not a very good predictor of *E. coli* numbers.

River discharge

Regression analysis was also performed with *E. coli* (MPN) and discharge rate (m^3/sec). Multiple regression analysis was performed with *E. coli* against precipitation (cm) and discharge (m^3/sec). Discharge rate (m^3/sec) produced analogous results with a low R^2 of 0.001. Multiple regression analysis between precipitation (cm) and discharge (m^3/sec) against MPN of *E. coli* resulted in an R^2 of 0.16. As with rainfall, discharge volume is not a good predictor of *E. coli* numbers.

Chlorophyll *a*

The chlorophyll *a* data were not especially remarkable, with most values at <15 μg/liter (Figure 6). This puts the river in the range of oligotrophic to mesotrophic (Dodds et al. 1998). However, some of these values are classified as less than desirable (7-15 μg/l) by the State of New Hampshire for rivers, and potentially a nuisance (>15 μg/l). The larger spikes are, at present, unexplained. However, there are very few of these. There

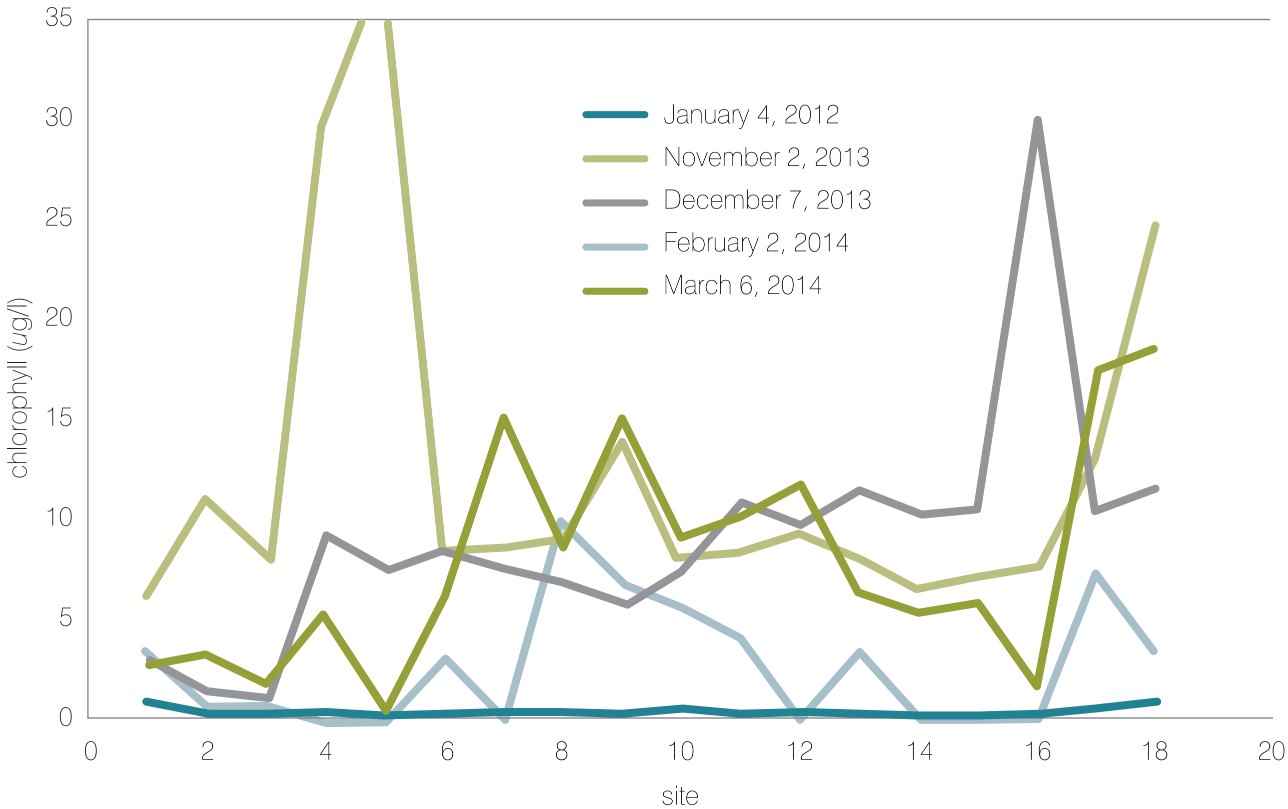


FIGURE 6 Chlorophyll *a* concentrations along the Saco River.

is a seasonal pattern of chlorophyll that coincides generally with the growing season but apparently extends late into the year (Figure 7). The reason for this extended growing season is unclear. One explanation could be that the dataset is limited and may be missing some key months during the chlorophyll sampling. The November sampling had two very high values at stations 4 and 5 in the Fryeburg, ME, area. With leaf fall in autumn, decreased shading could potentially lead to higher phytoplankton

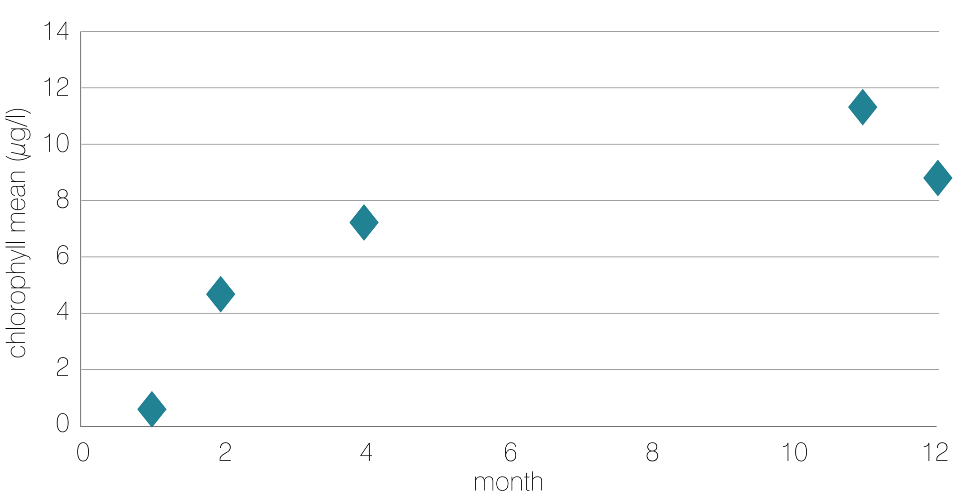


FIGURE 7 Seasonal pattern of mean chlorophyll concentrations.

growth. Phytoplankton species composition could also be changing, and more tolerant species may be able to grow during the late fall and early winter (Read et al. 2014). Another possibility is that precipitation tends to be higher during October, November, and December, which might affect resuspension of phytoplankton from the sediments or flush them into the main stem of the river from the surrounding marshlands.

Nutrients

Nutrients were not sampled as frequently, and only a limited dataset is presented. Nutrient concentrations were variable, but not out of line with normal surface waters.

Nitrate

Nitrate + nitrite concentrations were generally less than 0.2 mg/L, with lower values in the middle and lower reaches of the river (Figure 8). Monthly averages are 0.07, 0.08, 0.12, 0.07,and 0.05 mg/L for Jan, Feb, Mar, Apr, and Nov, respectively. The data for March and April are somewhat elevated in the upper reaches of the river. These values are far below the critical levels of concern for human health set by US EPA, and below what the Cary Institute states is normal for rivers (1 mg/l). They are also below US EPA reference values in Subregion 58 (0.16 mg/l) and Subregion 59 (0.31 mg/l).

Phosphate

Phosphate concentrations were also low, with two exceptions (Figure 9). These are typical of the region as well. Monthly averages were 0.03, 0.05, 0.06, 0.07, 0.06, and 0.14 mg/L for Nov 2011 and Jan, Feb, Mar, Apr, and Nov 2012, respectively. Since we only measure orthophosphate and not total phosphorus, our numbers are hard to

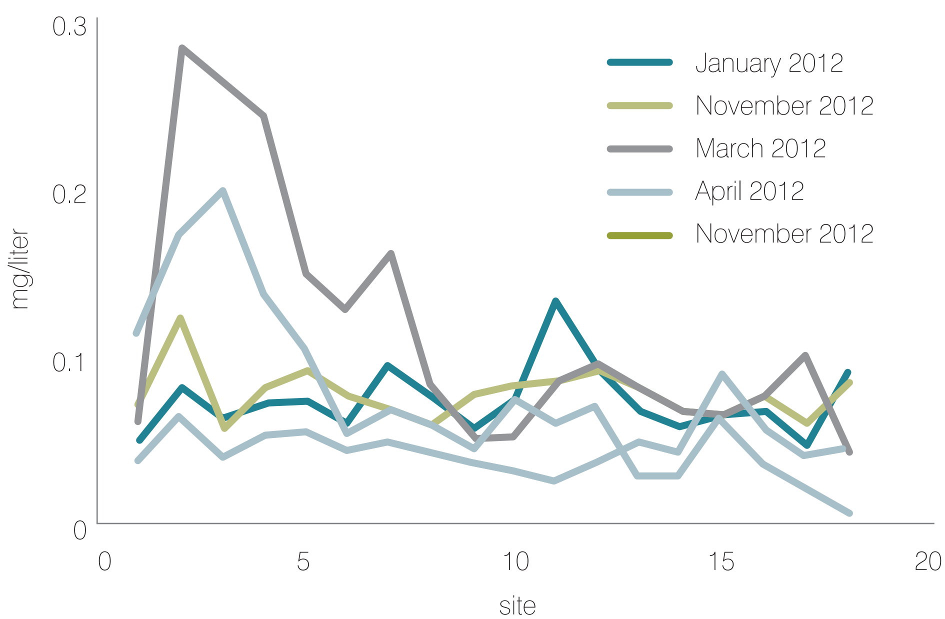


FIGURE 8 Nitrate plus nitrite concentrations (mg/L) along the Saco River.

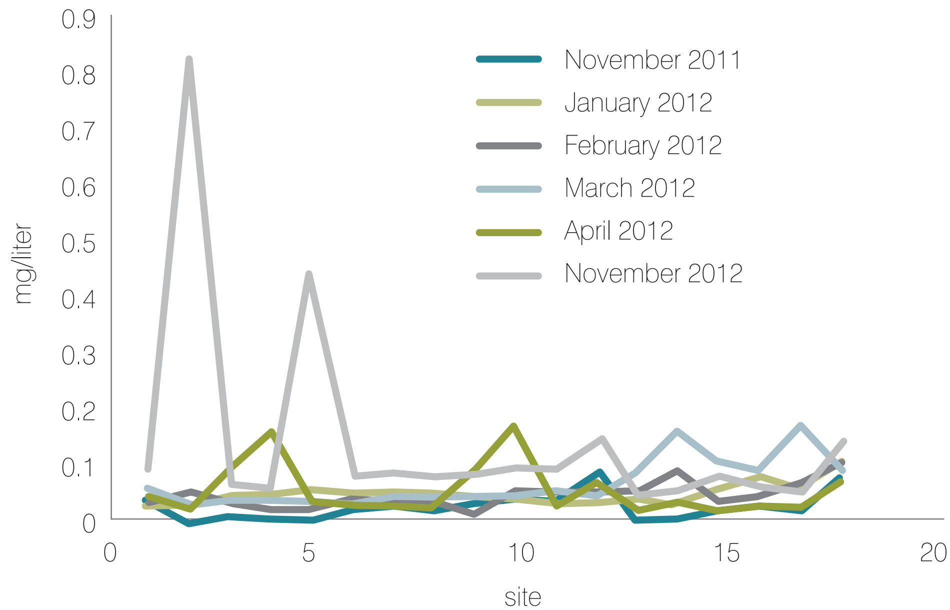


FIGURE 9 Phosphate concentrations (mg/L) along the Saco River.

compare with some of the criteria. The Cary Institute states that unpolluted waters are in the range of 0.01- 0.03 mg/l orthophosphate, which is less than most of our values, indicating there is some impact here. Even though our measured values represent only a portion of total phosphorus, they are greater than what the State of New Hampshire considers desirable for total phosphorus in rivers; >0.051 is excessive and may be a potential nuisance (http://des.nh.gov/organization/divisions/water/wmb/vrap/documents/wq-resultsinfo.pdf).

US EPA also conducted some nutrient sampling of the waters of Saco Bay on July 2, 2010. Again, these data show nutrient concentrations that are within expected levels for unpolluted waters.

Dissolved Oxygen

DO levels along the Saco River remained fairly high, between 90-105% saturation throughout our measurement period (Figure 10). Additional measurements made by the Saco River Corridor Commission also show that DO levels remain reasonably constant ranging from 6.5 mg/L–10.5 mg/L depending on location, with an average of 8.0 mg/L (SRCC 2010). The exceptions are problematic tributaries of Swan Pond Brook and Thatcher Brook where mean DO saturations are in the 80% or 60% level (Saco River Corridor Commission, http://srcc-maine.org/water-quality-monitoring/water-quality-data/).

Water Temperature

Water temperature of the Saco River varies depending on location and season. The surface may freeze above site 15 in winter, while summer water temperatures ranging from 20-25°C until the river reaches cooler ocean water. The estuarine sites (15-17) are also known to freeze on the surface, especially at site 15.

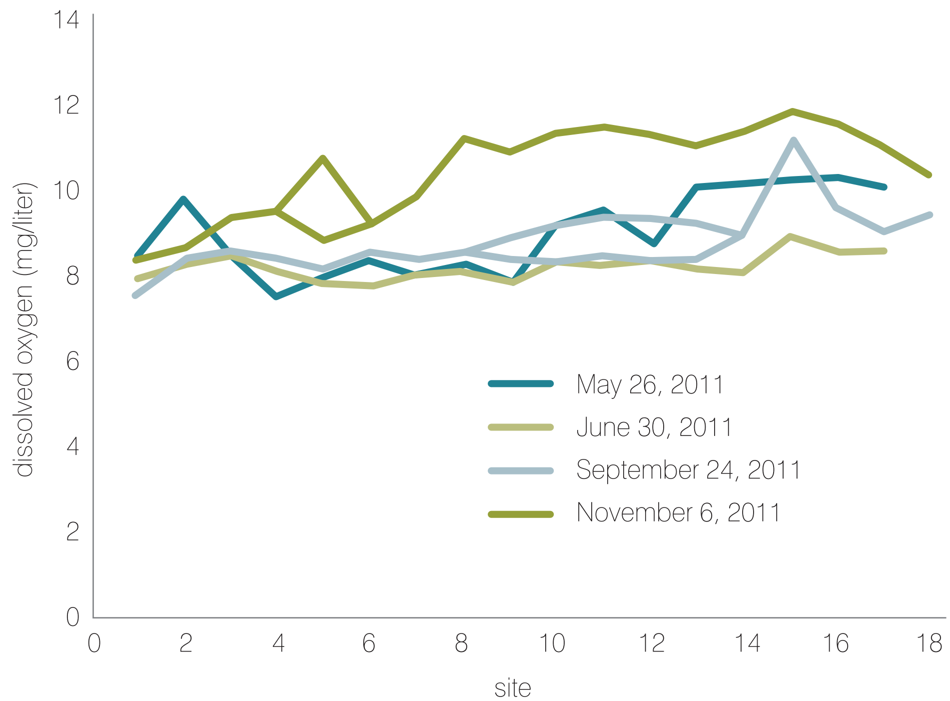


FIGURE 10 Dissolved oxygen concentrations (mg/L) along the Saco River.

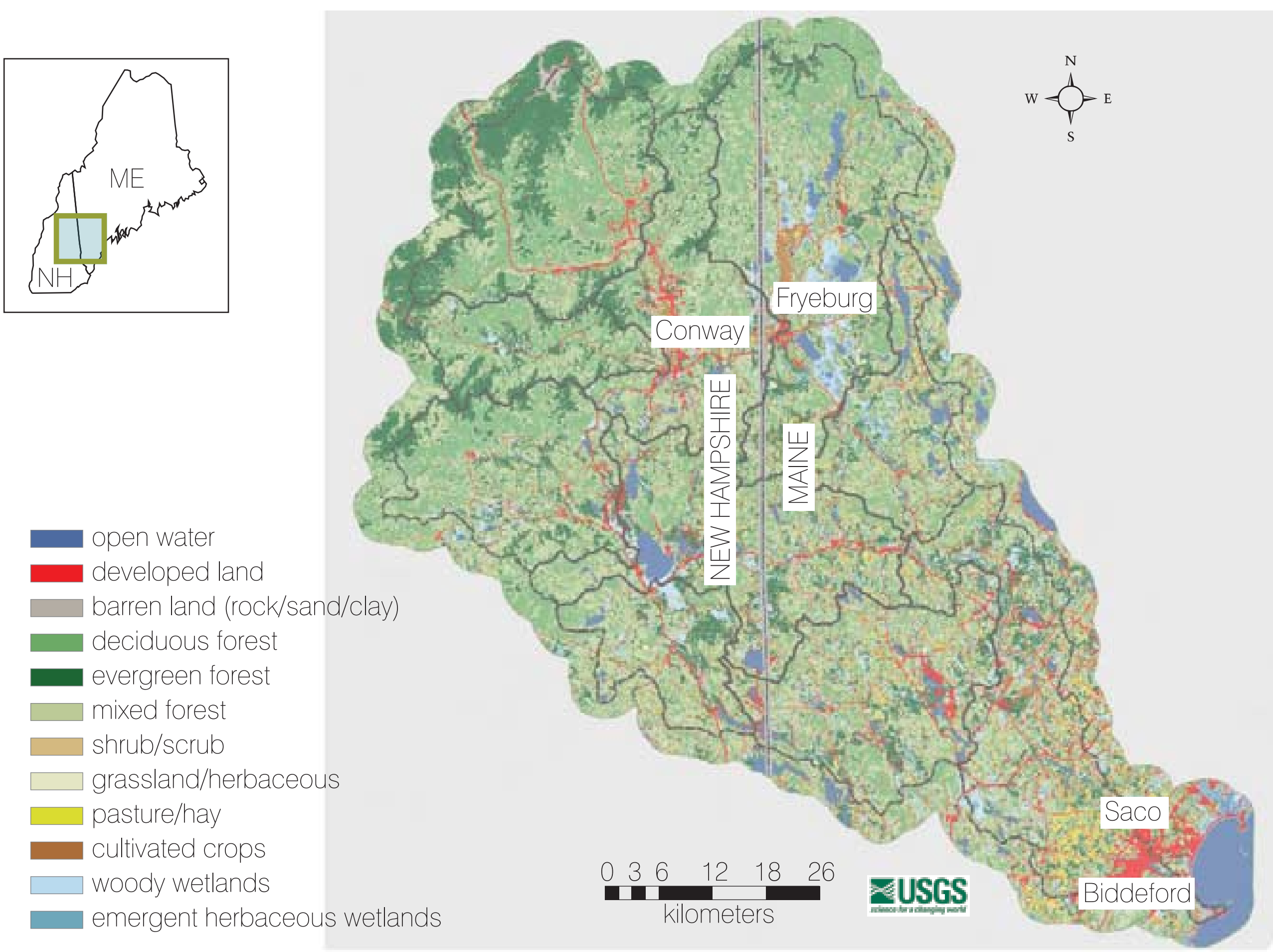


FIGURE 11 Major land cover types in the Saco River watershed.

Growth and Development Model

The Saco River watershed contains a mixture of land cover types (Figure 11). Most of the area is low-intensity developed forested land, with only a minor portion of developed land. The majority of the development is in the coastal area around the cities of Biddeford and Saco in Maine, with some in the resort region around North Conway, NH.

The population in southern Maine has increased modestly, between 5 and >25% in the last decade (Figure 12), while North Conway, NH, has seen a 13.5% increase in population from 2000-2010 (http://www.city-data.com/). These data encouraged us to look at the development trajectory in the region.

To examine future development potential, we used IDRISI Land Change Modeler to predict changes in the North Conway area. Starting with actual land cover data for 1992, 2001, and 2010 from USGS, we modeled what land cover would be in 2030 (Figure 13). A significant expansion of the developed area (red) can be seen throughout the sequence.

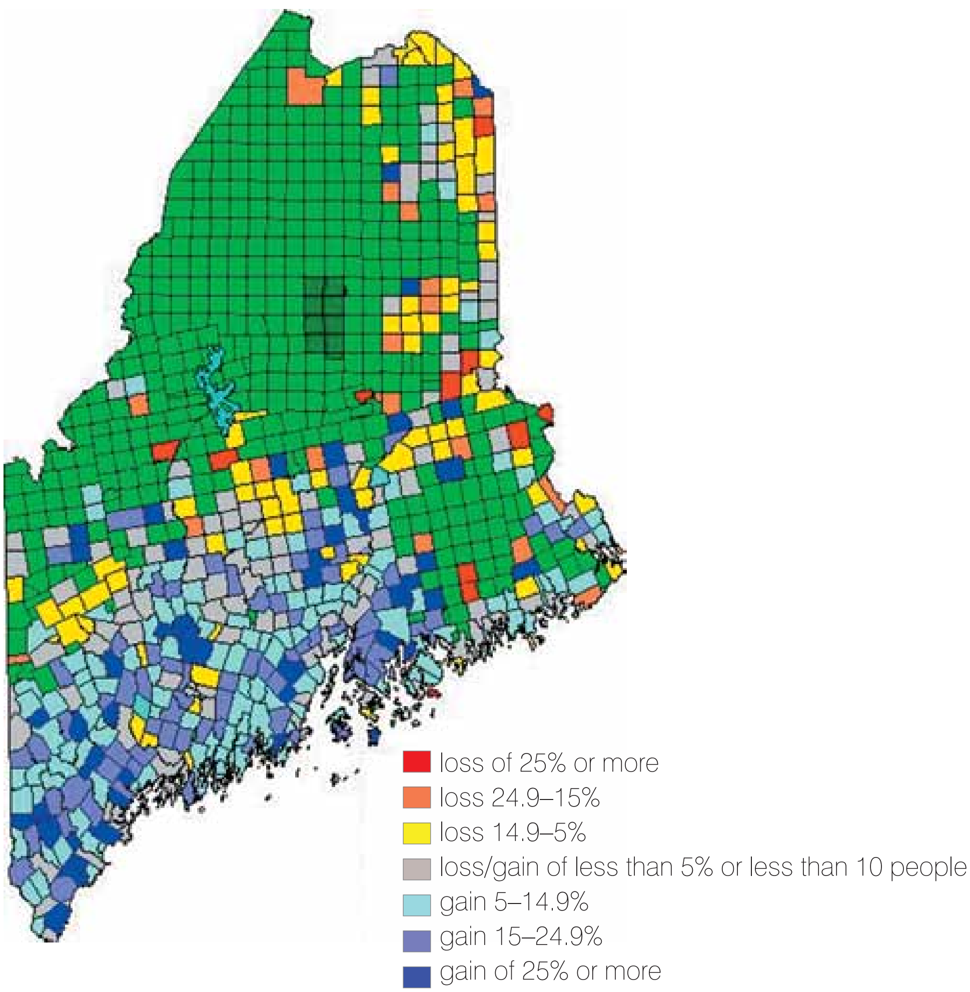
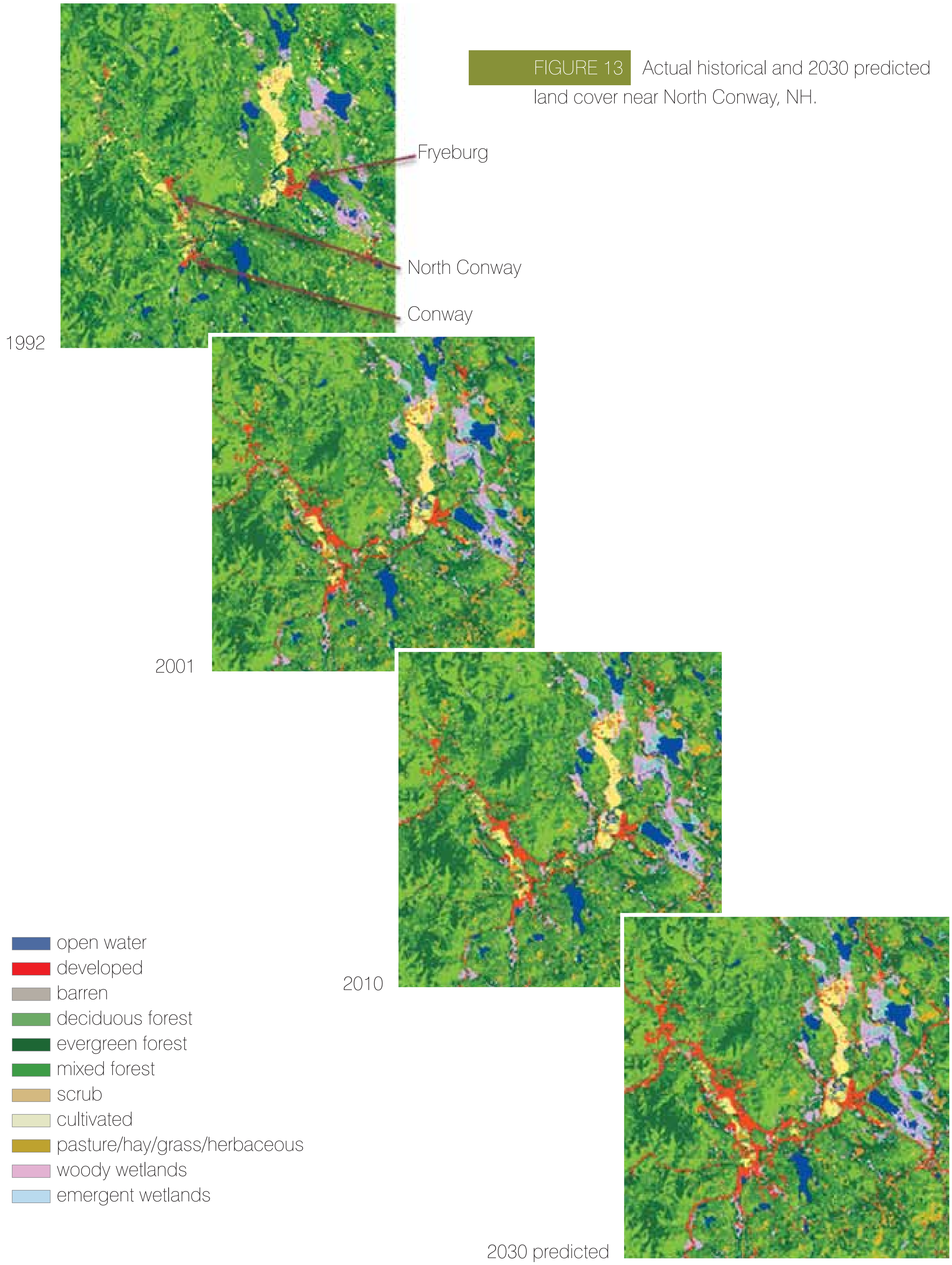


FIGURE 12 Population change in Maine towns between 1990-2000.
(Source: http://maineanencyclopedia.com/population-since-1741/

FIGURE 13 Actual historical and 2030 predicted land cover near North Conway, NH.



What do indicators of water quality tell us about the state of the Saco River?

According to the US EPA Watershed Assessment Report for 2010 (http://ofmpub.epa.gov/tmdl_waters10/attains_watershed.control), the Saco River is in good condition except at the Biddeford-Saco area, where it is impaired due to high *E. coli* counts. Also identified as sources of *E. coli* are a combined sewer overflow (CSO) at Bear Brook in Saco, Thatcher Brook in Biddeford, and Swan Pond Brook at South Street in Biddeford. The state as a whole has made significant progress on reducing discharges from CSOs (Breau 2013). Even as precipitation is increasing in the Northeast, discharges from CSOs have been reduced. Biddeford currently has nine CSOs that empty into the Saco River and one that drains into Thatcher Brook. The City of Saco has three CSOs that empty to the Saco River and one to Bear Brook. Over the period 1987-2012, Biddeford has lowered its annual CSO flows by 80% and Saco by 98%.

CONCLUSIONS

We made the following conclusions based on our study of water quality and development in the Saco River watershed:

- Aside from occasional outliers in the data, the Saco River watershed remains below the recommended fecal indicator bacteria (specifically *E. coli*) levels for recreational waters set by US EPA. While this is a positive result in terms of ecosystem health of the Saco River, continual monitoring of fecal indicator bacteria is still recommended based on its highly variable nature. The results also indicate that other factors than those reported here affect the variability of indicator bacteria. Further study of fecal coliform in sediment and variable human population impacts should help make these causes better understood.
- Other water quality criteria measured also showed levels within the very good to excellent range. Chlorophyll levels were mostly <15 mg/l, indicating non-bloom conditions. Nutrients were in the range considered to be below or close to background levels for natural waters. Dissolved oxygen measurements were near saturation for all measurements.
- Our modeling of future land cover suggests that increased development is very likely. This is a concern especially for the headwaters of the Saco River watershed. Some contaminants not included in this study, such as mercury and new and legacy pollutants, should be studied further. These pollutants include toxins and endocrine disruptors that have the potential to harm aquatic life as well as human health.

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