POESTEN KILL FACT SHEET: WATER QUALITY

INTRODUCTION

Water quality monitoring is an incredibly vital component of stream assessments. Selecting what parameters to include in a stream survey can be challenging, given all the options. However, relatively simple and inexpensive tests, such as temperature, dissolved oxygen, pH, and water clarity, can provide a tremendous amount of information on overall stream health. By understanding what each parameter measures, its relative importance in an aquatic ecosystem, and how parameters may interact with each other in the natural environment, researchers and citizen scientists can better predict and understand the responses of aquatic organisms. And in doing so, one can make more informed assessments of stream health and prioritize monitoring, restoration, and/or conservation efforts. Thus, an invested interest in water quality is an invested interest in the health, diversity, and abundance of biota.

Water quality includes a number of parameters that environmental scientists use to measure the "health" and character of natural waters. Water quality has a direct relationship with the biota living within the water body. Technicians, scientists, and citizens can measure physical and chemical measurements directly in the field (in-situ) or via laboratory analysis. Common water quality parameters include, but are not limited to (1):

- **Temperature**
- **Dissolved oxygen**
- **Salinity (specific conductivity; total dissolved solids)**
- **Turbidity (suspended solids, water clarity)**
- **Alkalinity and pH**
- **Pathogens / Fecal indicator bacteria (e.g., fecal coliform, E. coli, Enterococcus, total coliform)**
- Hardness (calcium and magnesium)
- Major ions (e.g. chloride, sulfate)
- Nutrients (e.g., phosphorus and nitrogen
- Trace metals (e.g. copper, iron).
- Trace organic chemicals (e.g. pesticides, PCBs, herbicides)

---

(1) Parameters that were measured as part of the Poesten Kill Ecological Survey are denoted in bold and discussed in further individual factsheets.

The concentration at which water quality parameters are measured and reported cover an extremely wide range, from part-per-trillion levels (e.g. dissolved mercury) to part-per-thousand levels (e.g. salinity); emphasizing that the effects of these parameters on water quality and wildlife is relative and do not exert the same effects. Moreover, multiple factors in a waterbody can compound effects and exacerbate impacts to stream health and biological quality. Measurements of water quality can be incredibly informative to understanding overall stream health. However, due to the dynamic nature of waterbodies, and in particular stream systems, identifying the potential sources of impairment to water quality can be particularly challenging. Measures of water quality at a given location are not necessarily indicative of water quality for the entire stream reach and can be relatively localized in spatial extent and effects on stream health. And likewise, most sources of water quality impairment and pollution originate at, or are a result of, sources from outside of the stream (Fig. 1).

Figure 1. Sources of stream pollution can originate from multiple sources.
(Image obtained from: FilterWater.com)

POESTEN KILL WATER QUALITY: TEMPERATURE

Stream temperature is a very easy water quality parameter to measure and can be incredibly informative to understanding the health of a stream system. Water temperature is most commonly measured with a thermometer or a water quality meter equipped with a temperature sensor. Stream temperature is largely a function of climate, influenced by season and altitude (e.g., higher elevations tend to maintain colder stream temperatures). Water temperature can be locally influenced by groundwater inputs, shade canopy provided by overhanging vegetation, and human activities. In temperate climates, such as the Northeastern United States, aquatic life is adapted to colder stream temperatures. Therefore, warmer stream systems are more likely to preclude aquatic life than colder stream systems (Fig. 1). As a result, colder stream temperatures can be suggestive of a healthy stream system capable of supporting abundant and diverse aquatic life.

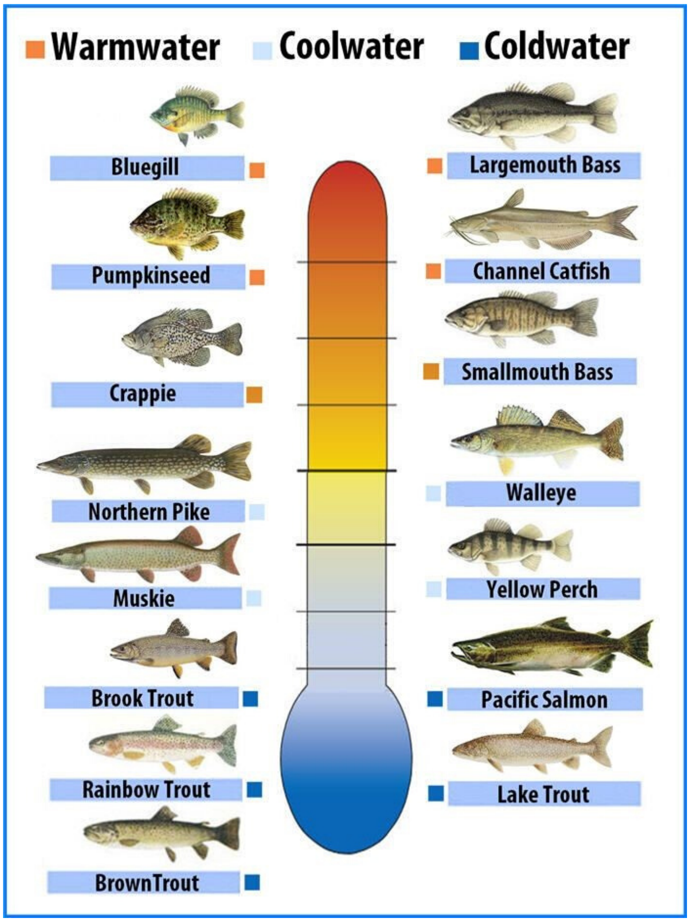

Figure 1. Examples of fish thermal tolerance designations. (Image obtained from: ShaddockFishing.com)

Sensitive species, such as trout require low temperatures year-round. Excessive heat in the summer can limit the available habitat and/or threaten the sustainability of fish populations. The loss or absence of sensitive species such as trout in streams once capable of supporting such species could be indicative of a change in temperature and suggestive of a decline in stream health.

IMPLICATIONS

- As water temperature approaches 70˚ F (21˚C), trout are less able to compete with other fish species for food. Lethal temperatures for trout range from 73˚F to 79˚F (23˚– 26˚C) (Cushing and Allen 2001).
- Temperature is inversely related to dissolved oxygen (please see below). Therefore, measures of temperature can inform scientists about potential impacts to dissolved oxygen, and thus, aquatic life.

WATER TEMPERATURE IN POESTEN KILL

Stream temperatures in Poesten Kill ranged between cool (14.72˚C) and warm (21.93˚C) ranges (Fig. 2). During each survey, stream temperatures were warmest at the most upstream site (Site #31). This site was directly downstream of the Dyken Pond outlet. The large, open waterbody has a high exposure to sunlight with relatively stagnant conditions; likely contributing to the higher temperatures at this site. Overall, stream temperatures were within normal ranges for mid- to late-June and were not indicative of any impairment to water quality or biotic health.

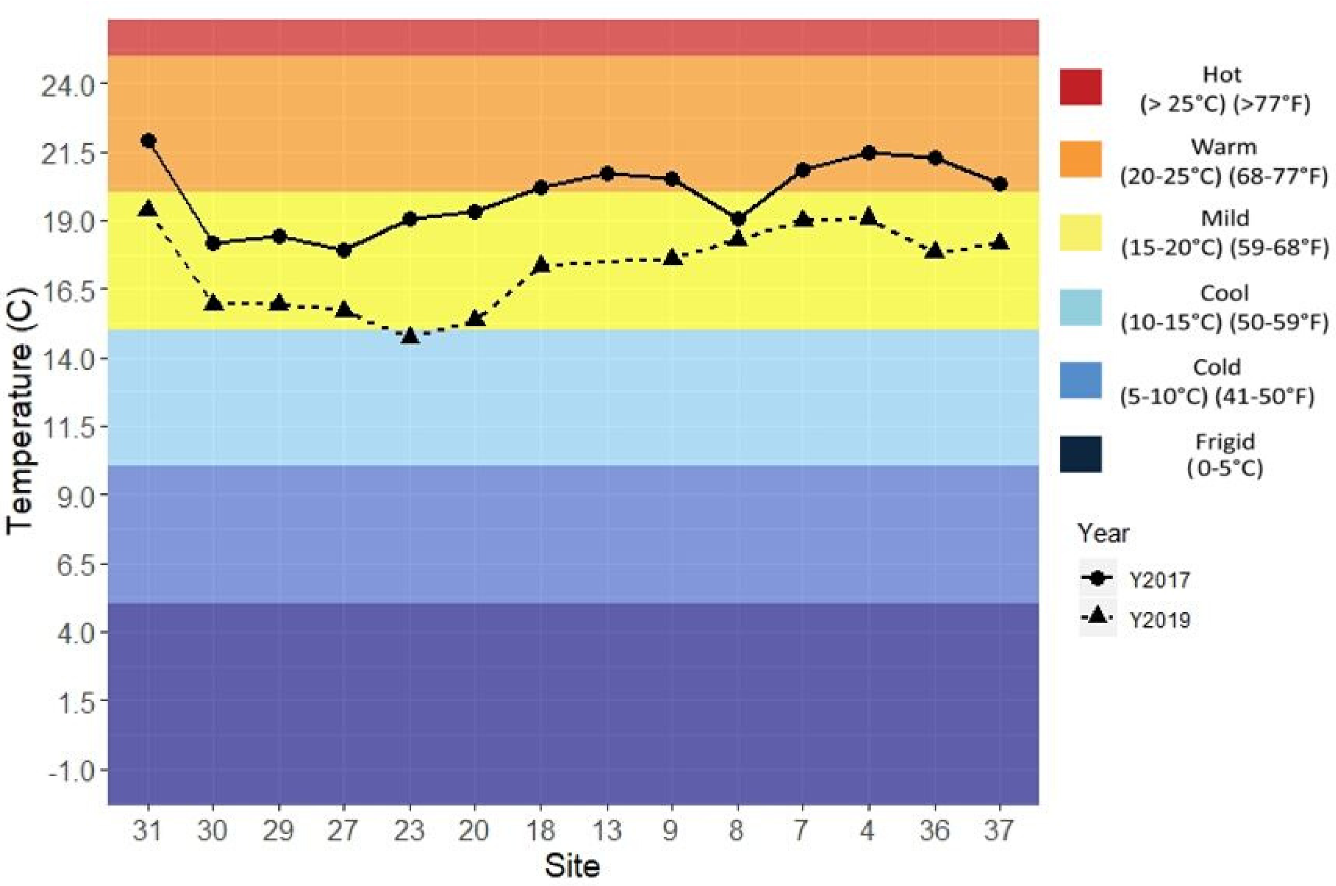

Figure 2. Stream temperatures in Poesten Kill (2017 & 2019). Sites are arranged in downstream order.

POESTEN KILL WATER QUALITY: DISSOLVED OXYGEN

Dissolved oxygen (D.O.) is one of the most important water quality indicators because nearly all aquatic life, ranging from bacteria to fish, require oxygen. Even plants, which produce oxygen via photosynthesis during the daylight hours, need oxygen to respire. Only certain forms of microorganisms do not require oxygen to survive. In addition to its critical biological role, oxygen also regulates chemical reactions in aquatic systems. Inversely related to temperature, as oxygen levels decline, species richness and diversity decline, and sensitive organisms decline or become absent altogether (Fig. 1).

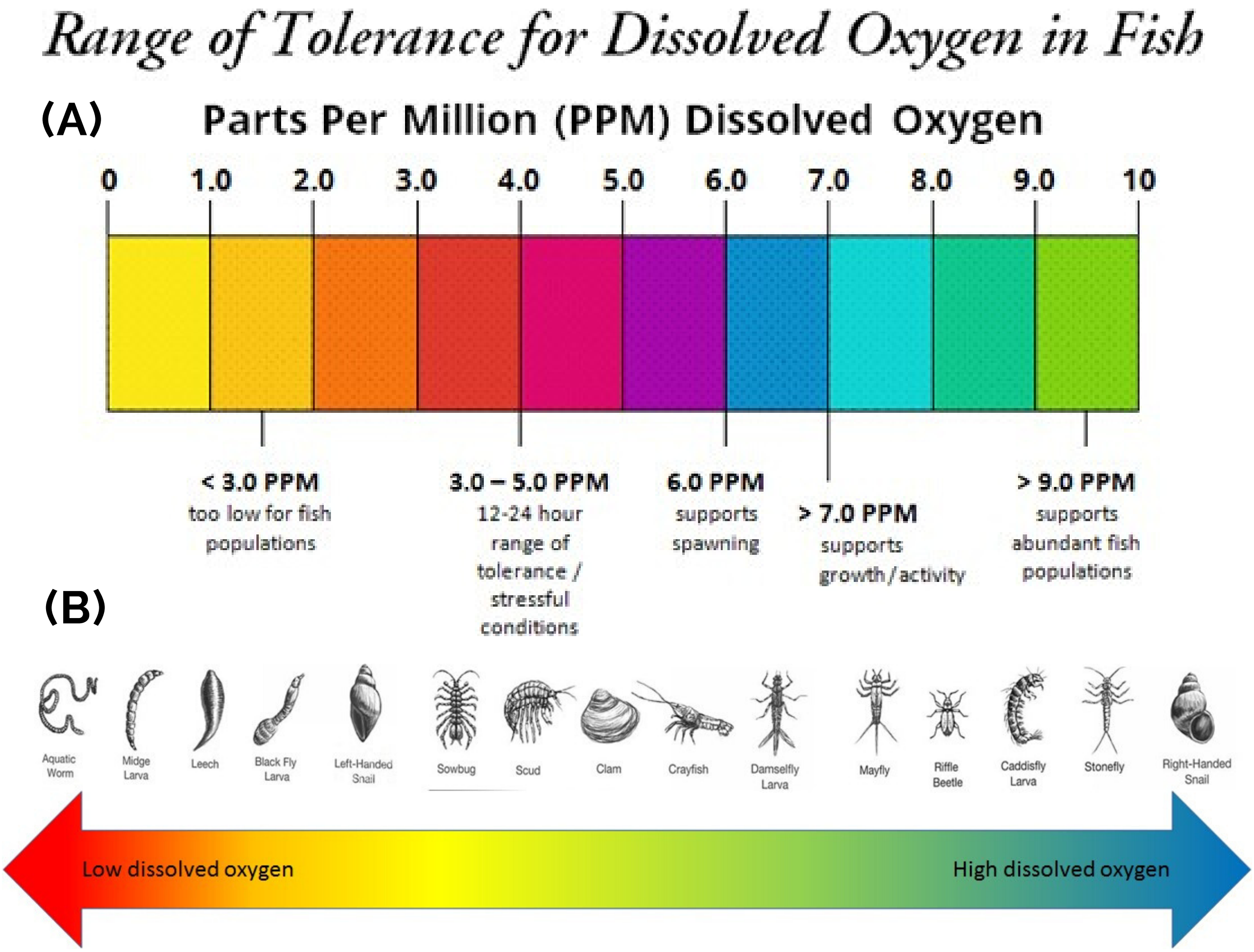

Figure 1. Dissolved oxygen tolerances for (a) Fish and (b) Macroinvertebrates. (Images obtained from: limnoloan.org and fineartamerica.com, respectively)

D.O. is highest (13-15 mg/L) in cold weather, and lowest in the summer (8-9 mg/L) because the solubility (the ability to dissolve in water) of oxygen decreases as temperature increases. Animal respiration also increases when temperatures increase. As a result, oxygen levels become further reduced (Fig. 2). High salinity concentrations also affect D.O. solubility, causing a reduction in total D.O. levels.

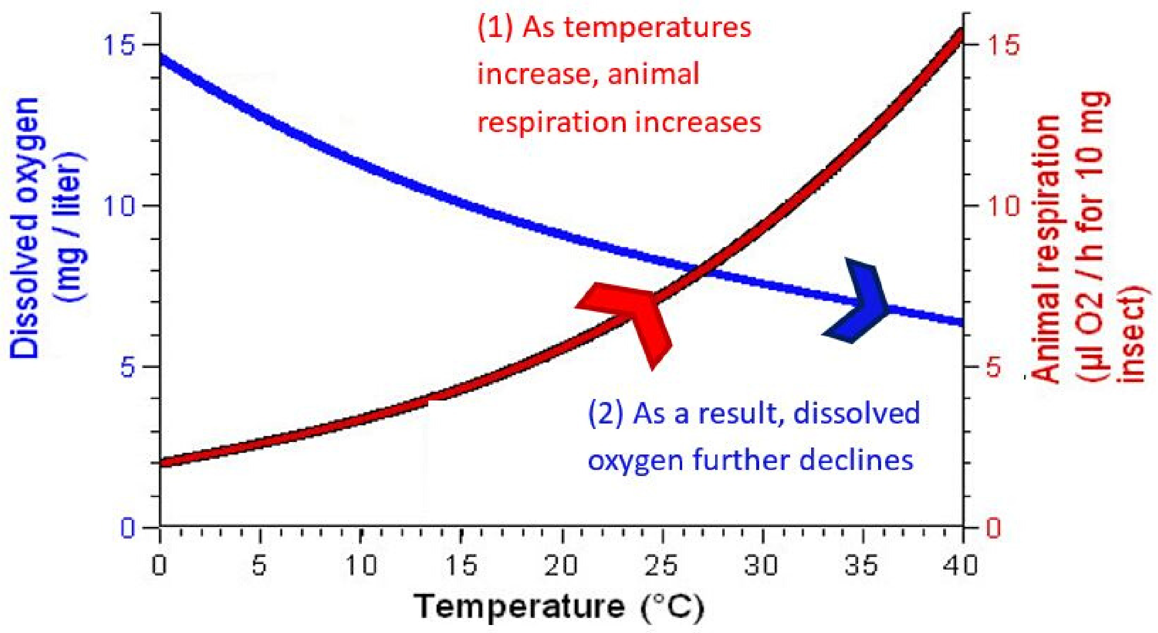

Figure 2. Relationship between dissolved oxygen and temperature.

WHERE DOES OXYGEN IN STREAMS COME FROM AND WHERE DOES IT GO?

Dissolved oxygen concentrations in streams are affected by many different physical, chemical, and biological processes (Text Box 1).

TEXT BOX 1: DISSOLVED OXYGEN IN STREAMS – SOURCES & SINKS

OXYGEN SOURCES:

- Aquatic plants, algae (photosynthesis)
- Aeration from the atmosphere
- Forces that increase aeration:
  - Wind energy
  - Kinetic energy & turbulence – movement of water through stream channel

OXYGEN SINKS (INPUTS WHICH REMOVE OXYGEN):

- Sewage inputs
- Carbonaceous (organic) matter decomposition
- Sediment oxygen demand
- Plant and microbial respiration

In streams affected by organic (i.e., sewage) pollution, a characteristic oxygen sag curve is often observed (Fig. 3)

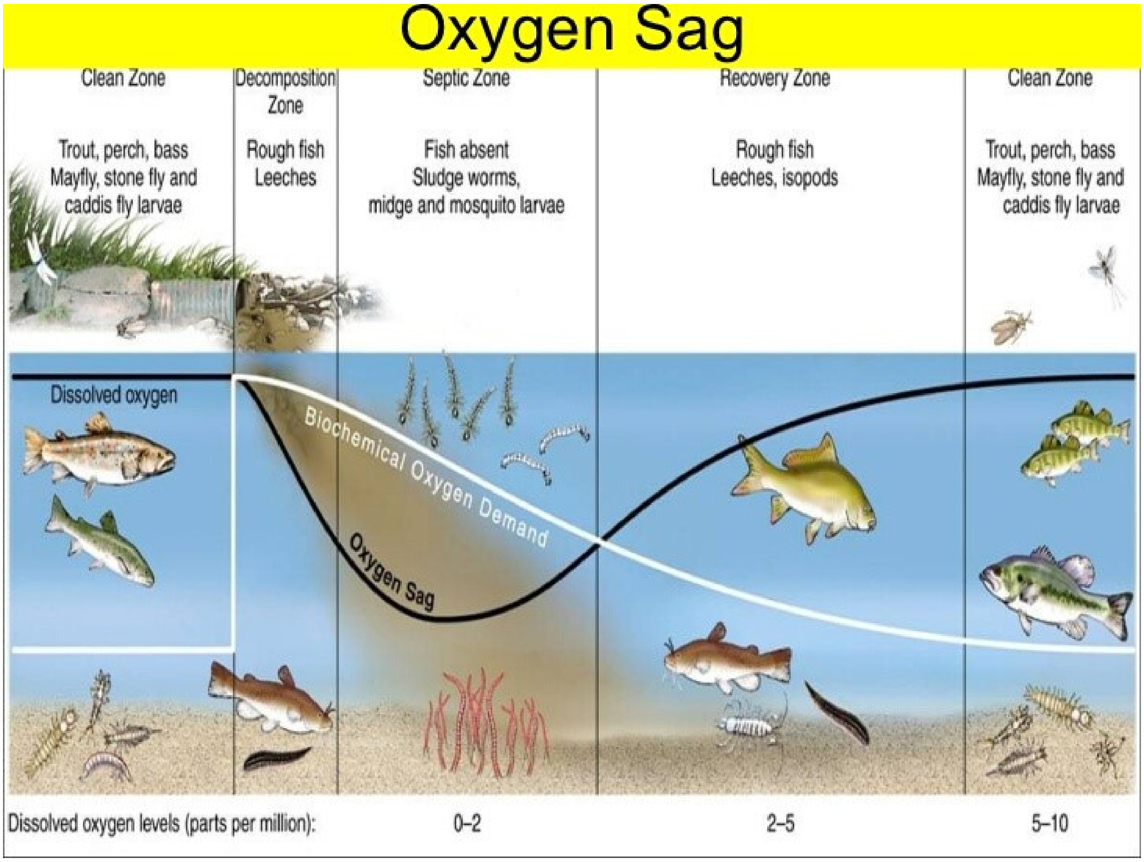

Figure 3. Dissolved oxygen sag curve typical of streams affected by organic pollution and the predicted effects on stream biota. (Image obtained from: slideshare.net)

IMPLICATIONS

- D.O. concentrations below 5 mg/L can begin to stress aquatic life, ultimately leading to mortality.
- Rapid changes in D.O. concentrations can cause "fish kills" that significantly reduce populations in a short period of time. Prolonged reductions in D.O. can cause long-term impacts to fish populations, significantly reducing reproductive success and juvenile survival.
- Declines in D.O. can also induce reductions in important prey items for fishes (e.g., aquatic macroinvertebrates), causing significant alterations to the food web.

DISSOLVED OXYGEN REQUIREMENTS IN NEW YORK STATE

New York State Department of Environmental Conservation (NYSDEC) sets a regulatory standard for allowable D.O. concentrations in streams, based on stream class. In Poesten Kill, waters are classified as Class C(T) in the lower watershed and Class C(TS) in the upper watershed. Such designations have classified Poesten Kill as a waterbody best suitable forfishing (Class C), capable of supporting trout populations (T) in the lower watershed and trout spawning (TS) in the upper watershed. Based on these classifications, minimum daily average D.O. concentrations in Poesten Kill shall not be less than 6.0 mg/L in the lower watershed and not less than 7.0 mg/L in the upper watershed. Additionally, at no time in Poesten Kill shall dissolved oxygen concentrations be less than 5.0 mg/L (NYSDEC 2019a)

DISSOLVED OXYGEN IN POESTEN KILL

D.O. concentrations in Poesten Kill were relatively consistent among sampling sites and between survey years (Fig. 4). D.O. was consistently within the 'high' range and indicative of good water quality. The relatively constant D.O. concentrations throughout the reach did not indicate evidence of organic pollution as modeled by the Oxygen Sag Curve (Fig. 3). D.O. concentrations were found well above the required concentrations set forth by NYSDEC, maintaining concentrations necessary for the survival, growth, and reproduction of trout.

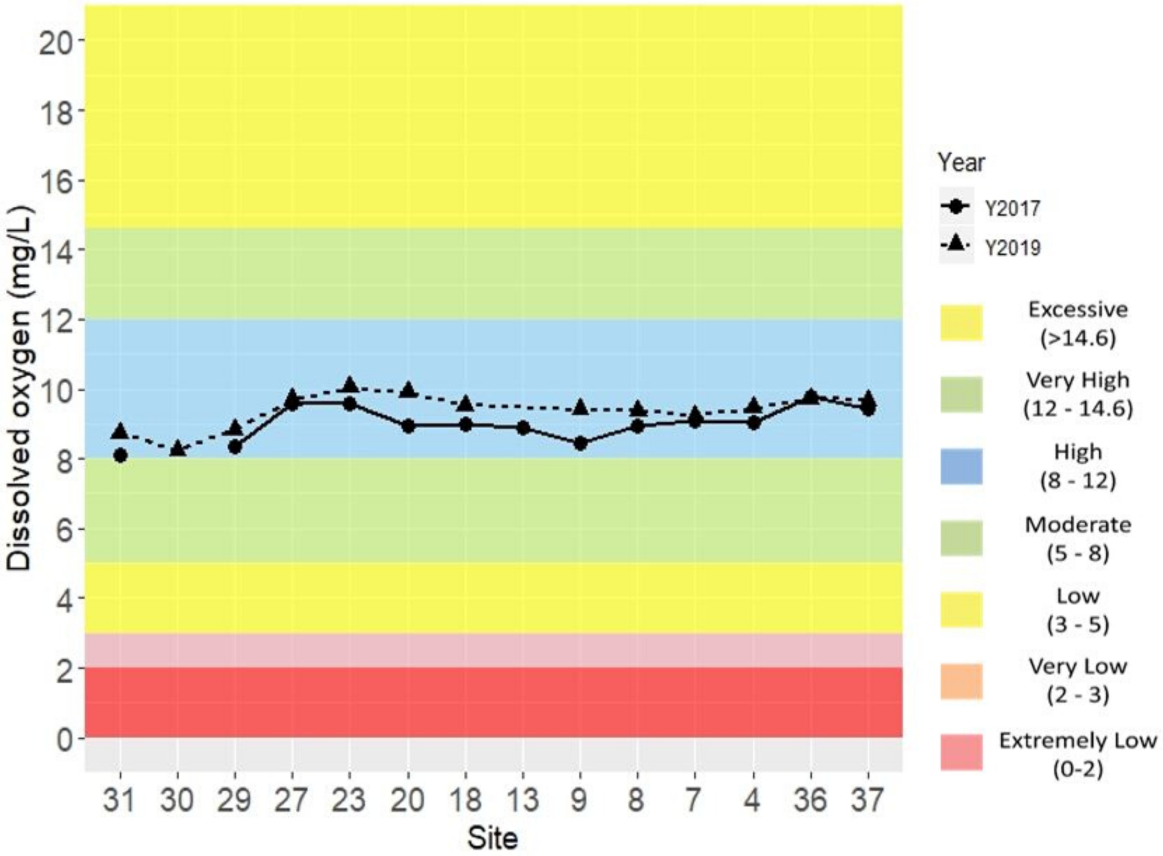

Figure 4. Dissolved oxygen levels in Poesten Kill (2017 & 2019). Sites are arranged in downstream order.

POESTEN KILL WATER QUALITY: SALINITY

Natural waters contain dissolved solids, primarily inorganic salts. Salinity is the concentration of salts in water. These salts consist of positive and negative ions, including:

MAJOR POSITIVE IONS

Calcium (Ca^{++})
Magnesium (Mg^{++})
Sodium (Na^{+})
Potassium (K^{+})

MAJOR NEGATIVE IONS

Bicarbonate (HCO_3^-)
Chloride (Cl^-)
Sulfate ($SO_4^{=}$

Other dissolved inorganic constituents, including nitrate (NO_3^-), silica (SiO_2), and iron oxides (e.g. Fe_2O_3), occur at relatively minor concentrations. Dissolved salts do not affect the appearance of water, while in solution. Often, salts become visible when forming solid precipitates. Dissolved salts above 500 mg/L can affect the usefulness of water as a source of drinking water and above 1000 mg/L for agricultural purposes. Salts can adversely affect some freshwater organisms. (Allan 1995)

Salinity (saltiness) can be measured as:

- Total dissolved solids (TDS) [units = mg/L]
- Specific conductivity (or conductance) [units = microSiemens per cm (μS/cm)]
- Sum of individual ions (e.g. chloride) [units = mg/L]

Table 1 provides the reader with a frame of reference for differing levels of salinity in the environment.

	uS/cm
DISTILLED WATER	0.5 - 3
MELTED SNOW	2 - 42
TAP WATER	50 - 800
POTABLE WATER IN THE US	30 - 1500
FRESHWATER STREAMS	100 - 2000
INDUSTRIAL WASTEWATER	10000
SEAWATER	55000

Table 1. Typical concentrations of conductivity (μS/cm) in various types of water. (Image obtained from: Fondriest Environmental, Inc.)

SALINITY SOURCES

Contributions of salts to freshwater systems can come from natural (e.g., salt springs, erosion of rocks) and anthropogenic (human) sources (Fig. 1). Increases in salinity can significantly impair biological communities in streams, as well as negatively affect the use of waterbodies by humans (e.g., drinking, swimming, recreation).

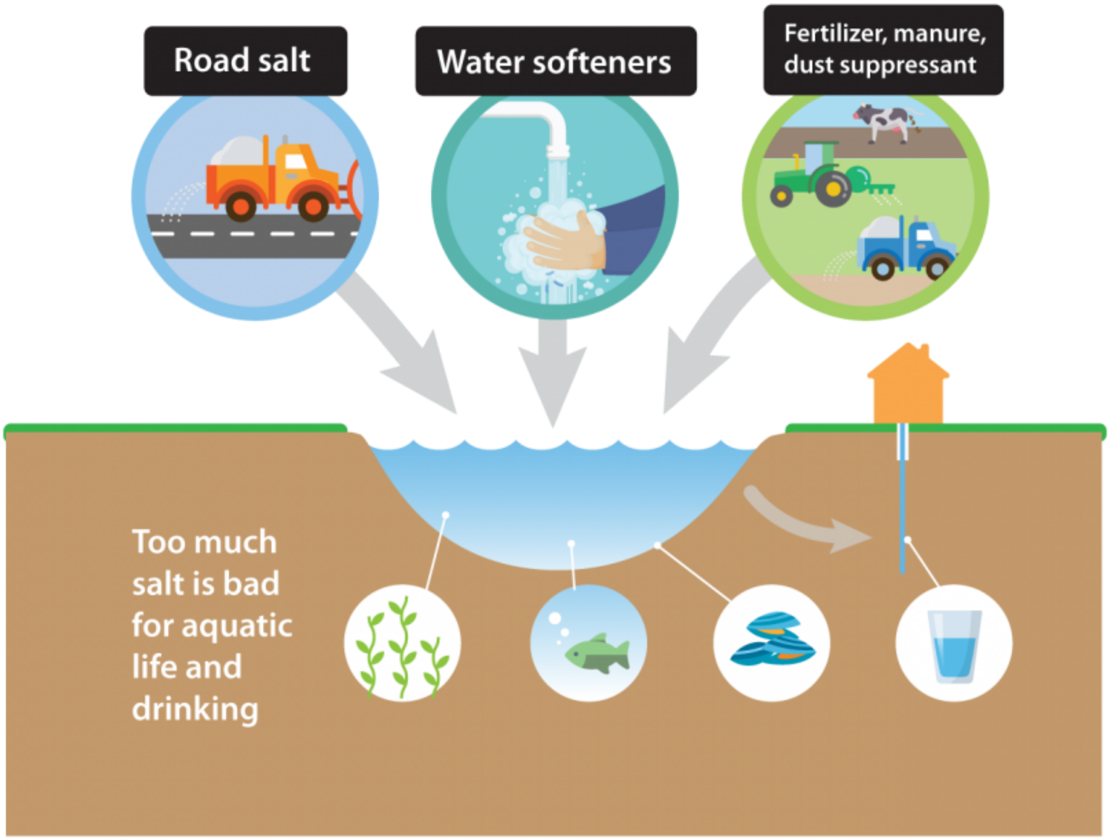

Figure 1. Sources of salt into waterbodies. (Image obtained from: pca.state.mn.us/water/chloride-101)

More recently, scientists have discovered an alarming trend in freshwater streams across the United States; freshwater salinity is on the rise (Fig. 2). One of the most pervasive sources of elevated salinity concentrations is from road salt applications by state and municipal highway departments and homeowners. Researchers studying the Mohawk River basin in New York State concluded that the two major components of road salt, sodium and chloride, had increased by 130 and 240%, respectively over the period 1952-1998 (Godwin et al. 2002).

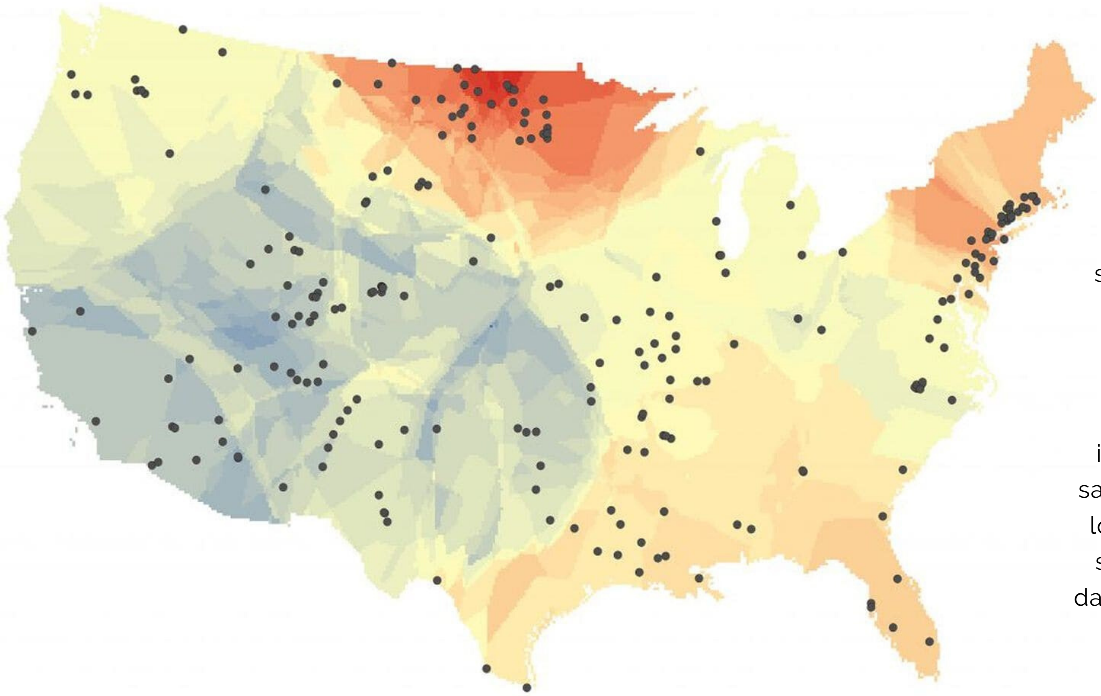

Figure 2. Changes in salinity in rivers and streams throughout the United States. Warmer colors indicated an increase in salinity, whereas cooler colors indicated a decrease in salinity. Dots indicated the location of USGS gaging stations from which the data to build the map were derived (Dennis 2018).

IMPLICATIONS

- Freshwater aquatic organisms are adapted to low conductivity waters. Increases in turbidity can alter their internal controls for regulating internal salt concentrations (i.e., osmoregulation); which can induce stress and cause mortality.
- Increases in salt inputs can suppress aquatic plant growth, altering physical habitat and food web dynamics.

SPECIFIC CONDUCTIVITY IN THE POESTEN KILL

Conductivity concentrations in Poesten Kill fell within the normal range for freshwater streams, with all sites considered 'pristine' during both surveys (Fig. 3). However, a noticeable downstream increase in conductivity was evident during both surveys. From the headwaters to the outlet, land use follows a distinct rural-urban gradient. The increase in urbanization, and thus road density and impervious surfaces, along the stream gradient is likely contributing to increased road salt runoff and ultimately stream conductivity levels. Of the water quality parameters measured during this survey, conductivity appears to pose the greatest impact to stream health. In the future, road salt application management may need to be considered by municipalities for the long-term protection of Poesten Kill.

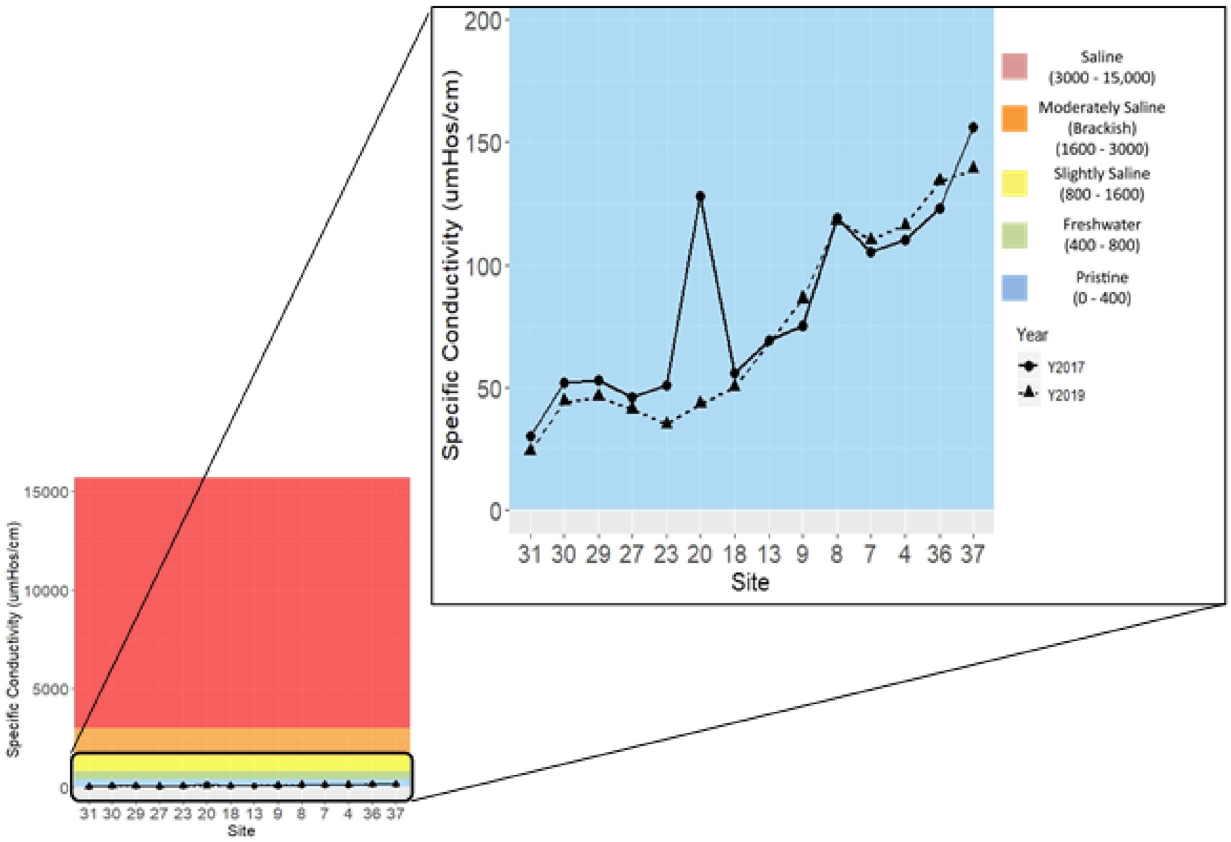

Figure 3. Conductivity levels for Poesten Kill (2017 & 2019). Sites are arranged in downstream order. The inset is meant to highlight the narrow range of conductivity levels measured in the Poesten Kill relative to the total color-interpretative scale used.

POESTEN KILL WATER QUALITY: ALKALINITY & PH

Alkalinity is a measurement of ions that control the pH of water. A pH of 7 is considered neutral. A pH value above 7 is considered alkaline and below 7 is considered acidic. Alkalinity is determined primarily by the amount of bicarbonate and carbonate ions in water. Levels of pH are largely driven by the geological composition of the watershed and often change very little in stream systems. Water draining from land characterized by limestone (calcium carbonate) rock can be strongly alkaline, whereas water draining from lands characterized by igneous rocks tend to be more acidic. Generally, alkaline waters are more biologically productive than acidic waters (Cushing and Allan, 2001). However, inputs from industrial and municipal discharges, as well as urban runoff can negatively impact the pH of freshwater systems. More recently, scientists have identified climate change, as a result of increased carbon emissions, as a primary cause of aquatic acidification, particularly in oceans (NOAA 2013). Highly acidic or highly alkaline waters can stress aquatic life and ultimately alter the biological community (Fig. 1).

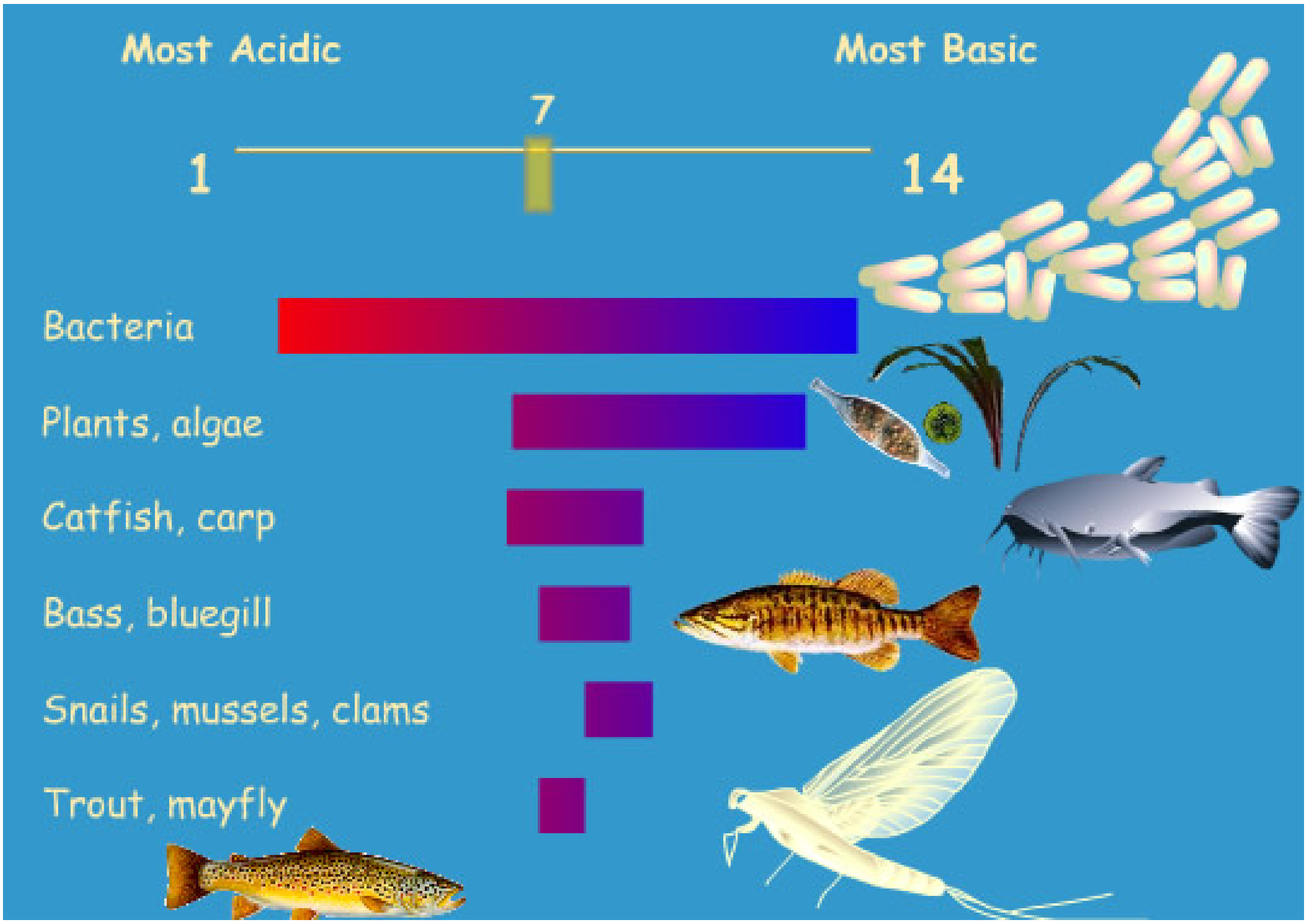

Figure 1. Examples of pH tolerances of freshwater organisms. Image obtained from: techalive.mtu.edu.

IMPLICATIONS

- Slight rapid and/or pervasive changes to pH can stress aquatic life, affect reproductive success, and lead to mortality
- For sensitive species such as trout and mayflies, deviations beyond a neutral pH (< 7 or > 8) can affect populations.
- For most fish species, a pH of < 6.5 and > 9 can cause stress or mortality.
- Changes to pH can significantly alter other water quality parameters and pollutants:
  - Lower pH levels can mobilize heavy metals, making them more toxic to aquatic life and humans (Fondriest Environmental, Inc. 2013)
  - Changes in pH can increase the solubility of nutrients, such as phosphorus, causing changes in plant and algal productivity; ultimately affecting parameters such as water clarity, dissolved oxygen, and temperature.

PH LEVELS IN POESTEN KILL

Levels of pH ranged between alkaline (pH = 8.49 at Site #31 in 2019) and slightly acidic (pH = 6.01 at Site #27 in 2017) conditions (Fig. 2). For most sites during both years, pH was considered neutral. Surveys did not identify anthropogenic factors that could be affecting pH; rather, pH appeared to be indicative of natural conditions. Levels of pH were within ranges not considered harmful to aquatic life.

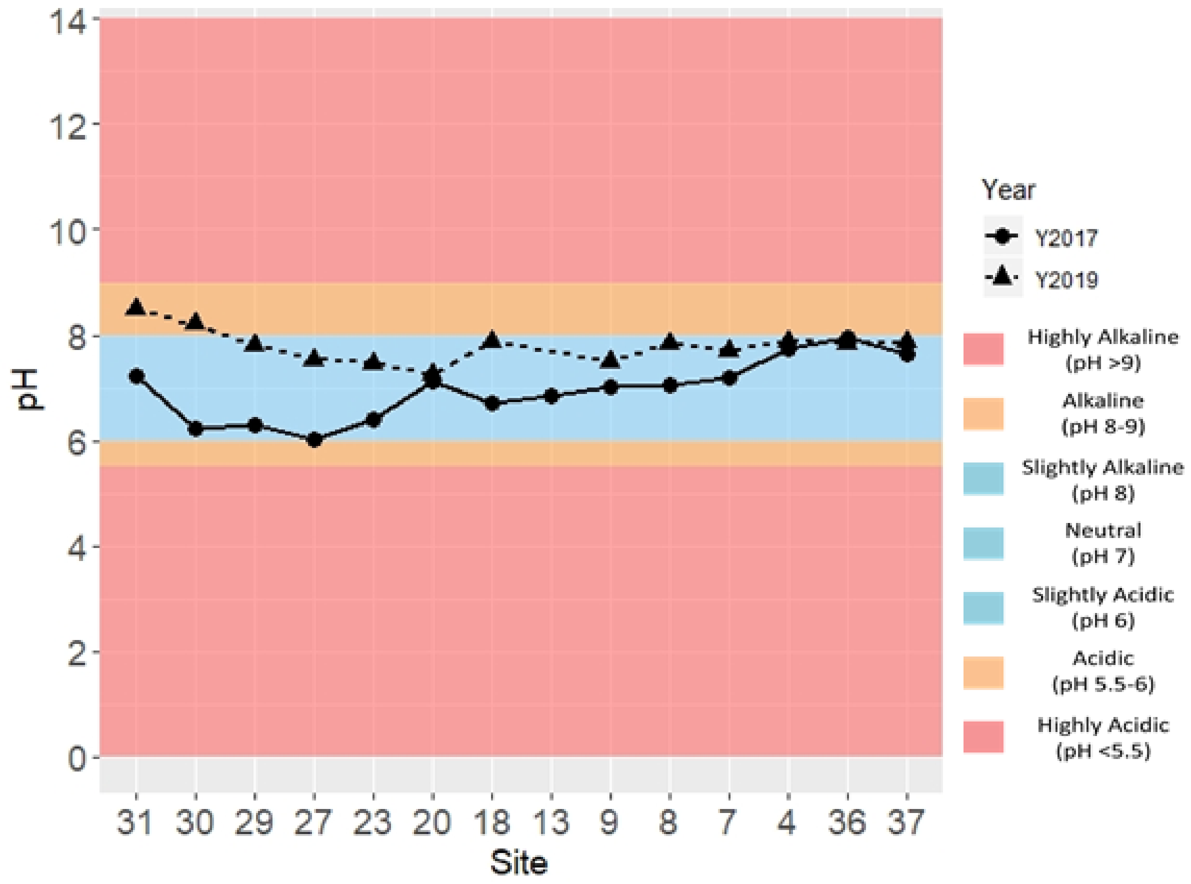

Figure 2. pH levels in Poesten Kill (2017 & 2019). Sites are arranged in downstream order.

POESTEN KILL WATER QUALITY: TURBIDITY

Particles in water are measured two different ways: turbidity and total suspended solids (TSS). Turbidity is a measure of water clarity, or light attenuation (extinction), caused by materials (e.g., clay, silt, and sand, algae, plankton, microbes, & other substances, including dissolved substances) suspended in the water. TSS is the dry weight of suspended (not dissolved) particles in the water. Turbidity and TSS are well-correlated (the presence of one predicts the other) and are very dynamic. In most stream systems, they are low when stream flow is constant and high during major runoff and storm events when scour and erosion occur. Fluctuations in turbidity can be caused by both natural (e.g., snow melt, rainstorms) and anthropogenic events (e.g., land/soil disturbance, point-source pollution).

IMPLICATIONS

The effects of elevated turbidity in aquatic systems includes (FISRWG 1998) (Fig. 1):

- Suffocation of aquatic insect and fish eggs/larvae
- Interference with fish reproduction
- Clog and abrade fish gills
- Aesthetically displeasing
- Sediments can serve as a transport mechanism for toxic substances (e.g. pesticides), pathogens, and nutrients such as nitrogen and phosphorus
- Settled sediments can interfere with stream flow, fish passage, and navigation by filling in channels
- High volumes of deposited sediments can reduce the storage capacity of the channel, thereby increasing flooding risks

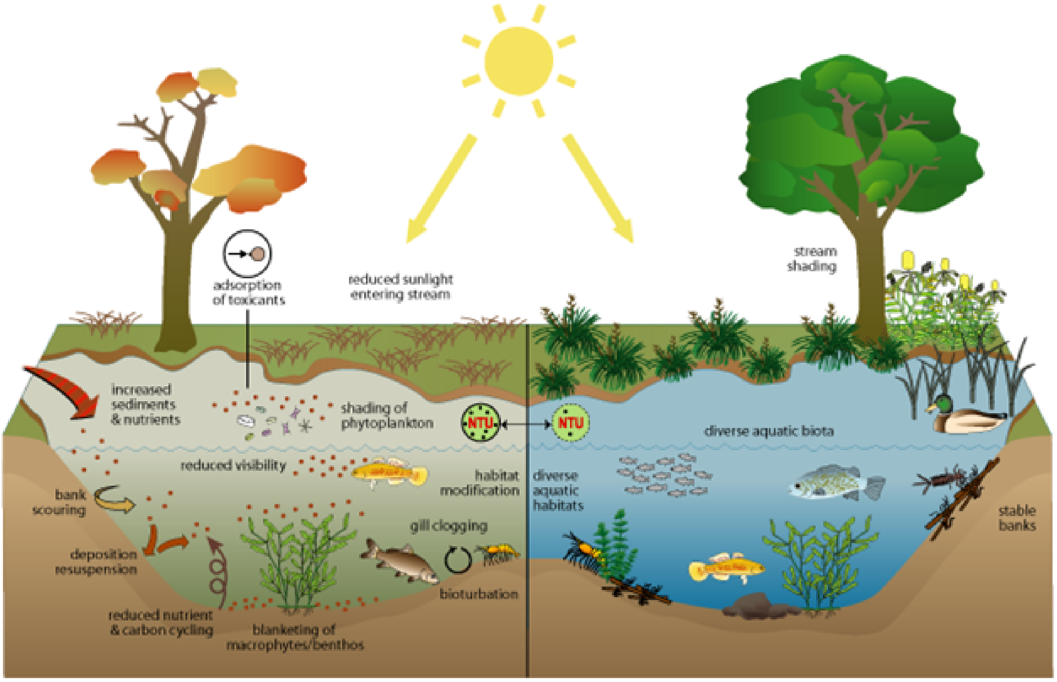

Figure 1. Effects of high (left) versus low (right) turbidity in aquatic systems. Image obtained from: wetlandinfo.des.qld.gov.au.

TURBIDITY LEVELS IN POESTEN KILL

The 2017 and 2019 ecological surveys in Poesten Kill found turbidity levels to range between 'pristine' and 'very low' levels (Fig. 2). The very low turbidity levels indicate pristine water clarity. During the 2019 survey, water levels were slightly elevated compared to 2017 due to a large rain event that had preceded sampling; possibly explaining why levels (albeit still very low) were a little more variable in 2019. Overall, the Poesten Kill is lined with large boulders and bedrock, with very little fine sediment. This appears, in part, to limit sediment transport, and thus, turbidity during high flow events.

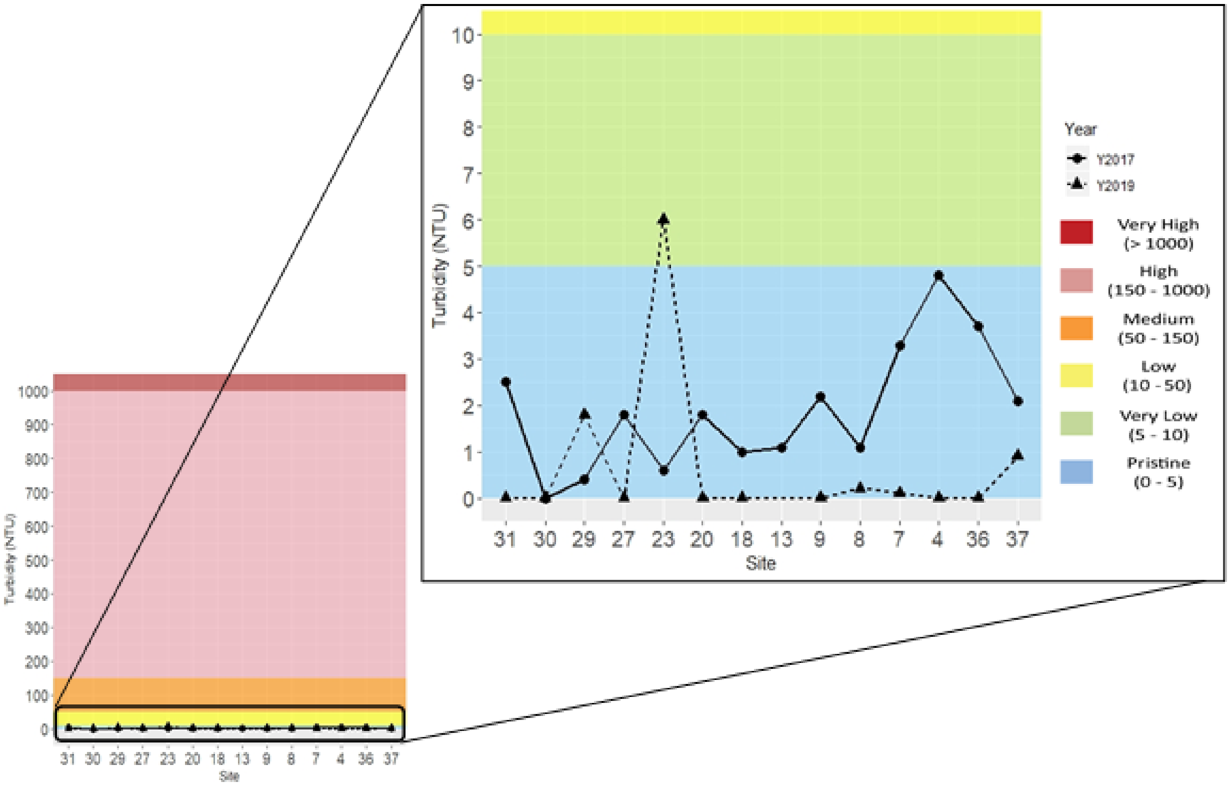

Figure 2. Turbidity levels in Poesten Kill (2017 & 2019). Sites are arranged in downstream order. The inset is meant to highlight the narrow range of turbidity levels measured in the Poesten Kill relative to the total color-interpretative scale used.

POESTEN KILL WATER QUALITY: PATHOGENS

Figure 1. Examples of sources of fecal contamination into waterbodies. Image obtained from: whatcomcounty.us/2169/Sources-of-Bacterial-Pollution.

Pathogens are microorganisms such as bacteria, viruses, and protozoans that can cause disease. Pathogens are commonly associated with decomposing carcasses and fecal material from animals of all kinds (human, other mammals, birds, etc.). Sources of fecal contamination to surface waters include untreated sewage, on-site septic systems, domestic and wild animal manure, and storm runoff from agricultural and urban lands (USEPA 1997) (Fig. 1).

Two bacteria groups, coliforms (2) and fecal streptococci, are used as indicators of possible sewage contamination because both groups are commonly found in human feces. Although generally not harmful, both groups indicate the potential presence of pathogens that also live in human and animal digestive systems. It is not practical to test for every pathogenic organism, so water is tested for indicator bacteria instead (USEPA 1997).

Because fecal bacteria can survive in waterbodies for varying periods of time, their introduction to aquatic systems can have lasting impacts that are affected by numerous, often compounding, factors and ambient conditions (Fig. 2).

---

(2) Coliforms, as the name suggests, are bacteria having a form similar to E. Coli, which is a major bacterium present in the intestinal tract of humans and other warm-blooded animals.

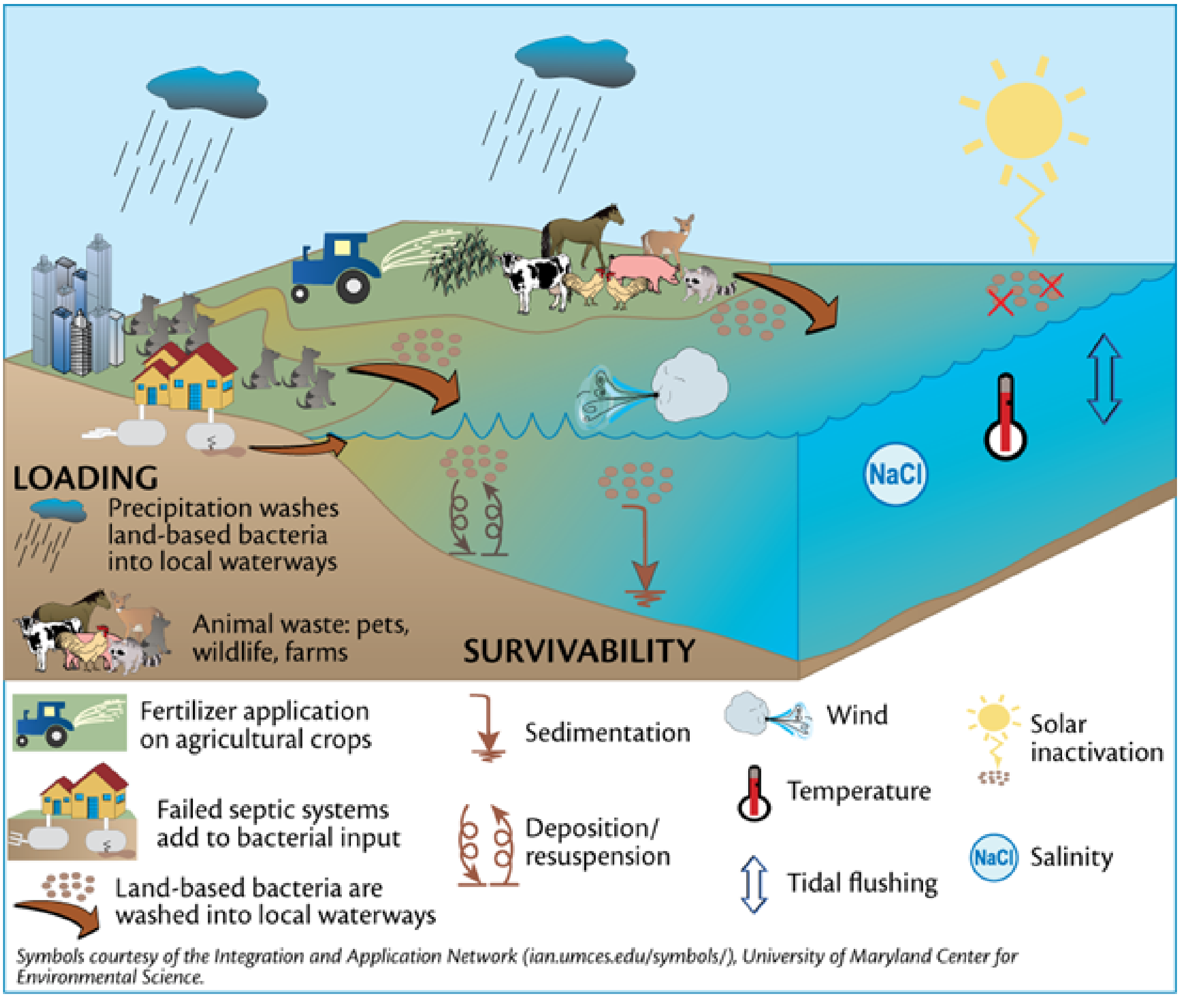

Figure 2. Conceptual model of factors affecting bacteria contamination and concentrations in an aquatic system. Image obtained from: aacounty.org.

IMPLICATIONS

- Fecal contamination can lead to algal blooms, causing significant alterations to the trophic structure of an aquatic ecosystem
- Fecal contamination can deplete oxygen levels, inducing stress on aquatic life
- High bacteria concentrations can impede recreation, such as swimming, boating, and fishing
- Fecal contamination can pollute drinking water sources, causing drinking water restrictions and shortages

WATER QUALITY STANDARDS

Fecal indicator bacteria are a primary measure used to evaluate compliance with water quality standards. In New York State, total coliforms and fecal coliforms are used to measure water quality compliance for bacteria in freshwater systems. In Class C waters (e.g., Poesten Kill), the monthly median value (from ≥ 5 samples) and >20% of total coliforms are not to exceed a concentration of 2400 colonies/100 mL and 5000 colonies/100 mL, respectively (NYSDEC 2019b). For fecal coliforms, the monthly geometric mean (from ≥ 5 samples) shall not exceed a concentration of 200 colonies/100 mL (NYSDEC 2019b).

PATHOGENS IN POESTEN KILL

Samples were collected for fecal coliform and Bacteroides analysis in 2017. Fecal coliform results indicated the concentration and extent of potential fecal contamination in Poesten Kill, providing a quantitative analysis of bacterial pollution. Bacteroides analysis is a genetic-based test that indicates the host-source (e.g., human, cow, deer, etc.) of bacterial contamination; which could then be used to isolate the physical source(s) of contamination (e.g., farm versus public sewer system).

In Poesten Kill, fecal coliform concentrations were relatively low, ranging between 'low' (27 colonies/100 mL at Site #29) and 'moderate' (300 colonies/100 mL at Site #37) (Fig. 3). The highest fecal coliform concentrations observed occurred at the three most downstream locations (Sites #4, #36, #37), suggesting that increased urbanization may be affecting bacteria concentrations. In Troy, residents are connected to municipal sewer lines. Aging infrastructure has been identified as a known source of fecal contamination, particularly in cities in the Northeast (OEI 2019). It is possible that a similar problem could be occurring in Troy. However, fecal coliform levels were still low compared to streams impacted by Combined Sewer Overflows (OEI 2019). Due to the comparably low fecal coliform levels, Bacteroides analysis did not yield any findings, with all sampling below detectable limits for host-source identification. Because only one sampling event was performed, comparisons to water quality standards could not be made.

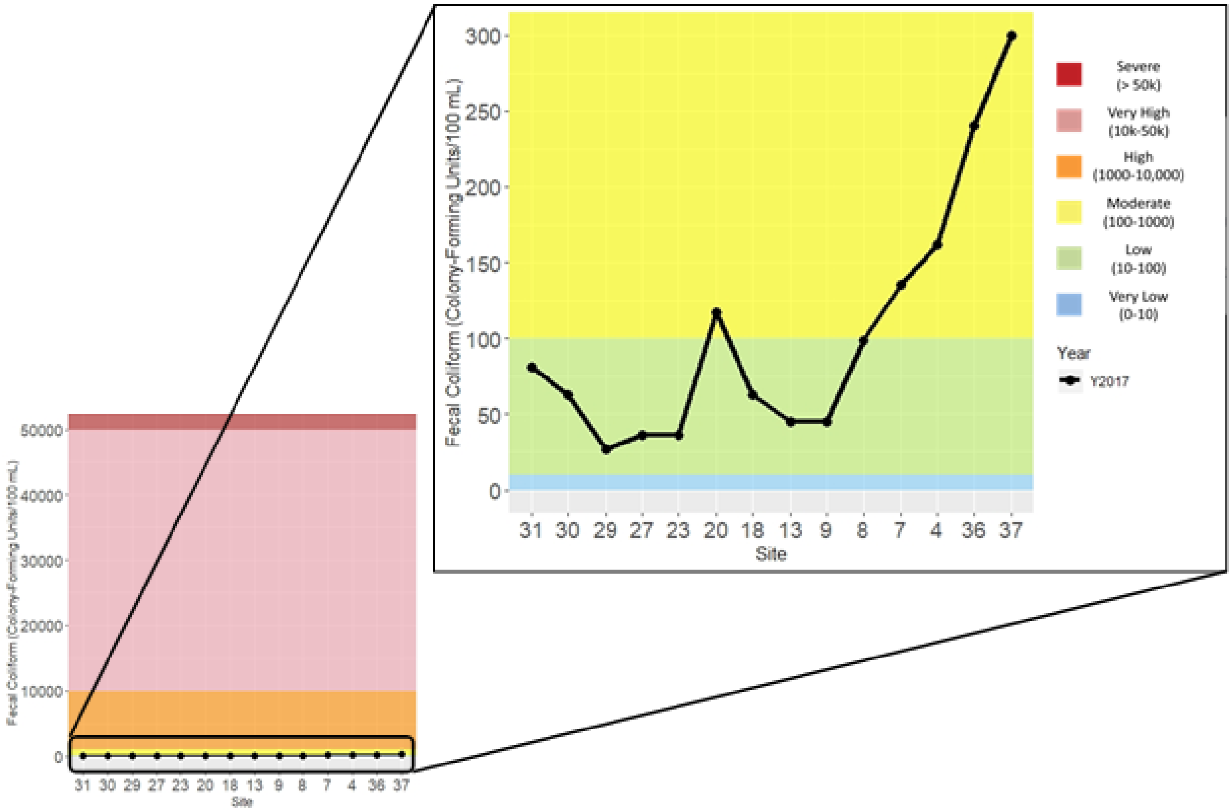

Figure 3. Fecal coliform concentrations in Poesten Kill (2017). Sites are arranged in downstream order. The inset is meant to highlight the narrow range of fecal coliform concentrations measured in the Poesten Kill relative to the total color-interpretative scale used.

LITERATURE CITED

Allan JD. 1995. Stream Ecology: Structure and Function of Running Waters. Boston, MA: Kluwer Academic Publishers.

Cushing CE and Allan JD. 2001. Streams: their Ecology and Life, Academic Press, San Diego, Ca.

Dennis B. 2018. The nation's rivers and streams are getting dangerously saltier. Washington Post [Internet]. [cited 22 October 2019]. Available from: https://www.washingtonpost.com/news/energy-environment/wp/2018/01/08/the-nations-rivers-and-streams-are-getting-dangerously-saltier/.

[FISRWG] Federal Interagency Stream Restoration Working Group. 1998. Stream Corridor Restoration: Principles, Process, and Practices, National Technical Information Service.

Fondriest Environmental, Inc. 2013. pH of water: fundamentals of environmental measurements [Internet]. [Cited 2019 October 24]. Available from: https://www.fondriest.com/environmental-measurements/parameters/water-quality/ph/.

[NYSDEC] New York State Department of Environmental Conservation. 2019a. Rules and Regulations 6 NYCRR Part 703.3 Water quality standards for pH, dissolved oxygen, dissolved solids, odor, color and turbidity [Internet]. Cited [22 October 2019]. Available from: www.dec.state.ny.us/website/regs/part703.html.

[NYSDEC] New York State Department of Environmental Conservation. 2019b. Rules and Regulations 6 NYCRR Part 703.4 Water quality standards for coliforms, enterococci, and E. coli. [Internet]. Cited [22 October 2019]. Available from: www.dec.state.ny.us/website/regs/part703.html.

[NOAA] National Oceanic and Atmospheric Administration. 2013. Ocean Acidification [Internet]. [Cited 22 October 2019]. Available from: https://www.noaa.gov/education /resource-collections/ocean-coasts-education-resources/ocean-acidification.

[OEI] Onondaga Environmental Institute. 2019. Phase 3 Microbial Trackdown Study. A Report Prepared for: NYSDEC and the Onondaga Lake Partnership.

USEPA (1997) Volunteer Stream Monitoring: A Methods Manual, U.S. Environmental Protection Agency, Office of Water. EPA 841-B-97-003. Washington, DC November 1997. Accessed at http://www.epa.gov/volunteer/stream/stream.pd