City of Austin
WATERSHED PROTECTION

Contact Recreation Considerations for Lady Bird Lake

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ABSTRACT

Recreational use of the Lady Bird Lake reservoir, the last inline reservoir on the Colorado River flowing through downtown Austin, Texas, is an important amenity for locals and visitors. Though popular with non-motorized recreational uses, swimming has been banned in the reservoir by City Code since the 1960's due to safety risks related to unseen debris and unpredictable flows and currents rather than water quality issues. Occasional requests from public and municipal stakeholders to lift the swimming ban to fully realize the recreational potential of the reservoir are circulated to officials from the Parks and Recreation Department and the Watershed Protection Department (WPD). In order to fulfill this request from a water quality standpoint, the Environmental Resource Management Division of the WPD can report Escherichia coli counts in the reservoir and compare them to the contact recreation criteria established by the Texas Commission on Environmental Quality (TCEQ). This data report summarizes nearly two decades of routine water quality monitoring of E. coli concentrations, makes comparisons with TCEQ criteria, and attempts to link E. coli values with rainfall and discharge, the most common environmental drivers of bacterial concentrations in a water body. For the sites monitored, contact recreation standards were met, with only 17 singular site E. coli concentration exceedances out of over 450 discreet observations. Spatial and temporal variations were related to rainfall and proximity to the Tom Miller Dam. In general, increasing rainfall amounts closer to the day of sampling was positively correlated with E. coli concentrations. This report represents only a first step in what would be a multi-agency effort toward changing the ordinances banning swimming, but suggest that, broadly, contact recreation could be supported in many portions of the reservoir.

INTRODUCTION

Austin's most prominent reservoir, Lady Bird Lake (LBL), is a focal point for recreation. Kayaks, canoes, standup paddleboards, scullers, and bass boats are frequently seen throughout the reservoir, and wading is common downstream of Barton Springs Pool. However, there is a prohibition to swimming in reservoir in the City Code of Ordinances:

> § 8-5-48 - SWIMMING IN LADY BIRD LAKE.
>
> A person may not swim in Lady Bird Lake. This prohibition does not apply to a person:
>
> (1) performing an official duty as an officer or employee of the city;
> (2) attempting to rescue or recover another person;
> (3) performing dredging or construction work authorized by the city council; or
> (4) participating in a public event or exhibition authorized by the city council.

Source: 1992 Code Section 14-1-11; Ord. 031009-11; Ord. 031211-11; Ord. No. 20190307-014 , Pt. 9, 3-18-19.

Though swimming in Barton Creek between the reservoir and Barton Springs Pool is allowed:

§ 8-5-49 - SWIMMING IN BARTON CREEK.

(B) An owner or handler of a dog may allow the dog to swim in Barton Creek between Lady Bird Lake and Barton Springs Pool. Section 3-4-1 (*Unrestrained Dog Prohibited*) does not apply to an owner or handler for purposes of this section.

Source: 1992 Code Section 14-1-9; Ord. 031009-11; Ord. 031211-11; Ord. No. 20141211-186, Pt. 1, 12-22-14.

The ban on swimming was originally established by Ordinance 640611-C which followed a May 28, 1964 City Council meeting that included discussion of 30 confirmed drownings in the reservoir over the previous decade (http://www.austintexas.gov/edims/document.cfm?id=41480). The drownings were of various causes including several due to the release of water from Tom Miller Dam, but the majority were attributed to people who were "uninformed", "unskilled", and/or "drinking". The ban originally went so far as to make it "unlawful for any person to willfully swim, bathe, wade, or go into the waters" and was promoted by a council member to "protect the health, safety and welfare of the public". The ban has been upheld (with modified language) in code changes since this time. Anecdotally, others have indicated support for the ban due to underwater hazards from flood debris, bridge construction debris, unpredictable currents from historic submerged dams, and the potential for unannounced swift current related to dam discharges and stormflow. Substantiating safety concerns for submerged debris, in May 2012 a swimmer who jumped in the reservoir impaled his foot on submerged rebar near the Lamar bridge (https://www.kvue.com/article/news/video-shows-why-swimming-in-lady-bird-lake-is-unsafe/269-343658787). News headlines periodically lend credence to swimming and storm related safety concerns as well. On May 21, 2020 a swimmer drowned in LBL of unknown reasons (https://www.statesman.com/news/20200521/swimmer-pulled-from-lady-bird-lake-dies-ems-medics-say), and just a few days later, on May 24, twelve individuals required rescue by the Austin Fire Department after being stranded on LBL underneath bridges despite the clear and present advance of a storm system (https://www.statesman.com/news/20200524/update-flood-warning-until-1215-am-for-parts-of-travis-county). Many of the same concerns regarding various safety issues are justified more than half a century after the original ban, as well as the emergence of new safety concerns (e.g., https://www.kxan.com/news/local/austin/woman-jumping-from-bridge-lands-on-kayaker-in-barton-creek/).

Internet searches for "ban on swimming in Lady Bird Lake" reveal that the citizenry has several misconceptions attributing the ban on such things as bacteria levels, harmful wildlife, mercury, dead bats, water quality, etc. This negative perception of the water quality of LBL is not necessarily unjustified because much of the stormwater flowing from Austin's urban watersheds is from development constructed prior to water quality and stormwater detention control requirements. There are surely also some lingering memories of lakeside signage from 1987–1999 when the Austin-Travis County Health Department issued a health advisory stating people should not consume certain fish due to Chlordane (a pesticide banned in 1983) concentrations in fish tissue. Other discrete aquatic issues such as harmful cyanobacteria proliferations, invasive plants, and high turbidity perpetuate negative perceptions of the water quality of the reservoir.

Periodically, citizens and staff question the continued applicability of the prohibition of swimming with optimism to more fully utilize the waterbody for the benefit of the community. However, there are several obstacles to be addressed and stakeholder groups that would need to be engaged to change code to allow swimming in LBL including, but not limited to:

- the lengthy code revision process which would include the input of a diverse group of stakeholders and several departments including, but not limited to: Parks and Recreation, Watershed Protection, Austin Water, Austin Police, Austin Fire, etc.;

- an assessment of the hazard/liability posed by debris (e.g., historic dam, construction, storm);
- a determination of locations that could serve as appropriate for swimming and how these areas could be defined and/or partitioned;
- verifying suitable water quality at specific locations (water quality is not uniform) related to swimming risks that are historic (e.g., PAHs), on-going (e.g., *E. coli*), and emerging (e.g., cyanotoxins);
- determining criteria for swimming prohibition preceding and following a storm event, and how subsequent enforcement would be implemented;
- the cost associated with various actions deemed necessary including, but not limited to infrastructure, signage/notification, supervision, surveys, debris removal, monitoring, liability, maintenance, etc.;
- environmental concerns with the various options considered (e.g., if the lake needs to be drained to remove debris, what effect will that have on fish or native Unionid mussel populations); and,
- consideration of potential conflicts between recreational use and the potential use of LBL for Indirect Potable Reuse of reclaimed water.

Although most of these obstacles are outside the purview of WPD, water quality evaluation in the context of human safety can be partially addressed with existing data. Water quality data is routinely collected as part of the WPD mission to protect lives, property, and the environment by reducing the impacts of flood, erosion, and water pollution. In addition to routine assessments, in 2005 WPD compiled a special study report that looked at fecal coliform concentrations in LBL in relation to storm magnitude (Glick 2005). This review of historic fecal coliform data suggests that within a week after a storm event there is typically a trend of increasing concentration downstream with greater variability between sites. The most upstream sites typically had low concentrations even shortly after most rain events, which is expected due to inflows dominated by dam operations. However, sites receiving significant urban watershed runoff such as those downstream of the Lamar Blvd bridge may be unsafe for as long as 7 days after a large (i.e., >0.5") rain event but may be safe as soon as 24 h after a small (<0.5") rain event. These findings based on fecal coliform may represent a general understanding of bacterial contamination following storms; however, they are not based on contemporary conditions, and do not use the parameter recommended (i.e., *Escherichia coli*) by the Texas Commission on Environmental Quality (TCEQ) for recreational considerations.

Escherichia coli is used by the TCEQ as a recreational indicator of fecal contamination to determine appropriateness of primary (e.g., swimming) and secondary (e.g., wading) contact recreation. Current standards for contact recreation are a single grab sample not to exceed 399 colony forming units/100ml (cfu/100ml) and a geometric mean ("geomean") of at least 10 samples not to exceed 126 cfu/100ml. A recent report by WPD (Porras 2020) describes the history and logic of these standards, discusses the applicability of geomean values, and categorizes Austin streams within that framework. The WPD has routinely assessed *E. coli* since 1999 as part of the Austin Lakes Index (ALI) long-term reservoir monitoring program (Richter 2011). This report summarizes *E. coli* concentrations collected by WPD as part of the ALI program and in the context of TCEQ criteria for contact recreation and as related to antecedent storm events and discharge volumes from the Tom Miller Dam to provide information for management considerations. This report also discusses some limitations of using currently available data for management decisions as well as considerations for future water quality monitoring if the prohibitions on swimming were to be removed.

METHODS

The *E. coli* data evaluated in this report were collected between August 1999 and August 2019 from Lady Bird Lake sites #5 (Red Bud Isle), #2 (South 1st St. bridge), and #1 (Basin) (Figure 1). Data are available to the public through the City of Austin Water Quality Sampling Database (https://data.austintexas.gov/Environment/Water-Quality-Sampling-Data/5tye-7ray). Samples were typically collected bi-monthly (even months), but in 2018 sampling of odd months between May and October was added to better characterize reservoir water quality dynamics during the summer growing season and period of highest recreational use. Additionally, prior to 2014, sampling after randomly selected large storm events was carried out to capture system responses to urban tributary inputs and occurred in odd or even months outside of the routine efforts. As such, the analyzed sampling effort through the study period varied at a single site within and between years. Split or duplicate samples collected from a site were included in the data summary to capture intra-site variability. Summary *E. coli* concentrations are described with geomeans as that method tempers the potential exponential growth of bacteria that would otherwise skew normal summarizing techniques (e.g., average). Geomean summaries and single sample exceedances are compared with the TCEQ standard for freshwater systems to support contact recreation of 126 cfu/100 mL, and a single sample maximum of 399 cfu/100 mL, respectively (https://www.tceq.texas.gov/assets/public/legal/rules/rules/pdflib/307.pdf).

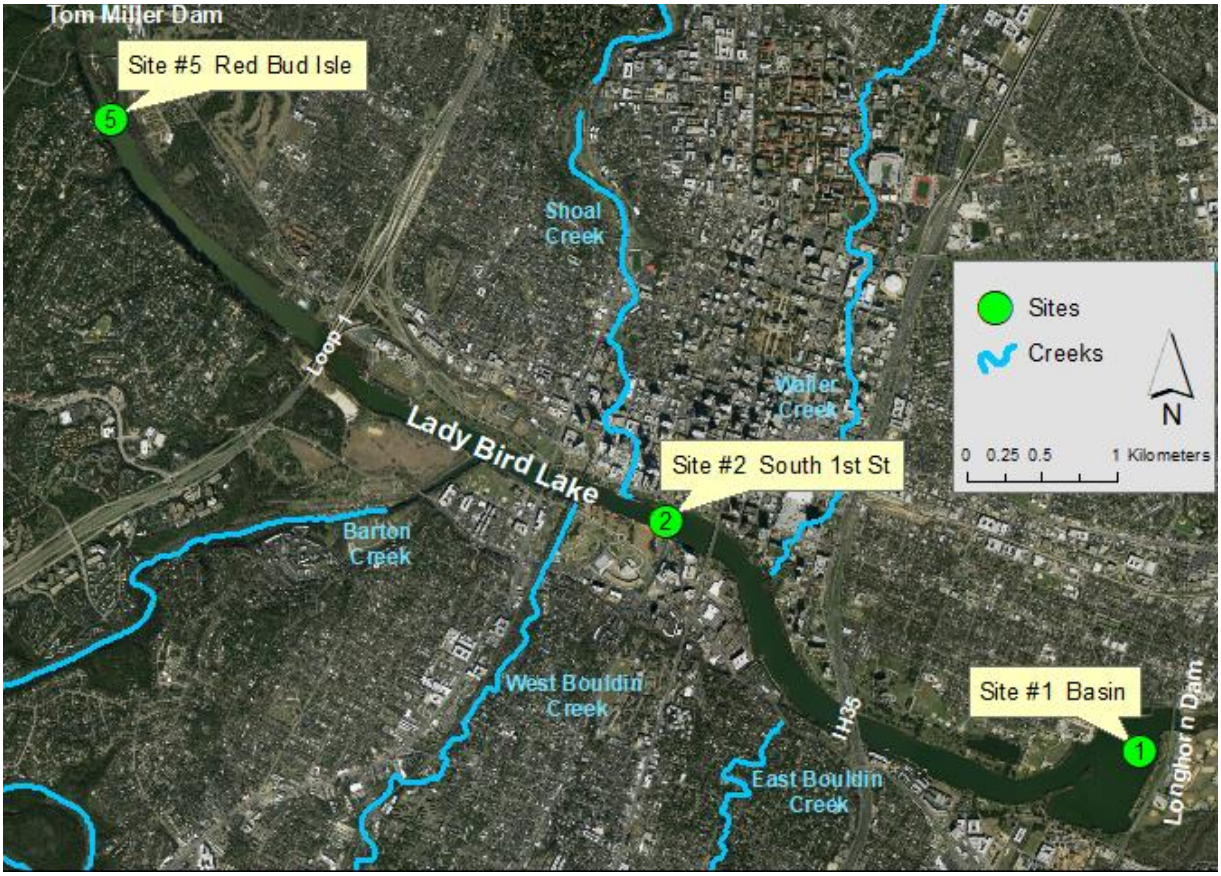

Figure 1. Map of sampling locations from upstream to downstream: site #5, Red Bud Isle; site #2, 1st St. bridge, and site #1, Basin. Select small and large urban tributaries are also shown.

Storm events and hydrologic (flow) events were hypothesized to influence water quality in LBL. Correlations (Pearson's correlation coefficient *r*) were determined between $\log_{10}$-transformed *E. coli* concentrations and 1) daily rainfall amounts up to two weeks before sampling, 2) the cumulative rainfall for the previous two weeks before sampling, and 3) Tom Miller Dam average discharge on the day of sampling. National Oceanic and Atmospheric Administration (NOAA) daily rainfall amounts from 08/01/1999 until 05/08/2020 measured at Camp Mabry's National Weather Service station (Austin Camp Mabry, TX US; GHCND: USW00013958; Latitude Longitude: 30.3208, -97.7604) were used to determine daily rainfall amounts. This station is located approximately 3 miles from LBL.

RESULTS & DISCUSSION

Across the period of record for all sites combined, there were a total of 457 observations with a geomean *E. coli* concentration of 19.0 cfu/100 mL (standard deviation of 5.0), which was below the TCEQ contact recreation geomean criteria of 126. However, there were 17 discrete observations over 399 cfu/100 mL (the TCEQ criteria for a single grab sample).

The highest annual geomean concentration was in 2015 (41.3 cfu/100 mL) and the lowest was in 2012 (8.2 cfu/100 mL) (Figure 2A). These high/low years correlate with climatic extremes: 2015 was an exceptionally wet year, with the Austin-area experiencing several large flooding events, whereas 2012 was near the apex of a "drought of record" period, with minimal rainfall and low flows from the contributing tributaries and throughout the Highland Lakes. The largest geomean for any given month for the period of record was in April (41.4 ± 7.9 cfu/100 mL) whereas the lowest was in July (12.8 ± 3.5 cfu/100 mL) (Figure 2B) which generally correlates to rainfall as well. Although Central Texas has a bimodal rainy season (spring and fall), the month with the highest average rainfall is May (https://www.rssweather.com/climate/Texas/Austin%20City/). There are several possible reasons for a geomean *E. coli* concentration peak in April, a month before the "rainiest" month. For example, it is possible that the early Spring storm events in April that typically follow a drier winter provide a "first flush" that washes fecal matter from the watershed into the reservoir, increasing the mean for that month. Additionally, the large storms/flow events typically realized in May/June may have inhibited reservoir access, precluding capture of large spikes in *E. coli* concentrations. Also, the large releases in May/June for down-river agricultural rights may have rapidly flushed and diluted *E. coli* (Bellinger et al. 2018). An analysis of antecedent weather conditions indicated that *E. coli* concentrations system-wide were significantly positively correlated with rainfall within seven days of sampling; strongest correlations were between system-wide *E. coli* concentrations and rainfall 1–2 days prior to sampling (Table 1; Figure 3), suggesting that isolated events and the immediate runoff of organic matter and waste contribute to *E. coli* concentration spikes. There were no correlations observed between discharge volumes and system-wide *E. coli* concentrations, but discharge was correlated at the site level (Table 1).

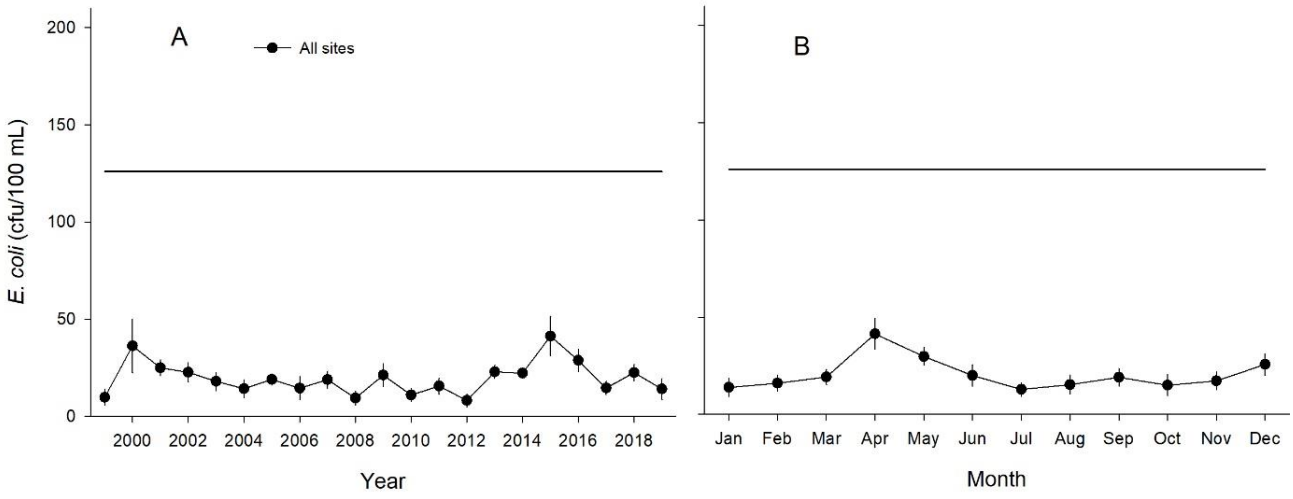

Figure 2. Annual (A) and monthly (B) geomean (± standard deviation) of *E. coli* concentrations (cfu/100 mL) for all 457 combined sample results from Lady Bird Lake. Combined results indicate that Lady Bird Lake appears to be well below the TCEQ contact recreation geomean freshwater criteria for *E. coli* of 126 cfu/100 mL.

Table 1. Pearson Correlation Coefficients (*r*) for log_{10}-transformed *E. coli* concentrations (cfu/100 mL) relative to daily rainfall (inches) occurring one through seven days prior to sampling and average daily Tom Miller Dam discharge (cfs).

Only significant correlations are shown: P < 0.001 P < 0.01 P < 0.05

Site	1 Day	2 Days	3 Days	4 Days	5 Days	6 Days	7 Days	*Discharge/cfs*
	Daily Rainfall (in/day)							
All sites	0.40	0.31	0.11		0.10	0.10	0.16	
Red Bud	0.46	0.32	0.20				0.27	-0.14
South 1st	0.51	0.35						-0.20
Basin	0.50	0.36						0.22

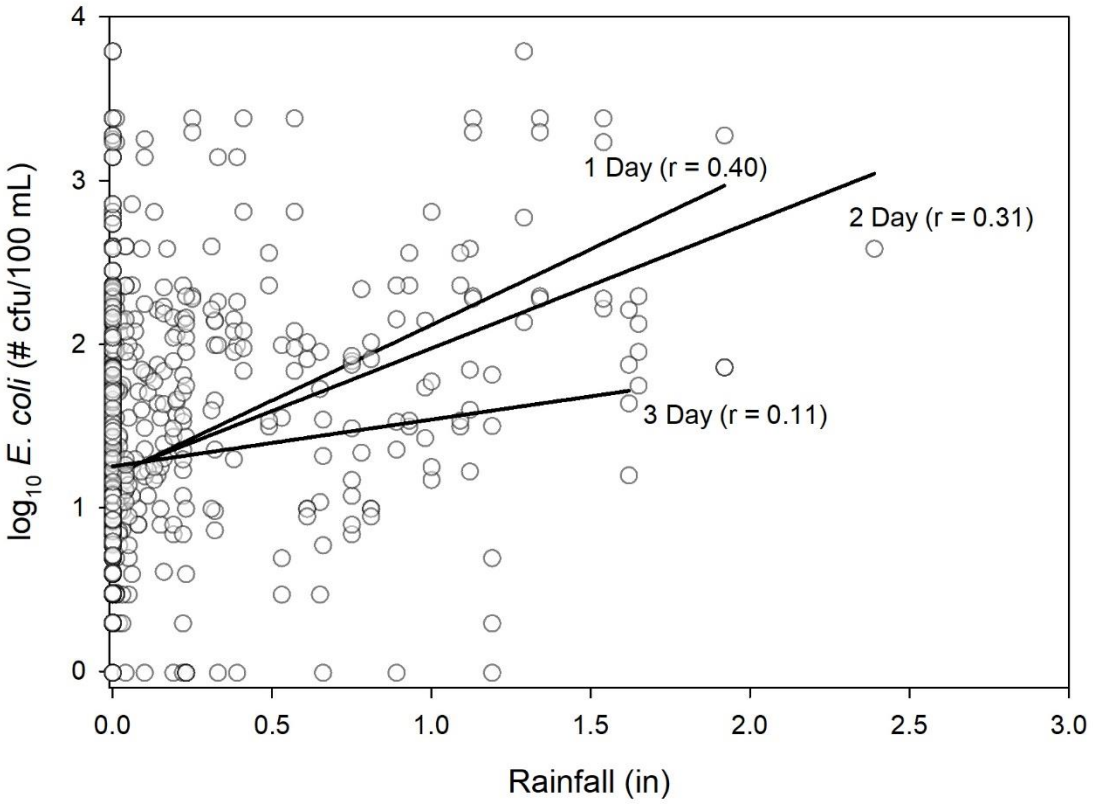

Figure 3. Relationships between rainfall event size (in) and $\log_{10}$-transformed *E. coli* concentrations (# cfu/100 mL) 1-3 days prior to sampling for all site observations. *E. coli* concentrations were significantly positively correlated with rainfall amount, but the relationship was strongest and largest 1 day prior to sampling.

Coupled with rainfall patterns, sampling frequency could have influenced how often TCEQ thresholds were exceeded (https://www.epa.gov/sites/production/files/2015-11/documents/sampling-consideration-recreational-waters.pdf). The proportion of samples with *E. coli* concentrations >399 cfu/100 mL was highest in April at 13.5% though it was not the most frequently sampled month (n = 37). Rather, August through November were the most sampled (52–64 observations), but the highest proportion of samples that exceeded 399 cfu/100 mL in October was only 5.3%. Spring rains may occur more frequently over a months-long period associated with numerous cold fronts, increasing the likelihood of sampling soon after a rain event. Conversely, large October storm events tend to occur late in the month, typically after routine monitoring, suggesting that the timing of sampling was also a factor influencing detecting exceedance of TCEQ *E. coli* thresholds. Summers tend to be dry, and the increased sampling frequency without measured exceedances would help to reduce the overall geomean reported. Surprisingly, December had the 3rd highest geomean and maximum concentration, with a rate of exceedance of over 7%. It is unclear why December *E. coli* concentration would be elevated as it is not an especially wet month, water temperatures are lower, and flows are not especially different relative to the other winter months.

In addition to temporal variations system-wide, there were spatial differences in *E. coli* concentration that may inform location-suitability considerations for contact recreation. Among sites, the highest geomean concentration was at site #2 S. 1st St. Bridge (60.9 ± 3.5 cfu/100 mL; n = 112), followed by site #1 Basin (23.2 ± 6.0 cfu/100 mL; n = 136), then site #5 Red Bud (8.8 ± 3.3 cfu/100 mL; n = 205). Therefore, for all years each site was below the TCEQ contact recreation geomean threshold of 126 cfu/100 mL. The following paragraphs describe *E. coli* data dynamics at each of the three sites.

Site #5, Red Bud Isle

This site is the most upstream and is almost exclusively influenced by Tom Miller Dam discharges from the hypolimnion of Lake Austin (Figure 1). Accordingly, there was a negative correlation between *E. coli* concentration and discharge rate (Table 1). Three of the five highest annual geomeans at this site were between 2013 and 2015 (Figure 4A), which coincided with periods of low discharges from the Tom Miller Dam. The largest monthly geomean *E. coli* concentrations were observed in December (14.0 ± 5.1 cfu/100 mL), followed by April, February, and May (Figure 4B). Single largest observations were captured in December 2001 (400 cfu/100 mL); however, that value could be suspect as a duplicate taken from the site at the same time had an *E. coli* concentration of only 40 cfu/100 mL. Next highest concentrations were in April 2016 (199 cfu/100 mL), and October 2000 (138 cfu/100 mL). Red Bud Isle is minimally influenced by tributaries, so it is unclear why daily rainfall had a relatively strong positive influence on *E. coli* concentrations (Table 1). While the upper reservoir typically has the lowest *E. coli* concentrations, and therefore may have more suitable water quality for contact recreation, the proximity to the Tom Miller Dam presents increased physical hazards. These hazards include unpredictable currents, large granite boulder debris (from a previous catastrophic failure of the Austin Dam), and higher velocities than downstream segments due to a shallower cross section.

Site #2, South 1st Street Bridge

Site #2 looks up at the downtown Austin skyline, downstream of the confluence of two large urban creeks with known elevated bacteria concentrations (e.g., Shoal and West Bouldin Creeks; https://austintexas.gov/faq/eii-reports-listed-watershed) (Figure 1). The single highest *E. coli* discrete sample from Lady Bird Lake was at site #2 in October of 2000 (6,200 cfu/100 mL). In 2000 the highest total suspended solids concentration was recorded in lower Shoal Creek for the 1996–2017 period (Shoal Creek Conservancy report 2019). There were three years in which geomeans exceeded the TCEQ criteria of 126 cfu/100 mL: 2000 (151.1 ± 10.9 cfu/100 mL), 2009 (128.6 cfu/100 mL), and 2015 (146 ± 10.8 cfu/100 mL) (Figure 4A). On average, *E. coli* concentrations were 145% greater at site #2 than at site #5. Aggregated monthly, the site geomean concentrations were below the contact recreation criteria with the exception of April (202.7 ± 6.3 cfu/100 mL; Figure 4B). Two of the three largest single observations at this site were in April of 2015 (2,420 cfu/100 mL) and 2016 (1,990 cfu/100 mL). *E. coli* concentrations were positively related to rainfall within two days of sampling, but there was a negative correlation with discharge volume (Table 1). This suggests that increasing average daily discharges from the Tom Miller Dam likely have a flushing and/or diluting effect whereas rainfall events and associated loading of fecal matter to this site from the urban creeks appear to have an immediate positive effect on *E. coli* concentrations.

Site #1, Basin

Site #1 is located at the downstream end of the reservoir, off the main river channel in a "basin" that was originally a quarry which was breached when LBL (then "Town Lake") was created. This site has an annual geomean *E. coli* concentration that is 74% greater than site 5, but 88% lower than site 2 with annual geomeans generally between 10–30 cfu/100 mL (Figure 4A). Elevated concentration in single grab samples occurred in August 2000 (1,800 cfu/100 mL) and June 2003 (1,900 cfu/100 mL). True concentrations reported in December 2015 and April 2016

(>2,420 cfu/100 mL) cannot be known due to laboratory method constraints. Highest monthly average concentrations occurred between March and June but were still below the contact recreation geomean threshold (Figure 4B). Lowest monthly geomean concentrations in October may be related to water column stratification. Site #1 is the only monitoring site that stratifies and turn-over tends to occur in October (Bellinger et al. 2018). Turn-over may dilute *E. coli* abundance due to the mixing of bottom and surface waters. Site #1 *E. coli* concentrations were positively correlated with rainfall within two days of sampling and was also the only site positively correlated with Tom Miller Dam discharges (Table 1). It was unexpected that the basin would have a positive correlation with discharge due to is location off of the main-stem of the river, and furthest from the upstream dam; however, this suggests that with increased flows, upstream water that is contaminated with *E. coli* is effectively transported and mixed in the lower reservoir.

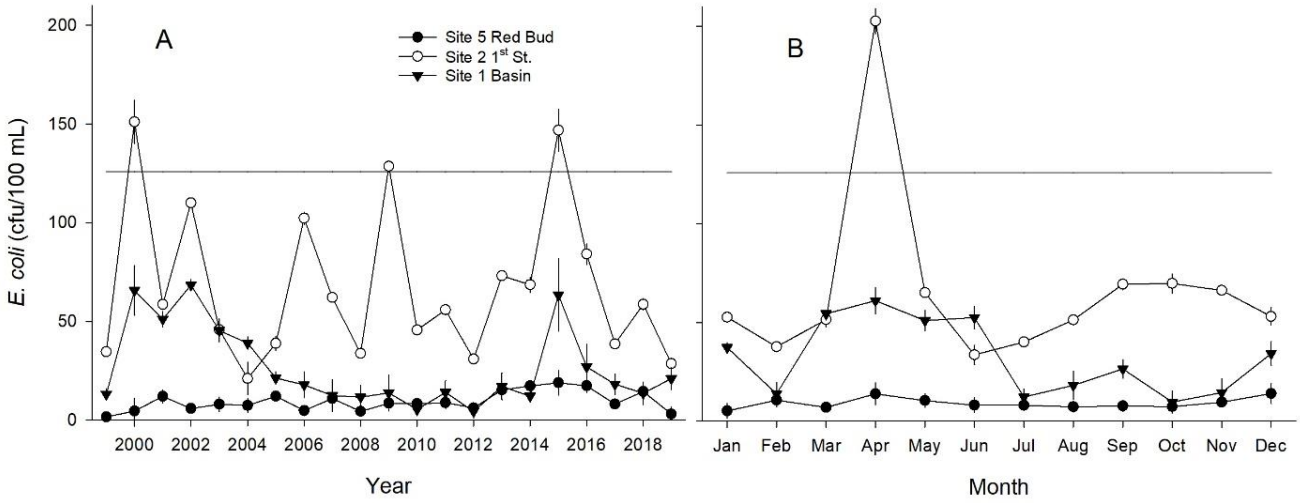

Figure 4. Annual (A) and monthly (B) geomean (± standard deviation) of *E. coli* concentrations (cfu/100 mL) for each monitoring site. TCEQ contact recreation geomean freshwater criteria for *E. coli* of 126 cfu/100 mL shown as a horizontal line.

The data generated by the Austin Lake Index monitoring program implies that LBL meets TCEQ geomean *E. coli* criteria for contact recreation (as determined in 2020). However, this data has the following limitations:

- Spatial variability – Although these three sites are a characterization of "Lady Bird Lake", there is considerable spatial variability to bacteria concentration, and therefore it cannot be inferred that other areas of the reservoir are similar to one or more of the three sites (https://www.epa.gov/sites/production/files/2015-11/documents/sampling-consideration-recreational-waters.pdf). Specifically, creek deltas and backwater sloughs are likely more like respective creek condition than that of the main body of the reservoir. In addition, the nearshore areas are more likely to have higher concentrations of *E.coli* than the open water sites due to shallow waters with frequently re-suspended sediments in proximity to common areas of high

human and pet recreation (e.g., parks, trails, open space, etc.) in which small rain events wash feces into the waterway. Therefore, although the characteristics of any given location can be like one of the three sites, it should not be assumed to be the same.

- Temporal variability – Weather and hydrologic influences also create temporal variability in *E. coli* concentration and persistence (https://www.epa.gov/sites/production/files/2015-11/documents/sampling-consideration-recreational-waters.pdf). Storm intensity, antecedent rainfall, drought, time of year, flow, and temperature all effect bacteria concentration. Some of the data used in this study represent conditions that reflect post-storm events. Although the duration of the effect that storm water has is different depending on the site location and storm intensity, it can be assumed that bacteria concentrations rise for a period of time following rain. Small rain events may increase concentrations for only a day or two, while large rain events may increase concentrations for a week or more.
- Other water quality parameters – Although *E. coli* is a commonly used as a surrogate for a diverse assemblage of pathogens in fecal contamination, it should be noted that there may be other bacterial, viral, or protozoan pathogens present, especially during times of hot weather with low flow, and that biological constituents are only one aspect of water quality. Several pollutants (e.g., metals, PAHs, pesticides, etc.) commonly adhere to fine sediment both at the bottom and sometimes suspended. Lady Bird Lake is a sink for sediments washing off several urban watersheds. In addition, emerging concerns such as zebra mussels and cyanotoxins generated from harmful algal blooms, add increasing uncertainty about the suitability of contact recreation.
- Underwater hazards – These recommendations do not preclude additional efforts that are not related to water quality such as physical hazards in the lake, unpredictable current, unannounced increases in flow, prohibitions on swimming both pre- and post- storm events, costs for maintaining designated swim areas, costs for enforcement/monitoring, etc.

RECOMMENDATIONS

Although baseflow water quality data from Lady Bird Lake generally does support contact recreation, an effort to change the current prohibition on swimming may warrant additional information including, but not limited to:

- A Special Study to further explore relationships between rainfall amounts and occurrence up to 7 days prior to sampling and *E. coli* concentrations;
- A thorough evaluation of other constituents that may pose health risks either seasonally (e.g., cyanotoxins) or following storm events (e.g., suspended sediment, herbicides/pesticides, emerging contaminants, etc.) that may factor into management decisions. Additional sampling may be required to inform the evaluation; and,
- At least one year of monitoring at any proposed contact recreation sites to evaluate suitability, with monitoring continuing after lifting prohibition, given the documented large intra- and inter-annual variability in concentrations (https://www.epa.gov/sites/production/files/2015-11/documents/sampling-consideration-recreational-waters.pdf). The seasonality of the *E. coli* peaks warrants higher sampling frequency in the wettest months with the largest flows (April–June, September–October) which coincidentally tend to be months of high recreational use.

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