A review of surface water quality trends in streams and reservoirs in Austin, Texas: 1994-2018.

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Abstract

The City of Austin has been collecting routine water quality data in its creeks and reservoirs for 25+ years, but to date, an overview of temporal trends has not been compiled. During this period, Austin has seen unprecedented population growth and increased urbanization, which are established predictors of degradation in surface water resources. By aggregating chemical, biological and physical data that has been collected using similar methods and locations for this extended period of record (~1994-2018), a robust assessment of temporal trends can be made. During this period, the receiving water reservoirs of the Colorado River, Lake Austin and Lady Bird Lake, have maintained fairly consistent overall water quality with the exception of an increase in blue green algae counts. Austin's creeks have also maintained consistent water quality during this period, and in many measures, are actually showing some recovery trends. The regulatory environment was assessed at a high-level by dividing development up into pre-regulation and other regulations (later water quality regulations and development outside Austin's jurisdiction), showing that those that were developed before water quality regulations were in place were consistently lower-scoring than the other categories. These results are likely due to a combination of long-term recovery from larger-scale degradation that occurred over the past 100 years, construction-phase management and other best practices by government and the private sector, water quality retrofits, and effective education and outreach efforts. Identification of key solutions and better cause-and-effect relationships are recommended via more targeted studies and analysis efforts.

Introduction

Background

The City of Austin has been routinely monitoring the ambient quantity and quality of its surface water resources since the mid-70's. Water quality surveys started with the most downstream reservoir of the Colorado River, called Town Lake at the time (Herrington 2007), and evolved into the more comprehensive citywide monitoring programs utilized currently, the Environmental Integrity Index (City of Austin 2002) and the Austin Lakes Index (Richter 2011). During this period there has been a wide variety of in-depth reporting efforts on the reservoirs and creeks (Duncan et al. 2010, Gilroy and Richter 2010, Scoggins and Richter 2010, Duncan and Wagner 2011, Clamann et al. 2015, Richter and Porras, Abel 2015, Bellinger et al. 2017), but to date, no general review of temporal trends in Austin's surface waters.

Austin lies at the juncture of the wide, flat gulf coast plain and the Central Texas Plateau uplift, where gulf moisture creates a dynamic climate that can drop large amounts of rain in short periods and have long periods of high temperatures and no precipitation (Caran and Baker 1986). The land towards Austin's western jurisdiction is characterized as the Hill Country, with rugged topography, thin soils, karst recharge features and exposed limestone. In contrast, the land towards Austin's eastern city limits is characterized as the Blackland Prairie, with flat topography and deep silt and clay soils. Regarding land use, the age of development in Austin has generally proceeded from the downtown urban core and spread out radially to the present jurisdictional limits.

Austin's population has grown from approximately 130,000 people in 1950 to 970,000 in 2018 (Robinson 2018). From 1970 to 1990, the population increased by approximately 210,000 people, but has increased by approximately 500,000 over the past 30 years. Austin's background climate, coupled with population increase, development patterns, and the increasing variability of climate change, result in an environment where spatial and temporal patterns in our surface-water resources are difficult to quantify (Hayhoe 2014, Larsen 2015, Hale et al. 2016). Accurate predictive models and causal relationships are rare in the assessment of surface water resources, especially in heavily urbanized areas. It is assumed that increasing population and expanded urbanization leads directly to degradation of surface water resources (Center for Watershed Protection 2003, Konrad and Booth 2005, Walsh et al. 2005b, Alberti et al. 2007, Booth and Bledsoe 2009, Roy et al. 2016, King et al. 2016). However, there has been recent work that looks more closely at how water quality regulations, stormwater controls, and development distribution and timing can result in alternative and sometimes positive water quality trajectories (Bernhardt and Palmer 2007, Scoggins et al. 2007, Kaushal et al. 2015, Bell et al. 2016, Utz et al. 2016, Walsh et al. 2016, Li et al. 2017).

Surface water regulations

Environmental regulations intended to be protective of water quality began in Austin in earnest in 1986 with the Comprehensive Watershed Ordinance (CWO). The CWO limited density of development and impervious cover in all watershed regulation areas except Urban (Fig 1), required erosion and sedimentation controls, limited development on slopes over 15%, and established protective buffer zones along waterways and sensitive features. It also established structural water quality control requirements for development, requiring the capture and treatment of at least the first one-half (1/2) inch of runoff and up to 1.3 inches of runoff from all contributing areas to the control, based on impervious cover. In addition, controls in the Edwards Aquifer Recharge Zone were required to have impervious liners (City of Austin 1986). In 1991, the CWO was extended to include the Urban watersheds and a payment-in-lieu option for some Urban watershed sites via the Urban Watershed Ordinance (UWO). Although there were upgrades and improvements to the code and criteria over the intervening years, including the Save Our Springs initiative in 1992 (SOS, which focused on the Barton Springs Zone watersheds), the next major change in water quality regulations applying to the entire jurisdiction did not come until the adoption of the Watershed Protection Ordinance (WPO) in 2013. The WPO increased water quality buffers on waterways both in scale and extent, improving protections to headwaters, riparian areas and floodplains (City of Austin 2013).

Development in Austin includes five distinct regulatory categories, Urban, Suburban, Water Supply Suburban, Water Supply Rural, and the Barton Springs Zone (Fig. 1). These distinct regulatory environments strongly influence new development but may affect redevelopment less depending on its regulatory category. However, in addition to the regulatory environment, the City of Austin also has a stormwater retrofit program that installs regional water quality controls as well as a city-wide education and outreach program. The stormwater retrofit program identifies high-priority locations for typically larger-scale stormwater control measures (SCMs) based on land availability and cost-effectiveness in catchments with poor water quality. Opportunities for such retrofits are limited and while pollution load reduction and hydrologic impacts can be quantified, it is challenging to measure the overall effect on receiving water quality. Similarly, the Watershed Protection Department's award-winning education and outreach program is robust and has a long history working with both adult and youth populations in Austin, including deep connections to the school system, the gardening community, and the outdoor-focused citizenry. While the education program likely has a significant impact to water quality, it is very difficult to quantify this impact.

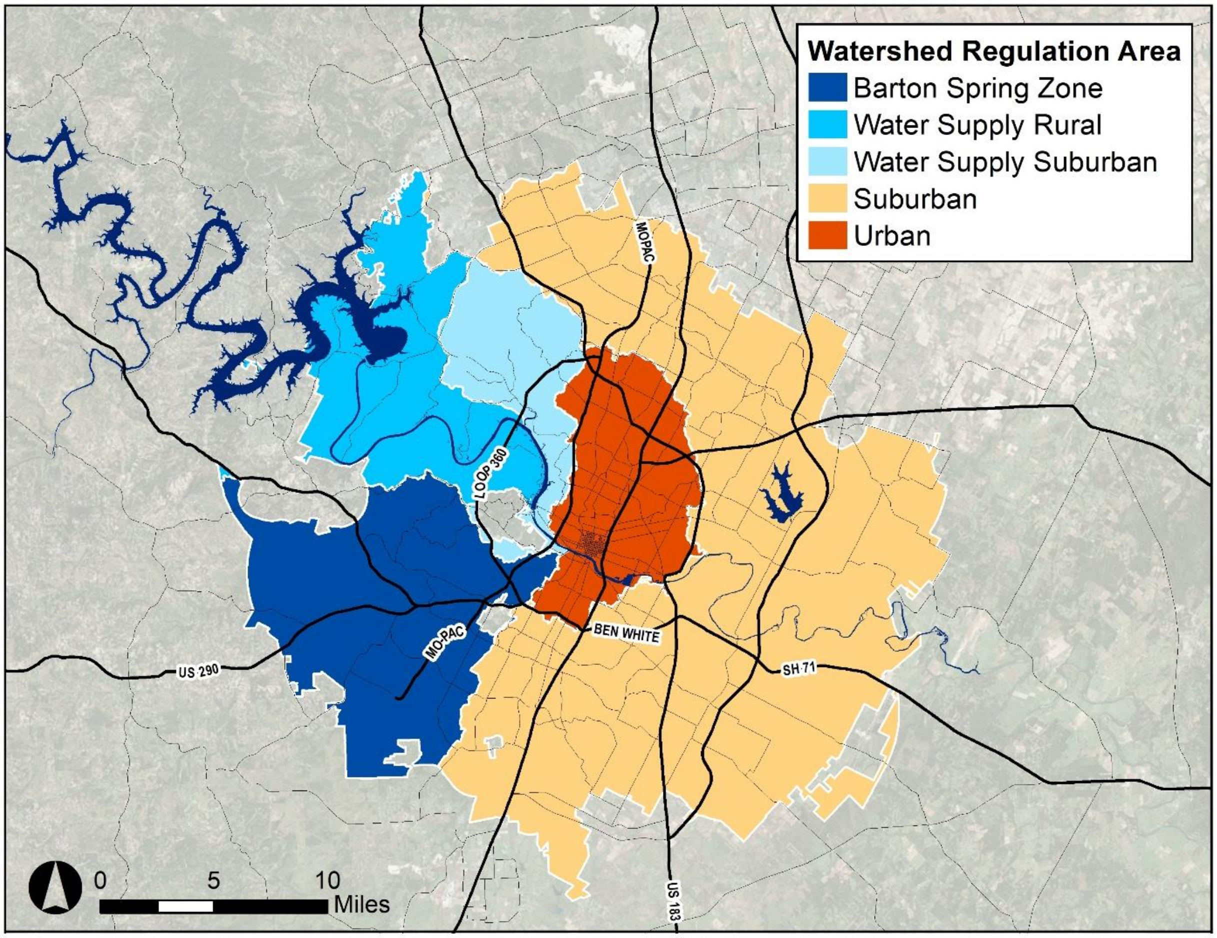

Figure 1. Watershed regulation areas in the City of Austin jurisdiction

The health of Austin's surface water resources is influenced by a complex mix of dynamic climate, urban stressors (biological, chemical, and physical), the geologic and hydrologic framework that its watersheds occupy; the patchy, ever-changing context of our regulatory environment; and the activities and practices of both residents and civil servants. Rather than a comprehensive review of these interrelated cause-and-response relationships, this paper presents a generalized review of the long-term trends from our routine monitoring programs to answer the question: How have Austin's surface water resources fared over the past 30 years?

Methods

Sites and monitoring history

The City has developed continuous, routine monitoring programs, using physical, chemical, and biological measures, to track the water quality in Austin's surface waters. One long-term monitoring program samples reservoirs, the Austin Lakes Index (ALI), and another samples streams, the Environmental Integrity Index (EII) (City of Austin 2002, Richter 2011). The reservoirs and streams datasets have been aggregated into indices and sub-indices to enable generalizations of a range of overall water quality measures. The ALI program monitors three reservoirs in the Austin area using water column chemistry, littoral and planktonic biologic communities, and riparian and aquatic vegetation measures to assess overall resource status (Richter 2011). The number of sites and frequency of monitoring varies between reservoirs based on constituent of interest (Table 1; Figs. 2A, B, C). The ALI was officially launched in 2011, with modifications in 2015 and 2018, bringing together unified methods, frequency, and reporting for all three reservoirs under a single project plan, but the periods of record for much of the chemical data for Lake Austin and Lady Bird Lake go back to the mid-70's (Richter and Porras, Abel 2015). Lake Long monitoring was initiated in 2011 and will only briefly be reviewed.

Table 1. Constituents monitored in the Austin Lakes Index, sites per reservoir, sampling frequency, and methods.

Constituent Name	Number of sites	Frequency per year	Method
Dissolved Oxygen (mg/L)	3	3–6	Hach Hydrolab
Specific Conductivity (µS/cm)	3	3–6	Hach Hydrolab
pH (Standard Units)	3	3–6	Hach Hydrolab
Temperature (ºC)	3	3–6	Hach Hydrolab
Oxidation-Reduction Potential (mV)	3	3–6	Hach Hydrolab
Ammonia as N (mg/L)	3	3–6	EPA 350.1
Nitrate as N (mg/L)	3	3–6	EPA 353.1
Total Kjeldahl N (mg/L)	3	3–6	EPA 351.2
Ortho-phosphorus as P (mg/L)	3	3–6	EPA 300.0
Total Phosphorus (mg/L)	3	3–6	
Total Suspended Solids (mg/L)	3	3–6	EAP 160.2
E. coli bacteria (MPN/100ml)	3	3–6	SM 9223 B
Littoral benthic macroinvertebrate surveys	3–6	1	(City of Austin 2018)
Phytoplankton community surveys	3	3–6	(City of Austin 2018)
Riparian habitat assessment	10	1	(City of Austin 2018)
Sediment quality analysis	1	1	EPA 6020, 8270, 8081

Figure 2. Reservoir sampling sites for water quality (circles), habitat (squares), and habitat and macroinvertebrates (stars) in Lake Austin (A), Ladybird Lake (B) and Lake Long (C).

The EII has a network of about 122 sites throughout 49 watersheds that drain into and out of Austin's jurisdictional area (Fig. 3; Appendix A). Watersheds were segmented into EII reaches based on drainage area (larger watersheds have more EII reaches) so that within a watershed each EII reach was roughly equivalent in drainage area size. Data collected at an EII site represents the EII reach in which it is located. From 1994–2009, sites were visited on a 3-year rotation and from 2009–2018 that frequency changed to a 2-year rotation. When a site was in-rotation, it would be visited 4 times (once per season) for water chemistry samples and once per year for biological, physical habitat, and sediment monitoring (Table 2) during the State of Texas index period (Texas Commission on Environmental Quality 2012).

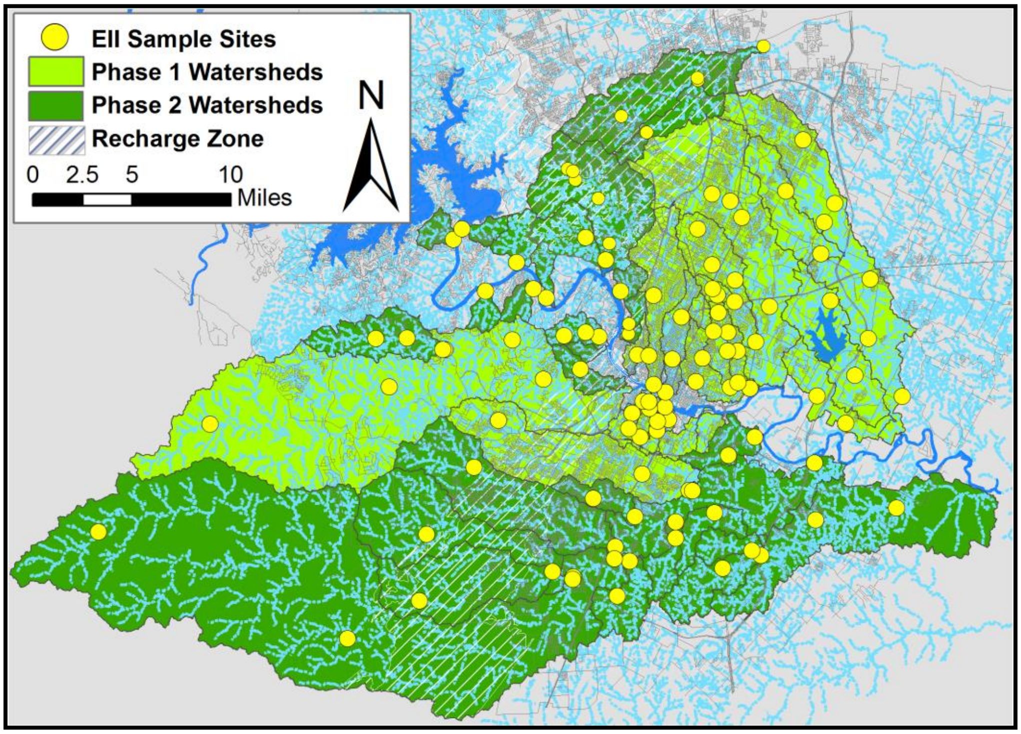

Figure 3. City of Austin monitored watersheds and site locations. Phase 1 and 2 watersheds are monitored on alternating years so that all watersheds are visited biannually.

Table 2. Constituents monitored in the Environmental Integrity Index, sampling frequency, and methods.

Constituent Name	Frequency per year	Method
Dissolved Oxygen (mg/L)	4	Hach Hydrolab
Specific Conductivity (μS/cm)	4	Hach Hydrolab
pH (Standard Units)	4	Hach Hydrolab
Temperature (°C)	4	Hach Hydrolab
Ammonia as N (mg/L)	4	EPA 350.1
Nitrate as N (mg/L)	4	EPA 353.1
Total Kjeldahl N (mg/L)	4	EPA 351.2
Orthophosphorus as P (mg/L)	4	EPA 300.0
Phosphorus as P (mg/L)	4	EPA 365.4
Total Suspended Solids (mg/L)	4	EAP 160.2
E. coli bacteria (MPN/100ml)	4	SM 9223 B
Turbidity (NTU)	4	ISO 7027
Benthic macroinvertebrate community surveys	1	(Barbour et al. 1999)
Diatom community surveys	1	(Barbour et al. 1999)
Physical habitat assessment	1	(Barbour et al. 1999)
Flow measurement*	1	(Kaufmann et al. 1999)
Sediment quality analysis (mouth sites)	1	EPA 6020, EPA 8270, EPA 8081
Non-contact Recreation surveys	1	(Herrington et al. 2012)

*Collected at sites within the Onion, Barton, Bull, and Walnut watersheds for the Clean Rivers Program.

Data Analysis

Annual ALI scores are a measure of overall environmental health that integrate water quality, sediment toxins, littoral, shoreline and riparian habitat, aquatic macroinvertebrates, and eutrophication metrics into one score (0–100; Table 1; (Richter 2011)). We took components of the ALI water quality and eutrophication scores to derive annual average trophic status index (TSI) scores for surface water samples (0.3 m depth). The TSI, based on total phosphorus (TP), Chlorophyll *a* concentrations (CHL), and Secchi depth (SD), provides insight into overall reservoir production potential driven by excessive nutrient enrichment which impacts phytoplankton growth and water clarity (Carlson 1977), but also shows the temporal trends of three important water quality constituents responsive to changes in land-use, development, habitat quality, and biological communities that may otherwise be averaged out in a broader index such as the ALI. Contrary to the ALI where a higher score is indicative of better overall ecosystem health, increasing trophic status typically negatively impacts recreational or municipal uses of a water body (0–100 scale, higher scores = more eutrophic/productive). Lastly, high resolution monitoring data for cyanobacteria densities in Lake Austin are presented. Cyanobacteria can have serious negative impacts to recreational and municipal water supplies. Densities tend to increase with overall ecosystem degradation, as trophic status increases, but their seasonal dynamics may be lost when averaging broader index components as with the ALI and TSI. Cyanobacteria densities will impact water clarity, CHL, and eutrophication sub-index scores in the ALI and TSI.

The EII is a robust measure of overall environmental health because it integrates biological, physical, and chemical measures into one overall EII score. More specifically the total EII score is composed of the water quality, sediment, contact recreation, non-contact recreation, habitat, and aquatic life sub-indices. The water quality sub-index is calculated from ammonia, nitrate, ortho-phosphorus, TSS, conductivity, and *Escherichia coli* (*E. coli*) samples collected four times a year in each EII reach. The aquatic life sub-index is calculated from benthic macroinvertebrate and diatom community metrics from a single yearly community analysis. Macroinvertebrate metrics include the Hilsenhoff Biotic Index (HBI), number of taxa, number of Ephemeroptera taxa, number of EPT taxa, number of intolerant taxa, percent dominance (top 3 taxa), percent as Chironomidae, percent as EPT, and percent as predator. Diatom metrics include the *Cymbella* richness, number of taxa, percent motile taxa, percent similarity to reference communities, and Pollution Tolerance Index (PTI). The EII monitoring data is useful for long-term comparison and assessment of trends since it uses consistent methods and locations at a relatively fine-grain scale throughout Austin's creeks.

The total EII score and each sub-index were examined within each EII reach for monotonic temporal trends using Mann-Kendall tests (Helsel and Hirsch 2002). In order to perform Mann-Kendall tests a minimum of four data points is required and the following EII reaches were excluded from analysis because they did not have four years of sampling data: BEW1, BSY1, CWC1, HAM1, LCK2, LCK3, MAH2, MAH3, WLB2, and WLB3. The Mann-Kendall test is a common test to determine if the central or median value changes over time without the need to assume normality in the data. The hypothesis tested is whether the Kendall's tau of the total EII index score or the individual sub-indices versus time is significantly different from zero. Tau is a rank-based measure of the monotonic relationship between variables and is computed by ordering the scores in time. If a positive trend exists, then the scores will increase more often than decrease as time increases. If a negative trend exists, then the scores will decrease more often than increase as time increases (Kendall 1938, 1975). The alpha value of these tests was set to 0.05, thus if the p-value was lower than 0.05 then the Kendall's tau was significantly different from zero and there would exist a significant positive or negative temporal trend.

Locally estimated scatterplot smoothing (LOESS) is a nonparametric regression technique used to capture general patterns in noisy, non-linear data (Cleveland 1979). To produce a LOESS curve, a specific width of points along the time axis (the bandwidth) is selected adjacent to the point of data being predicted. A polynomial equation is fit through that subset of data. Then the same process would be done on the next data point in the time series. The resulting polynomial equations are connected into a single curve which can be visually assessed for trends. The user controls the size of the bandwidth, with larger bandwidths resulting in smoother curves. LOESS regression was performed on total EII scores and each sub-index. LOESS regression was performed using the "proc loess" function in SAS 9.4 which uses a smoothing parameter of 0 to 1 to adjust the bandwidth. A smoothing parameter of 0.5 was used because smaller smoothing parameters led to curves that oscillated from year to year and the curves produced using larger smoothing parameters were not different from the curves produced using the 0.5 value. Temporal trends for raw water quality data, benthic metrics, and diatom metrics were assessed using LOESS regression. Ammonia, ortho-phosphorus, nitrate, and TSS datasets contained multiple detection limits as analysis techniques have improved over time. Thus, prior to LOESS regression data values lower than the highest detection limit for each of the above constituents were increased to that detection limit (i.e., ammonia 0.02 mg/L, ortho-phosphorus 0.02 mg/L, nitrate, 0.1 mg/L, and TSS 2 mg/L).

In addition, an ArcGIS exercise was completed to assign each EII reach into a development classification to examine general temporal trends of EII scores when reaches were developed under different water quality regulations. Applicable watershed regulations were estimated at the parcel scale by date of subdivision using an existing dataset. In this previous analysis, staff performed a union in ArcGIS of parcel data with subdivisions, impervious cover, watershed regulation areas, and jurisdiction. The subdivision and impervious cover data were only available for the zoning jurisdiction of the City of Austin. For this analysis, the ArcGIS layers were updated to include EII reaches and all parcels within the zoning jurisdiction were classified as undeveloped or developed based on the existing impervious cover. If a parcel had greater than 5% impervious cover, it was considered developed. Parcels within the zoning jurisdiction were then classified into multiple categories using the subdivision date. Parcels that did not have subdivision information were classified as "Unknown". Examples of parcels without subdivision information include properties that have not been subdivided and state-owned properties. Parcels with subdivision information but no available date were assumed to be "Pre-regulation" after checking a sample of these parcels in greater detail using City and Travis County records. Parcels classified as "Unknown" were also assumed to be pre-regulation.

All parcels with a subdivision date were classified into categories based on the adoption dates of applicable regulations: 1986 (Comprehensive Watershed Ordinance), 1991 (Urban Watershed Ordinance), and 2013 (Watershed Protection Ordinance). Then the total area and area of each development classification were calculated within each EII reach. If 70% of the developed area was classified as developed prior to water quality regulations then the entire EII reach was labeled as "Pre-regulation". The remainder of the EII reaches were labeled as "Other" and consisted of a mixture of pre-regulation development, development under CWO regulations, development under WPO regulations, and area outside the City. There were no reaches where the majority of development occurred under CWO or WPO regulations.

The regional Kendall test was used to assess whether a general trend in EII scores occurred across all EII reaches in Austin, “Pre-regulation” reaches, or “Other” reaches (Helsel and Frans 2006).

Although subdivision date is a reasonable proxy for age of development, it does not capture redevelopment that has occurred under watershed regulations or properties that developed without grandfathering after the land was originally subdivided. Also, as noted above, this analysis did not include subdivision or impervious cover data in the ETJ or outside of the City of Austin, which means an estimate of applicable regulations and/or whether a parcel was developed was not captured. If this exercise were to be expanded in the future, the GIS data used in this report could be combined with land use, subdivision, and impervious cover data to determine if parcels outside the City of Austin were developed.

Results and Discussion

Austin Reservoirs

Lake Austin and Lady Bird Lake are run-of-the-river reservoirs that are constant level and serve no flood control purpose. Lake Austin provides approximately two-thirds of the City’s drinking water, while Lady Bird Lake serves primarily recreational purposes. Lake Austin has mostly suburban development in smaller watersheds that continue to add density but are mostly built out, due to slope and impervious cover restrictions (Impervious Cover, IC = 11%). Lady Bird Lake is the primary receiving water body for the watersheds that flow from the older, fully-developed urban core of Austin, so it reflects a more urban condition (IC = 18%). Barton Creek flows into Lady Bird Lake and encompass large amounts of undeveloped land far away from the urban core, making the overall impervious cover value low compared to the small urban drainages, which are all in the 30-50% IC range. Lake Long was built as a power plant cooling reservoir to the east of Austin, with historically very little development around it (IC= 11%). The drainage area to the lake is relatively small (25 km^2) so the level of the reservoir is maintained by pumping Colorado River water to it regularly. The pumped river water is largely influenced by treated wastewater from the City of Austin and thus is nutrient rich. Lake Long is used as a recreational boating and fishing destination with increasing prevalence of trails, preserves, and passive outdoor activities.

In general, water quality for Lake Austin and Lady Bird Lake is strongly influenced by the Highland Lake system (Herrington 2007), and the modified flows that it imposes, while Lake Long water quality is driven by more intrinsic dynamics. Based on the ALI scores, overall trends for the past 10 years on all three reservoirs are fairly static, with all reservoirs scoring in the Fair to Good categories (50-70 on a 100-point scale; Fig. 4). The sub-indices of the ALI show that components can vary much more from year-to-year (Fig. 5), but when composited the overall scores may remain static. Inter -annual and -system variations between Lake Austin and Lady Bird Lake have been largely driven by shoreline development differences (“Habitat”), abundances of native or non-native submerged aquatic vegetation (“Vegetation”), and phytoplankton blooms (“Eutrophication”) (Fig. 5). Although Lady Bird is the more urbanized system, it often scores higher than Lake Austin due to better shoreline habitat and aquatic life (benthic macroinvertebrate) scores. Conversely, even though Lake Long is more eutrophic than either of the other two reservoirs, it often has better overall index scores than Lake Austin or Lady Bird Lake due to the undeveloped condition of the catchment and shoreline, as well as a rich diversity of benthic macroinvertebrates (Fig. 5).

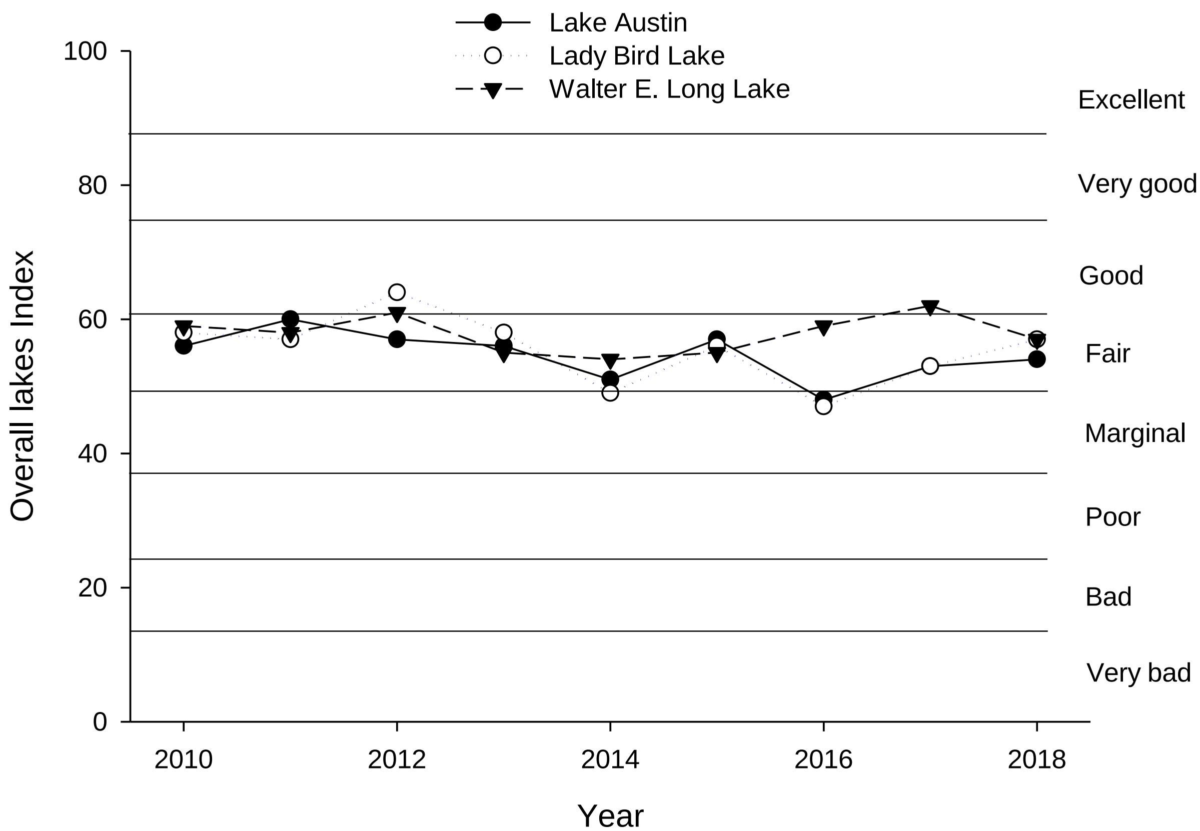

Figure 4. Composite Austin Lake Index (ALI) score for each of Austin's three reservoirs for the period of record (2010-2018).

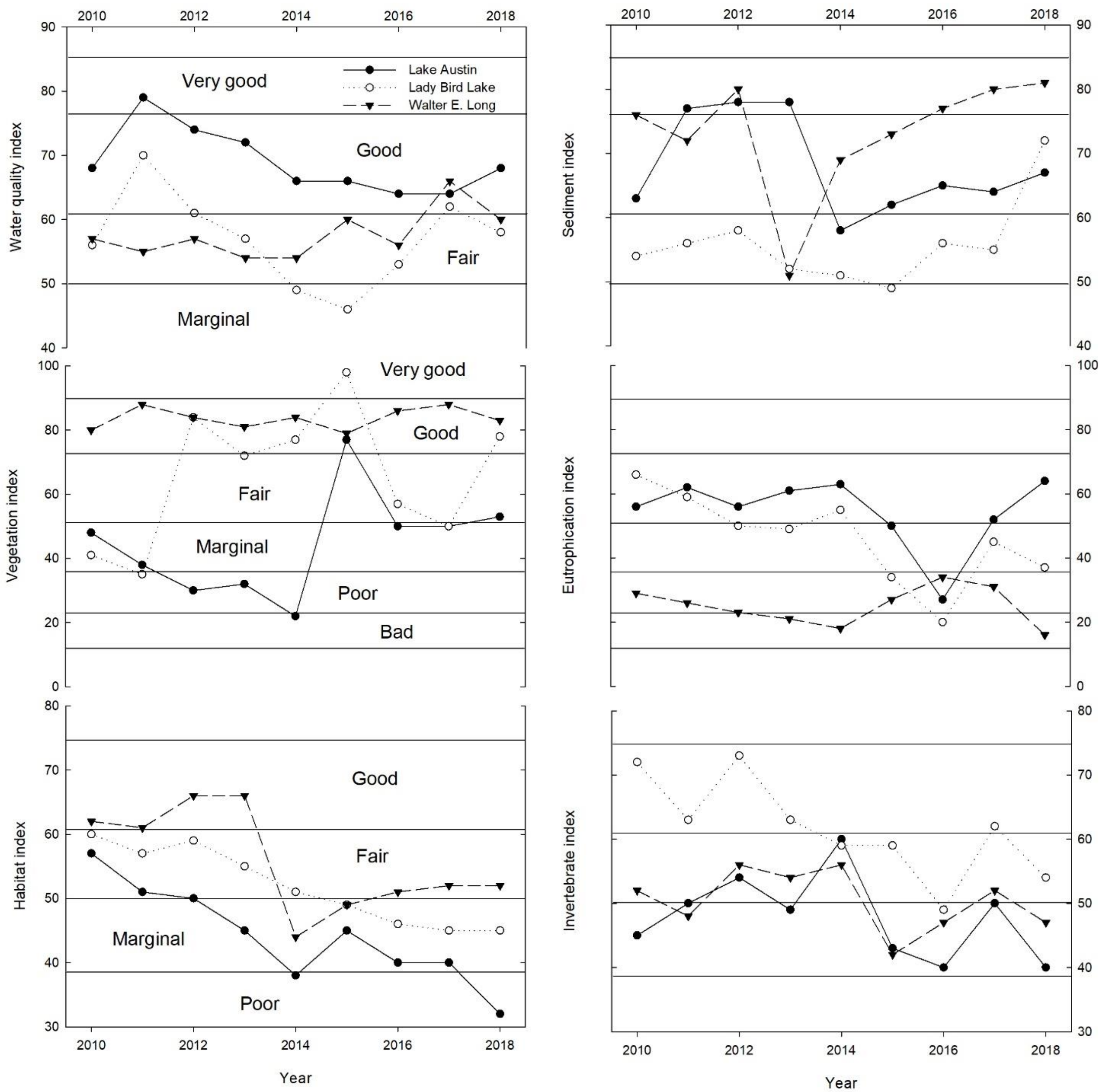

Figure 5. Sub-index component scores used in determination of the overall Austin Lake Index (ALI) score (Figure 4) for each of Austin's three reservoirs for the period of record (2010-2018).

When looking into the trophic status of the reservoirs, Lake Austin has been the most variable (Fig. 6). Lake Austin TSI (CHL) and TSI (SD) have generally indicated a mesotrophic to eutrophic condition (Fig. 6A). Temporal changes have been driven by the boom-and-bust of hydrilla and phytoplankton blooms during the drought period (2011–2015) (Bellinger et al. 2017). There has been a recent invasion by zebra mussels into the lakes which is predicted to reduce TP and phytoplankton concentrations while increasing water clarity, moving all TSI metrics lower (i.e., more mesotrophic).

Lady Bird Lake TSI scores have varied between 38 and 69 (out of 100) but have generally been indicative of eutrophic conditions (Fig. 6B). Though most water to Lady Bird Lake comes from Lake Austin and Barton Creek, the influence of urban tributaries appears enough to push the system toward a eutrophic condition. The TSI (TP) has been most variable through time, with lowest scores (i.e., lowest TP concentrations) coinciding with the drought period when nutrient loading to the system would have also been lowest and growth of the macrophyte cabomba would have also contributed to lower water column nutrient concentrations. Similar to Lake Austin, TSI (CHL) scores increased in Lady

Bird Lake during the drought. The recent decrease in all TSI scores, as in Lake Austin, are hypothesized to be the result of the spread of zebra mussels.

Unsurprisingly given the source water used to maintain Lake Long, TSI scores reflect a eutrophic to hyper-eutrophic condition (Fig. 6C). The high system production is reflected not only in phytoplankton biomass, but in the abundant aquatic vegetation and substantial fish biomass of the system (Farooqi and De Jesus 2014). A decline in TSI scores in 2016 was due to only being able to collect two sampling events (scheduling constraints), one of which occurred after the primary growing season when phytoplankton biomass was at a minimum and Secchi depth was at a maximum.

The ALI results show that within a given reservoir, large changes in condition are unlikely to occur unless the sub-indices are moved in a more consistent direction through both internal and external changes. Looking at the sub-indices gives insight into the management actions that would benefit each reservoir (e.g., habitat protection/restoration, mitigation of nutrient loading). Cultural eutrophication or hydrological changes driven by land-use, climate change, or changing management priorities could adversely impact the reservoirs in the future, evidenced by cyanobacteria biomass dynamics (Delpla et al. 2009, Paerl 2017, Bellinger et al. 2018). Although long-term algae count data were not available for Lady Bird Lake, the changes in cyanobacteria algae communities in Lake Austin were modeled recently and agreed very closely with field data (Richter and Porras, Abel 2015). These results show a recent, predictable increase in cyanobacteria concentrations, driven by hydrologic changes influencing nutrient loading rates, duration of stratification, and flushing rates (Bellinger et al. 2018). Cyanobacteria can cause taste, odor, and potentially toxic conditions that adversely impact drinking water supplies and recreational usage of a water body (Brooks et al. 2016, Paerl 2017). The concentrations of blue-green algae in the reservoirs have reached levels of moderate concern (World Health Organization 2003, Bellinger et al. 2017), meriting close attention, including better taxonomic resolution of individual nuisance species and identifying potential sources and solutions to inhibit or reduce bloom events. Of further concern are the impacts of climate change and zebra mussels, which could facilitate the proliferation and dominance of potentially toxigenic cyanobacteria species in the reservoirs (Knoll et al. 2008).

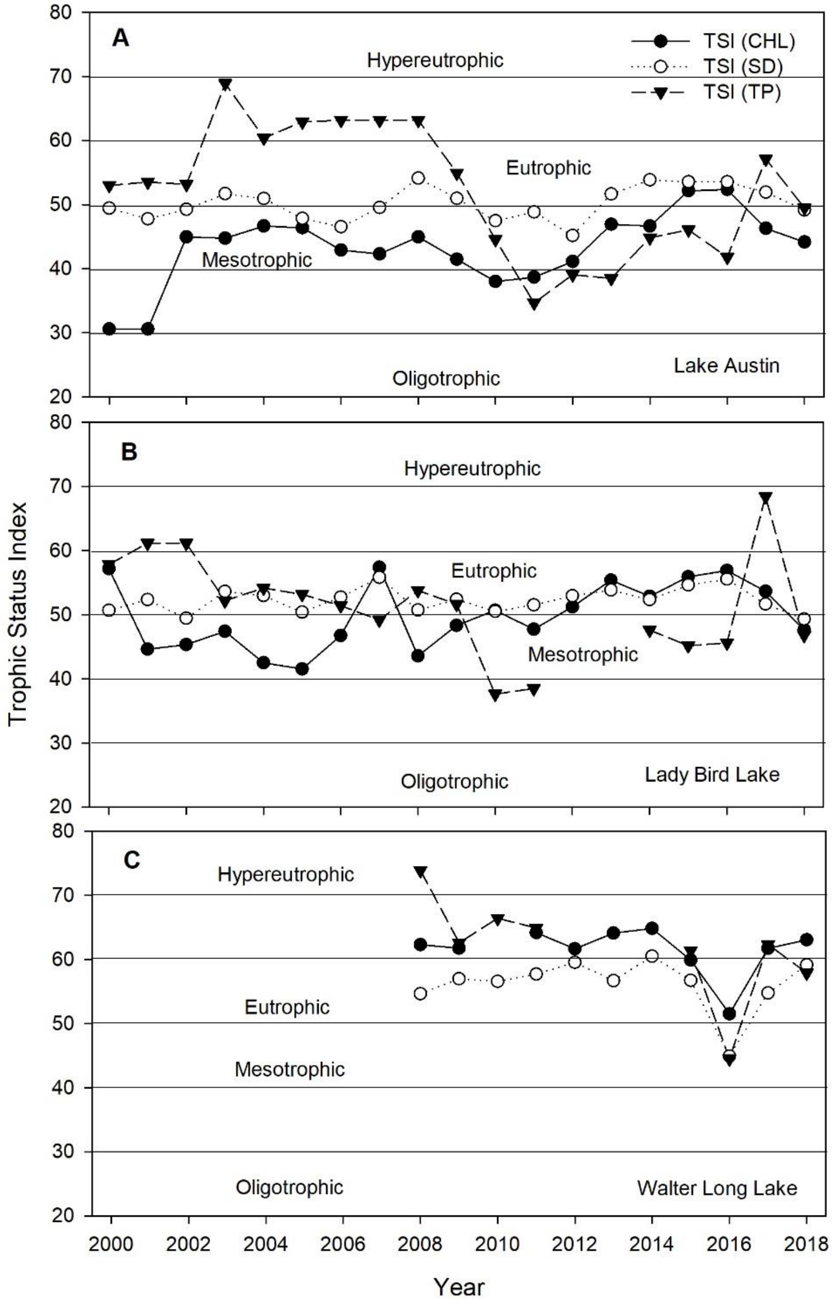

Figure 6. Annual average trophic state index (TSI) scores for chlorophyll *a* concentrations (CHL; solid circles), Secchi depth (SD; open circles), and total phosphorus concentrations (TP; closed triangles) in A) Lake Austin; B) Lady Bird Lake; and C) Walter Long Lake.

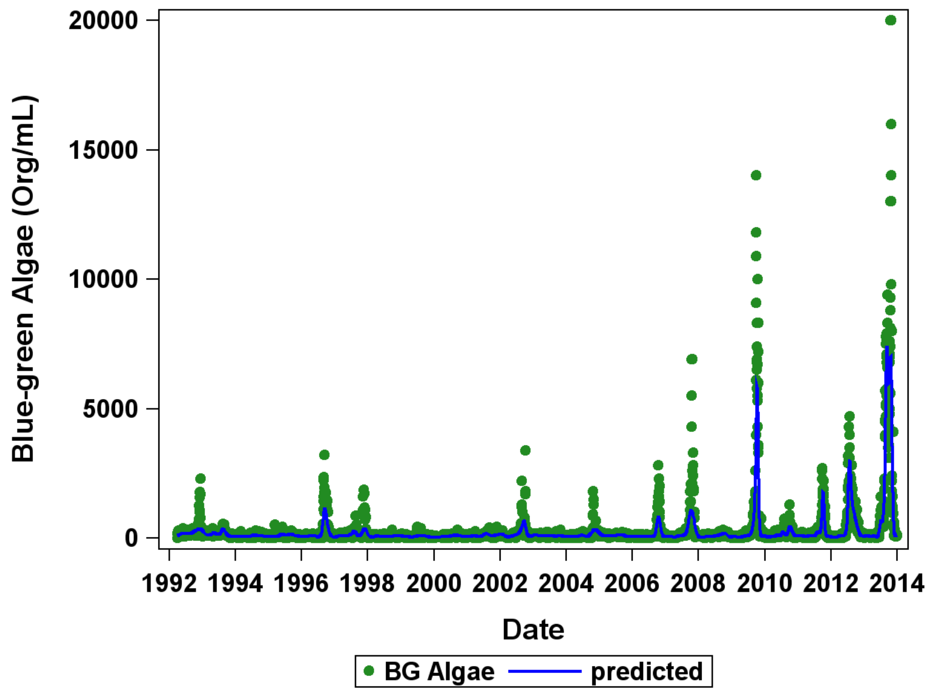

Figure 7. Modeled and measured long term blue green algae counts from Lake Austin at Davis water treatment plant (Richter and Porras, Abel 2015).

Austin Creeks – Overall trends

From 1994–2018, there was a significant positive regional trend in total EII scores for all reaches combined, “Pre-regulation” reaches, and “Other” reaches (Table 3). Similar significant positive regional trends existed for the water quality, aquatic life, habitat, and non-contact recreation sub-indices. No significant regional trends existed for any group of reaches for the sediment sub-index. Significant decreasing regional trends were noted in the contact recreation sub-index for all reaches combined, “Pre-regulation” reaches, and “Other” reaches. Individual reaches for which the total EII score showed a significant positive trend included BER3, BLU1, BOG2, BOG3, CAR2, DRE2, DRN1, HRS2, LBR1, MAR2, ONI4, RIN2, SFD1, SFD2, SLA1, TAN3, TYN1, WBL2, and WBO3 (Mann-Kendall, $p < 0.05$) (Appendix B). All other reaches showed no significant trend in the total EII score. All sub-index trends for individual reaches can be seen in Appendix B.

Table 3. Kendall tau for regional Kendall tests performed on total EII scores and each sub-index when all reaches were combined or split into pre-regulation and other reach groups. Tau is significantly different from zero if the p-value is less than 0.05 and indicates a significant positive or negative trend over time depending on the sign of Kendall’s tau. Theil-Sen’s slope represents the median rate of change over time within each dataset group.

Group of Reaches	Statistic	Total EII Score	WQ	Sediment	AQL	Habitat	NCR	CR
All	Tau	0.243	0.156	-0.0067	0.463	0.317	0.169	-0.322
	p-value	< 0.0001	< 0.0001	0.793	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Theil-Sen’s slope	0.286	0.211	0	1.25	0.571	0.3125	-1.039
Pre-reg	Tau	0.25	0.154	0.021	0.586	0.347	0.126	-0.37
	p-value	< 0.0001	0.00018	0.613	< 0.0001	< 0.0001	0.0012	< 0.0001
	Theil-Sen’s slope	0.312	0.222	0	1.875	0.625	0.232	-1.33
Other	Tau	0.238	0.157	-0.024	0.381	0.296	0.199	-0.292
	p-value	< 0.0001	< 0.0001	0.443	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Theil-Sen’s slope	0.28	0.2	0	0.833	0.545	0.364	-0.95

The LOESS regression for total EII score showed that mean scores within the "Other" regulations group of EII reaches were higher than mean scores within the "Pre-regulation" group of EII scores (Fig. 8). This suggests that areas where the majority of development has occurred without environmental regulations are more degraded than areas where little development has occurred or the development was built under a variety of regulations. Temporal trends indicated that total EII scores remained relatively stationary until 2010 when the scores began to increase for all reaches combined, "Pre-regulation" reaches, and "Other" reaches. Thus, the assessment of temporal trends from the LOESS regression is in accord with the findings of the reginal Kendall test.

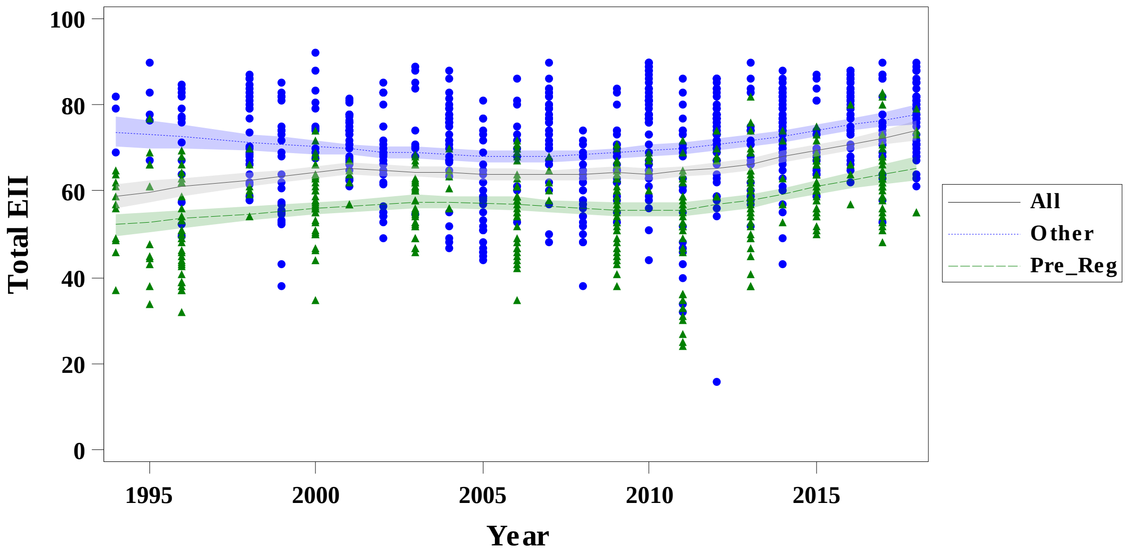

Figure 8. LOESS regression of total EII scores when all EII reaches are combined or split into "Pre-regulation" (green triangles) and "Other" (blue circles) reach groups.

The LOESS regression for the water quality sub-index showed that mean scores within the "Other" group of EII reaches were higher than mean scores within the "Pre-regulation" group of EII scores except for the period of 2005 to 2014 (Fig. 9). In the "Other" group of EII reaches, temporal trends indicated that the water quality sub-index decreased from 1994 to 2002 and slowly increased from 2002 to 2018. In the "Pre-regulation" EII reaches the water quality sub-index increased from 1994 to 2011 and then decreased from 2011 to 2018. Temporal trends showed that ammonia and ortho-phosphorus concentrations decreased over the full-time period while nitrate, conductivity, and TSS concentrations showed no trend over time (Fig. 10). Closer inspection showed that ammonia and ortho-phosphorus concentrations decreased substantially around 2010. If both ammonia and ortho-phosphorus concentrations decreased over time then the water quality sub-index should increase over time; however, the *E. coli* concentrations increased over time in many reaches (discussed in the contact recreation sub-index below) which caused the "Other" group to have a smaller positive trend and the "Pre-regulation" group to decrease from 2011 to 2018.

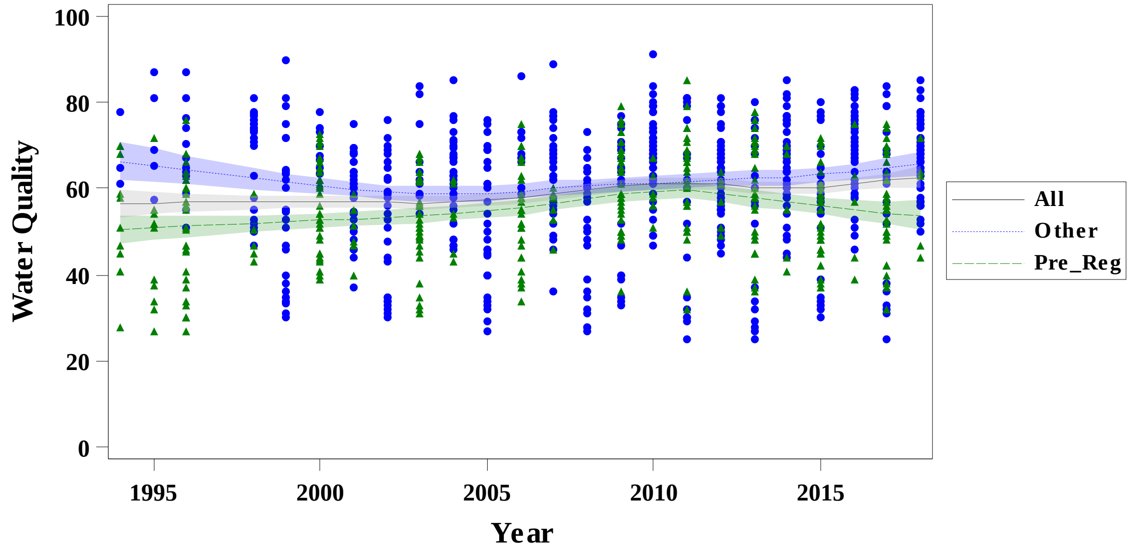

Figure 9. LOESS regression of the water quality sub-index when all EII reaches are combined or split into “Pre-regulation” (green triangles) and “Other” (blue circles) reach groups.

Decreases in ortho-phosphorus concentrations could be the result of the addition of regional stormwater control measures as retrofits or related to infill development (i.e., improved hydrology and pollutant removal from land uses that previously had no treatment), changes in general watershed practices by city government and citizens (i.e., construction and inspection practices, regulation of key pollutants, education and outreach efforts, etc.), or long-term recovery dynamics (discussed below). Additionally, changes in consumer products from regulatory bans or voluntary bans, such as the voluntary end of phosphate detergent for household laundry (Litke 1999), may also lead to decreases of phosphorus concentrations in waterways. Like laundry detergent, dishwasher detergent manufacturers voluntarily banned the use of phosphate within products around 2010, as multiple states had begun banning phosphorus-based detergents (Walsh 2010). This water flows from households to treatment plants through wastewater pipes, but urban leakage from these pipes can pollute creeks and streams. Lower concentrations of phosphorus in the water flowing through these pipes would lead to lower concentrations in creeks impacted by these leaks. Creeks downstream of on-site wastewater treatment facilities might also be positively impacted by such a ban. Further inspection of influent phosphorus concentrations to treatment facilities in Austin could be done to determine if similar trends existed during this time frame, which would provide further evidence of this possible explanation.

The Water Quality sub-index measures that did not have a trend (Nitrate-N, Conductivity, TSS, Fig 10) are more difficult to parse. Nitrate-N is an important measure in streams and reservoirs as it is both a tracer for urbanization and a critical nutrient in primary and heterotrophic productivity. Excess nitrate can lead to water quality problems and aquatic life degradation (Russo and Thurston 1991, Ging et al. 1996, King et al. 2005, Walsh et al. 2005a, Kaushal et al. 2008, Gift et al. 2010). No trend in Nitrate should probably be considered a good thing, considering the increase in population and development pressure, but there is a clear need for finer-scale examination of nitrogen forms and dynamics to understand potential water quality problems and applicable solutions. This same argument can be made for further study of conductivity data, since it is considered to be a robust measure of water quality degradation due to urbanization (Wenger et al. 2009, Pickett et al. 2011, Kaushal et al. 2014, Roy et al. 2014). No trend in total suspended solids however, is not too surprising, even though it is a key pollutant targeted by City of Austin regulations and best practices. Since EII monitoring methods target baseflow conditions, it is unlikely they will detect representative TSS conditions, which are driven almost entirely by storm flows and unpredictable pulse releases (construction, water-line breaks, etc). If TSS dynamics and trends were a priority, an alternative monitoring method which included real-time sensors would be necessary.

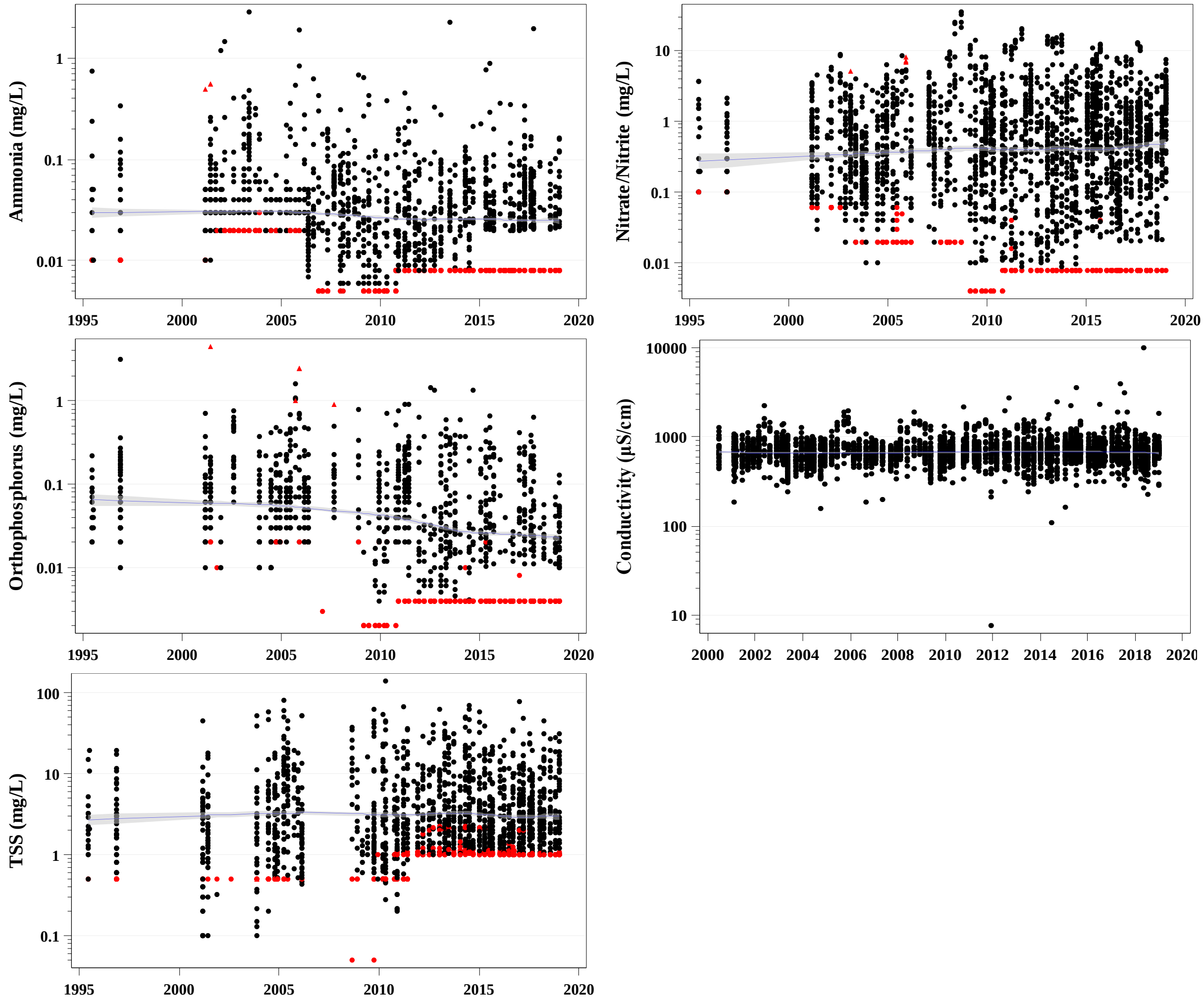

Figure 10. LOESS regression of ammonia, nitrate, ortho-phosphorus, conductivity, and TSS concentrations when all EII reaches are combined. These five constituents along with the bacteria concentrations are combined to calculate the water quality sub-index. Black circles represent uncensored values while red circles and red triangles represent values below or above a detection limit, respectively. Ammonia and ortho-phosphorus decrease over time.

The LOESS regression for the sediment sub-index showed that mean scores within the “Other” group of EII reaches were higher than mean scores within the “Pre-regulation” group of EII reaches, but no temporal trends existed for either group (Fig. 11). This is consistent with the regional Kendall test result for the sediment sub-index.

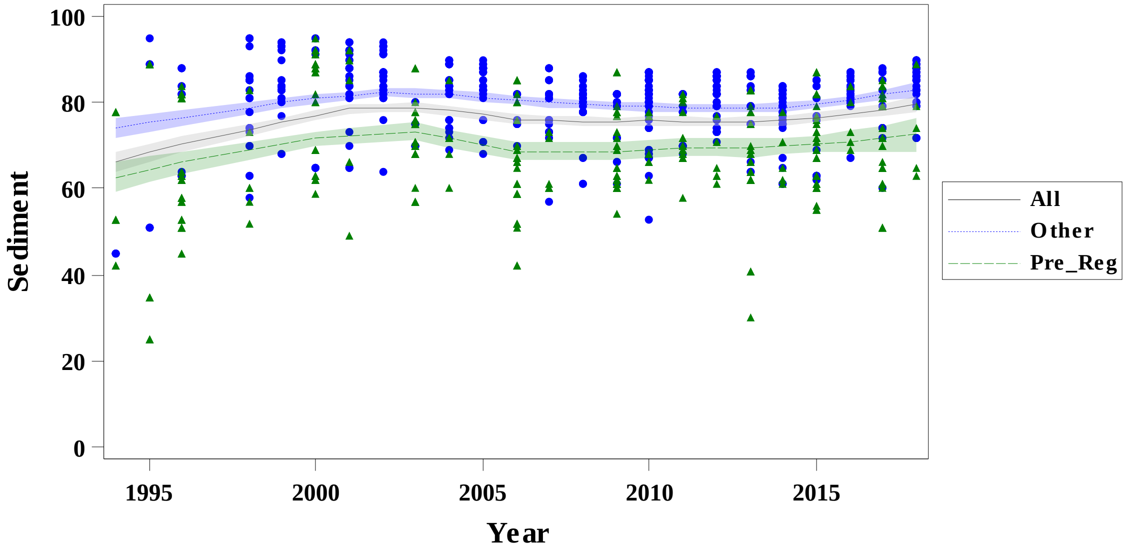

Figure 11. LOESS regression of the sediment sub-index when all EII reaches are combined or split into "Pre-regulation" (green triangles) and "Other" (blue circles) reach groups.

An additional view into overall trends in stream health is the aquatic life sub-index, which integrates benthic macroinvertebrate and diatom communities into a single ecological health indicator. This measure is particularly robust since the benthic macroinvertebrates represent longer antecedent conditions (weeks-to-months) and local physical habitat conditions, whereas the diatoms represent shorter term conditions (days-to-weeks) and are particularly sensitive to water chemistry variability. The LOESS regression for the aquatic life sub-index showed that mean scores within the "Other" group of EII reaches were higher than mean scores within the "Pre-regulation" group of EII reaches (Fig. 12). Temporal trends indicated that the aquatic life sub-index increased over the entire study period for the "Other" and the "Pre-regulation" reaches.

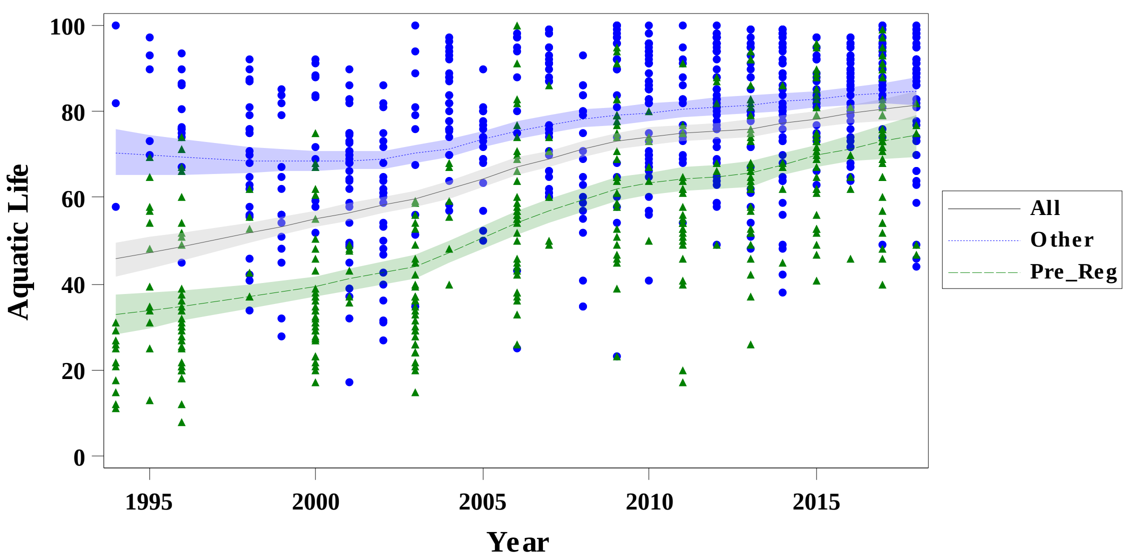

Figure 12. LOESS regression of the aquatic life sub-index when all EII reaches are combined or split into "Pre-regulation" and "Other" reach groups. Blue circles represent "Other" reaches while green circles represent "Pre-regulation" reaches.

For the benthic macroinvertebrate metrics HBI, percent dominance, percent as Chironomidae, and percent as predator, the lower the value the more pollution sensitive the community of macroinvertebrates. These four metrics all decreased over the time-period while the other macroinvertebrate metrics increased over the time-period (Fig. 13). This would suggest that the benthic macroinvertebrate community health has increased during the time-period in which sampling occurred.

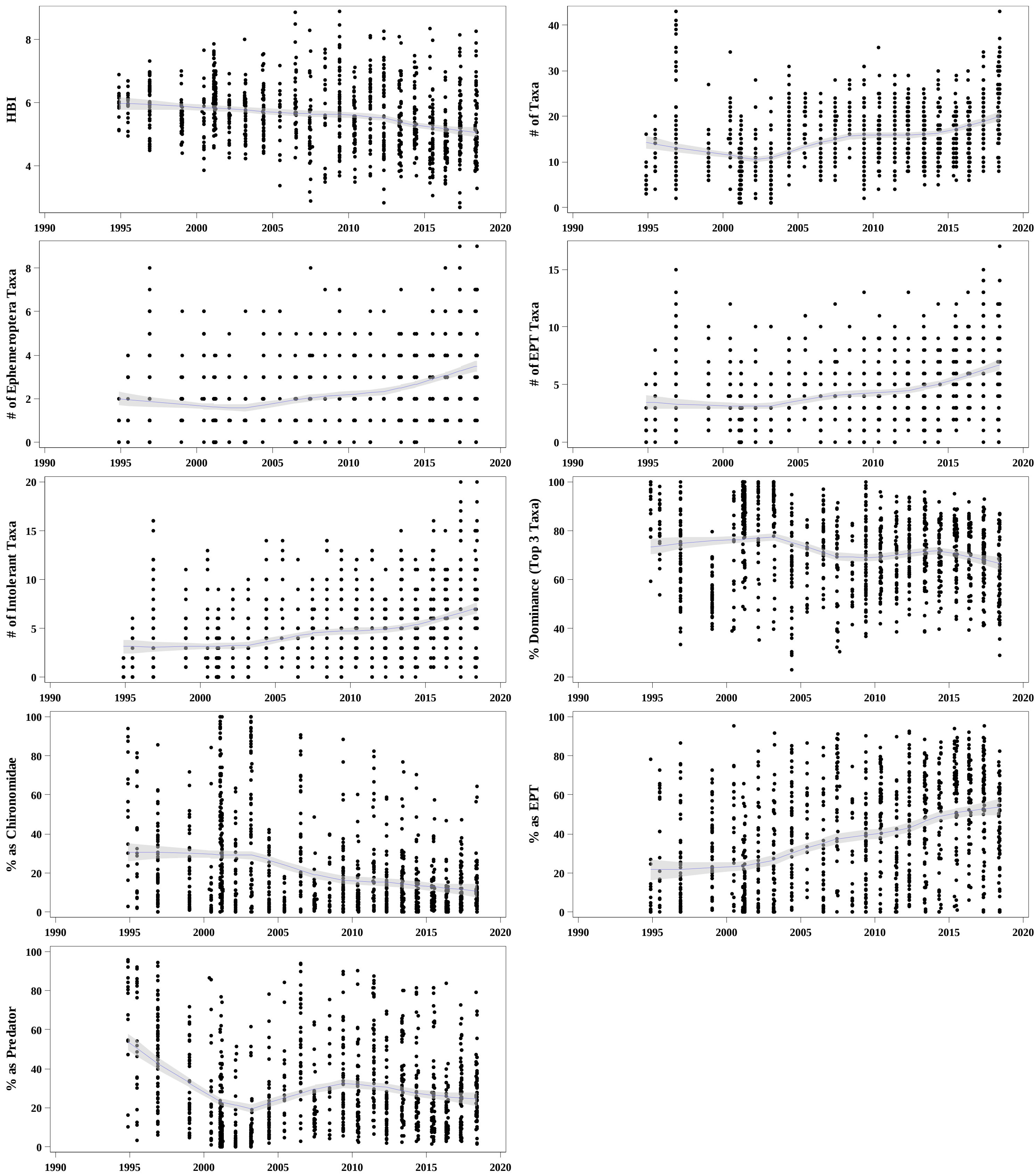

Figure 13. LOESS regression of Hilsenhoff Biotic Index (HBI), Number of Taxa, Number of Ephemeroptera Taxa, Number of EPT Taxa, Number of Intolerant Taxa, Percent Dominance (Top 3 Taxa), Percent as Chironomidae, Percent as EPT, and Percent as Predator metrics when all EII reaches are combined. These nine metrics along with the diatom metrics (e.g., Fig. 14) are combined to calculate the aquatic life sub-index.

In the diatom community, the lower the value of the percent motile taxa measure, the more pollution sensitive the community is. This metric decreased over time while the *Cymbella* richness, number of taxa, and PTI increased over time (Fig. 14). This would suggest that the diatom community health has increased during the time-period in which sampling occurred.

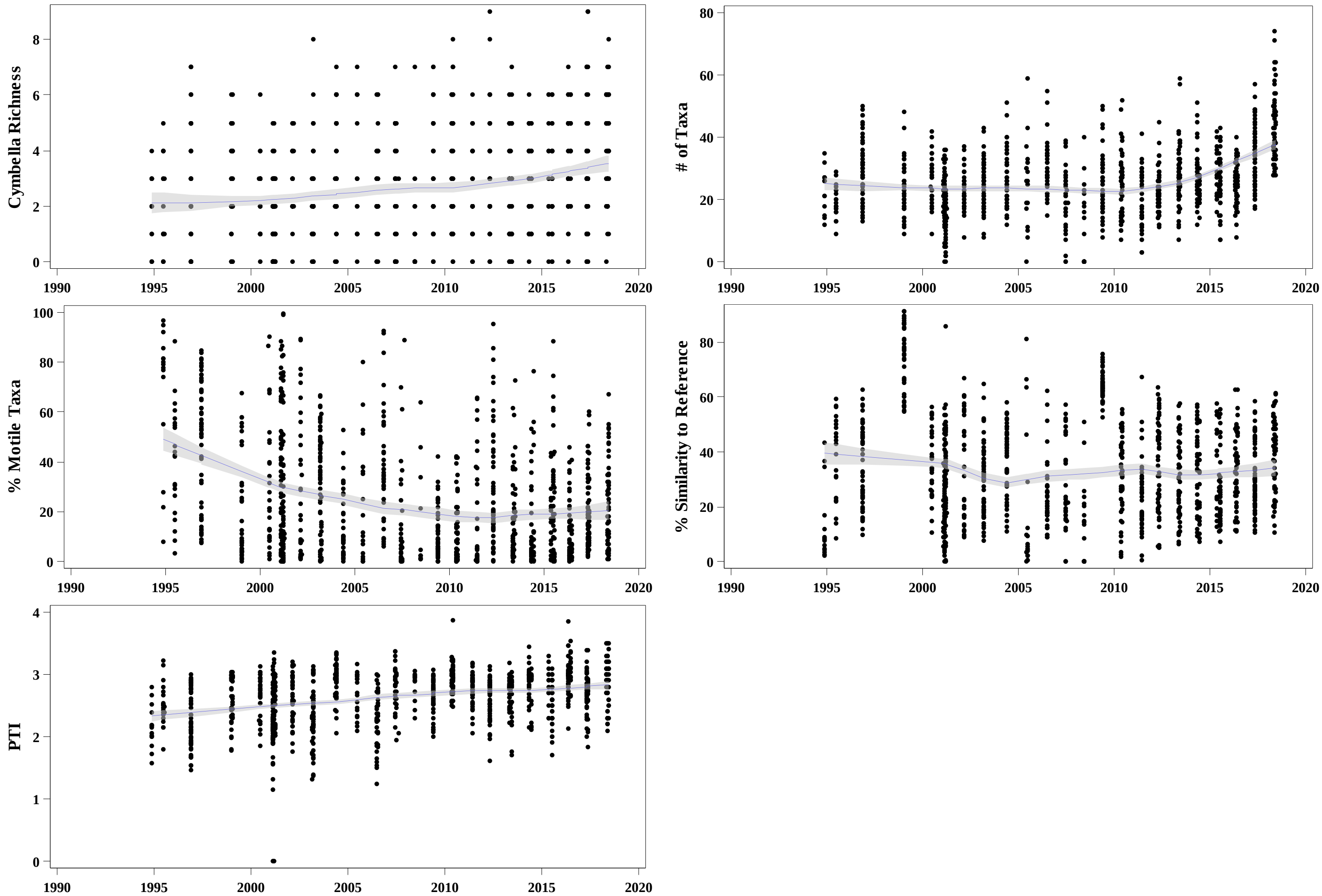

Figure 14. LOESS regression of Cymbella richness, number of taxa, percent motile taxa, percent similarity to reference communities, and Pollution Tolerance Index (PTI) metrics when all EII reaches are combined. These five metrics along with the macroinvertebrate metrics (e.g., Fig. 13) are combined to calculate the aquatic life sub-index.

These trends have a few potential explanatory variables, including improved water quality, local habitat (seen in the habitat sub-index trends below), and possibly stream hydrology due to stormwater retrofits. Other potential explanatory variables include redevelopment under an improved regulatory environment, climate, better taxonomic skills developed over time, and the more recent trend of taxonomists to split one species into two or more. Another hypothesis that has been raised in other City of Austin work is that the stream systems in this region are undergoing a longer-term recovery from relatively dramatic degradation that occurred during the initial development of this area from agriculture at the turn of the 19th century and then the urban development that followed in the middle of the 20th century (Gilroy and Richter 2010, Perry and Duncan 2010, Scoggins and Richter 2010, Duncan and Wagner 2011). In this hypothesis, the ability of a watershed to equilibrate and buffer large scale physical changes occurs over long time scales and is driven by both geomorphic and ecological successional processes (Schumm 1981, Ward et al. 2002, Hawley et al. 2012). In the Austin context, the observed overall improvement trend is likely a combination of several or all these factors, and although differentiation would be difficult, it is worth significant effort so that water resource managers can optimize potential solutions. For example, a deeper look at taxonomy trends within the biological data could isolate those changes over time and remove them from the relationship. The long-term recovery trends could be verified by looking at regional scale and longer history data sets, and at specific locations that have had little to no land cover change for

>100 years. These efforts could be carried out as a quality control measure for both the historical trends observed in this study, but also to improve and calibrate our monitoring methods moving forward.

The LOESS regression for the habitat (Fig. 15), non-contact recreation (Fig. 16), and contact recreation (Fig. 17) sub-indices showed that mean scores within the "Other" group of EII reaches were higher than mean scores within the "Pre-regulation" group of EII reaches. Temporal trends indicated that the habitat and non-contact sub-indices remained relatively stationary until around 2011 when the sub-indices began to increase over time. This would indicate that the local substrate, riparian vegetation, and aesthetics at EII sampling sites became more indicative of healthy ecosystems or more pleasurable to aesthetics over time. Temporal trends for the contact recreation sub-index showed that the sub-index decreased from 1994 to 2009 and remained stationary until 2018. This would indicate that bacteria concentrations increased from 1994 to 2009 and have not changed much since. LOESS regression results were consistent with the regional Kendall tests for each sub-index.

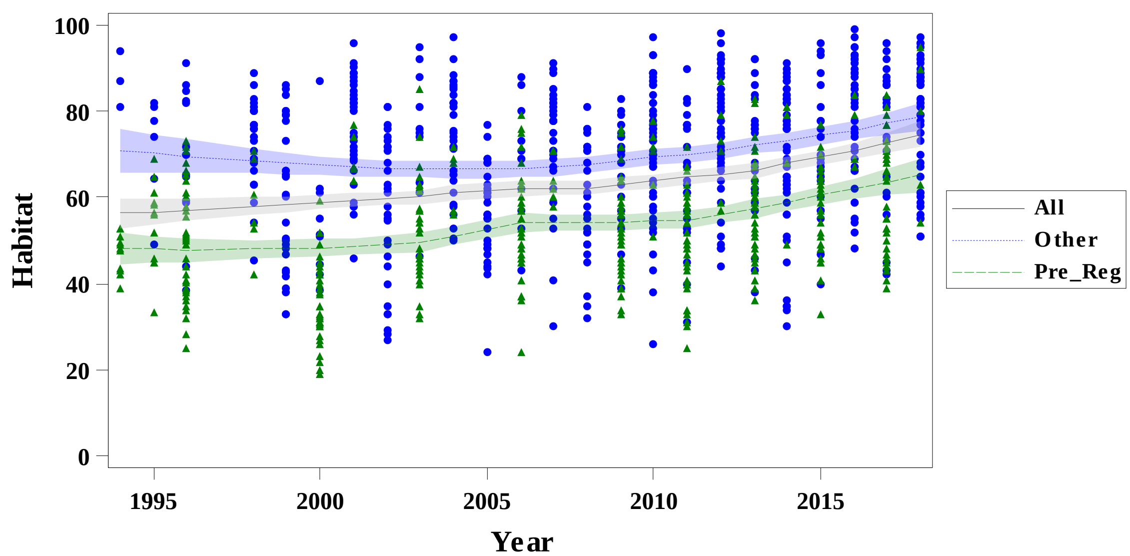

Figure 15. LOESS regression of the habitat sub-index when all EII reaches are combined or split into "Pre-regulation" (green triangles) and "Other" (blue circles) reach groups.

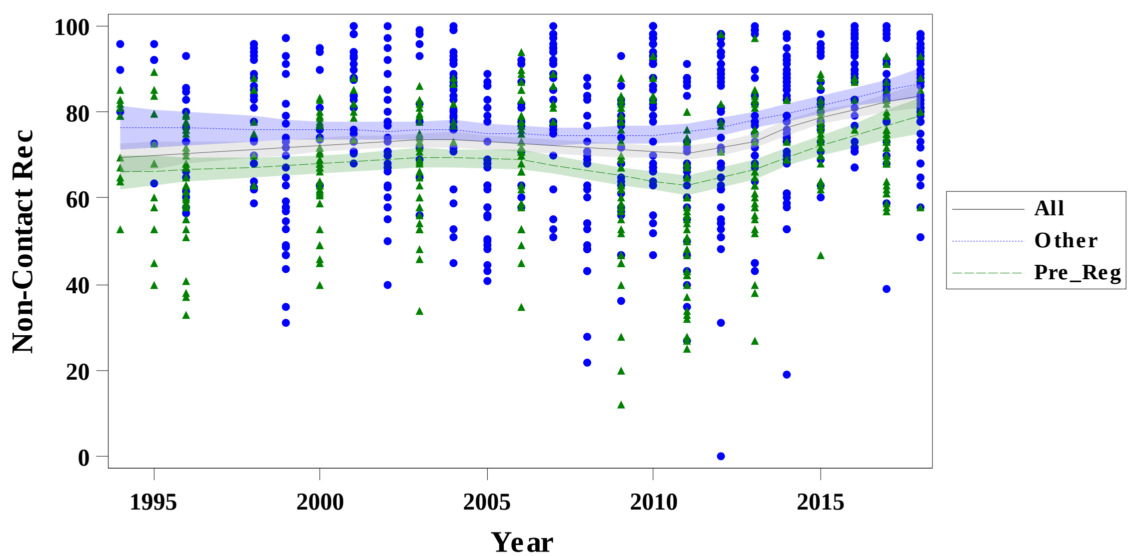

Figure 16. LOESS regression of the non-contact recreation sub-index when all EII reaches are combined or split into "Pre-regulation" (green triangles) and "Other" (blue circles) reach groups.

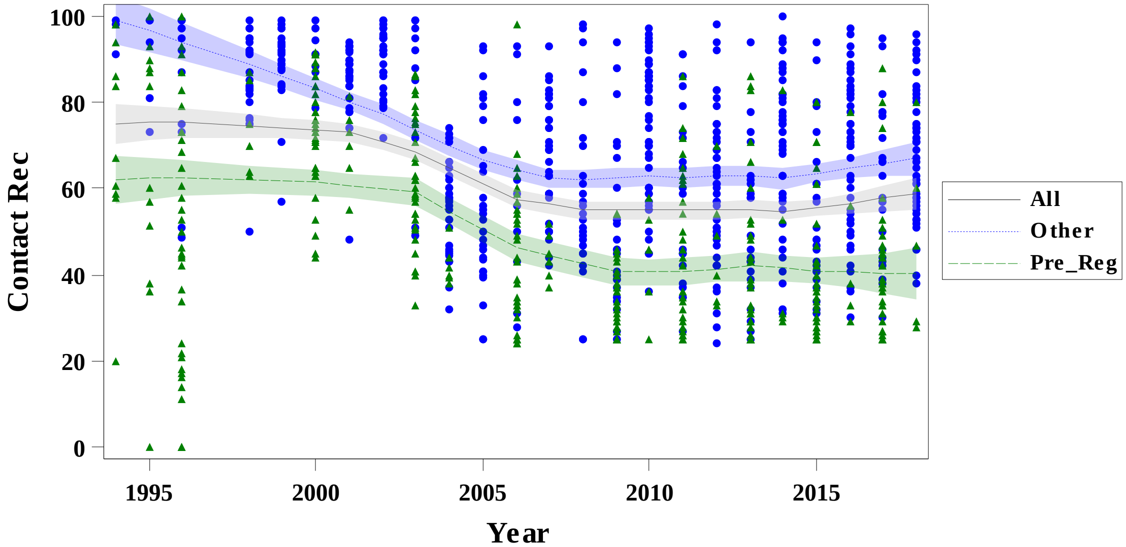

Figure 17. LOESS regression of the contact recreation sub-index when all EII reaches are combined or split into "Pre-regulation" (green triangles) and "Other" (blue circles) reach groups.

Conclusions

The data and period of record assembled for this analysis are sufficient to understand general trends of water quality measures in the Austin metropolitan area but insufficient to map these trends to any cause or conduct a more formal hypothesis test regarding how Austin's ordinances effect water quality. During this 25-year period, Austin has seen a wide range of climatic conditions, variation in rates and spatial distribution of development, and a host of potentially relevant hydrologic, ecological, and political shifts throughout the entire region. Due to these sources of variability and the very clear overlay of climate change (Nelson et al. 2009, Hayhoe 2014, Perica et al. 2018), the fact that any trends were observed in this analysis is notable. In addition, the model used in this analysis was not meant to be predictive or used for forecasting and should be strictly used to examine historical trends.

Overall, particularly in the reservoirs, the larger pattern does seem to show a neutral water quality condition over the period of record, but with some notable exceptions. Each reservoir has particular ecosystem characteristics that, if addressed, would improve overall system scores (e.g. riparian and aquatic habitat extent in Lake Austin, and excess nutrients in Lady Bird Lake and Long Lake). While watershed management might improve overall system conditions, the influence of drought and hydrologic changes can be seen as influencing TSI scores, and specifically cyanobacteria biomass, which can have negative consequences on reservoir beneficial uses. The intra-annual variability lost or observed with each index period are important when evaluating and conveying system conditions.

In the creeks, there appears to be a consistent decrease in phosphorus (in the form of Ortho-phosphorus) concentration across almost all streams assessed. This is remarkable and cannot easily be explained by development. It is possibly related to legacy soil sources from previous agricultural land uses that are slowly recovering over long time-scales or extensive education and outreach programs which sought to inform citizens about the benefits of not over-fertilizing. These hypotheses are worth exploring in future work and have ramifications on overall stream productivity and community structure, particularly in the less urban systems, where nutrient dynamics may be the most important driver of stream function. This is also possibly an explanatory variable for the other primary recovery trends, such as the aquatic life use measures, since phosphorus is often a limiting nutrient in algal productivity and has been shown to cause trophic status changes that can result in larger scale ecological shifts in the benthic macroinvertebrate, diatom, and fish community (King and Richardson 2003, Qian et al. 2003, Taylor et al. 2014, Bellinger 2018).

Although no definitive conclusions can be made at this point about the influence of the regulatory groups on water quality, this analysis did show that the reaches in the pre-regulatory catchments had lower means than the combined other group. Since the pre-regulatory environment is the oldest and most highly-impervious development in this region, the lower water quality scores for these sites is not surprising, and supports the idea that more recent development, and less-impervious development occurring outside of Austin's jurisdiction results in higher water quality measures. These trends may be partly a function of the environmentally-oriented citizenry of the whole region and the social and historical influence of Austin on its newer neighbors. While recent reviews indicate that many factors at multiple spatial scales influence land use and management decisions, nearby neighbors may be especially important influences (Roy Chowdhury et al. 2011, Cook et al. 2012). This concept has been studied widely and demonstrates that informal institutions, such as social norms and customs within neighborhoods, can be strong predictors of landscape practices (Nassauer et al. 2009, Hunter and Brown 2012, Belaire et al. 2016). This may be because when people believe or see that others are behaving in a certain way, they are more likely to do so themselves ("If everyone else is doing it, it must be a sensible thing to do," (Cialdini et al. 1990).

In older heavily developed watersheds, which are limited fundamentally by high-impervious development and limited room for treatment, EII scores remained lower than in more suburban development that at least partially occurred under modern water quality regulations. While some sub-indices of the EII score did improve over time in these watersheds, to continue to improve these heavily developed watersheds may require much larger investments than what has been done in the past. Continuing to look for high performing tools in the urban context, optimizing specific methods with specific outcomes, and understanding quantitatively what our water quality goals are on a sub-catchment scale will be necessary to continue to see positive trends in our surface water resources. Conversely, in more suburban development that at least partially occurred under modern water quality regulations, there were positive or neutral trends. It appears that a combination of vigilance in the enforcement our current code and improvements in code, design criteria, and land preservation methods should keep these surface water resources from degrading any further and on a recovery path in some situations.

Recommendations

- If there are further regulatory or disturbance assessment goals, an alternative monitoring program may be necessary. Environmental monitoring programs generally have at least one of three objectives: To assess a shift from background data, to assess an environmental program or solution, or to assess a perturbation or disturbance. Currently the EII monitoring program can determine shifts in background data but cannot assess any specific environmental program and is too large-scale to assess specific disturbances.
- Develop more targeted studies to determine environmental stress/response mechanisms rather than relying on large monitoring data sets which are not designed to examine these questions.
- Determine the mechanisms for decreasing ortho-phosphorus concentrations and increasing benthic/diatom taxa numbers throughout a large portion of Austin watersheds over the past 25 years.
- Develop a more detailed GIS layer of development patterns (including development timing, treatment levels, and regulations under which the development was built) and retrofit patterns (construction timing, treatment levels). To further explore impacts of regulations, more detailed spatial information is needed in order to either model impacts to receiving waters or design studies to statistically analyze.
- Using modeling and targeted studies, identify hydrological conditions that limit recovery of ecological health in urbanized streams and amend regulations and programs such that they are responsive to that condition. Identify practices that further promote the recovery of ecological health and adopt those practices in code and criteria.
- Develop programs and solutions that directly address E. coli bacteria contamination. Although positive trends in E. coli bacteria were observed in some of Austin's creeks, many do not meet state standards for contact recreation and this is the primary water quality barrier for public access and acceptance.
- Develop water quality controls and regulations that directly address the nitrate concentrations in Austin Creeks. Although the trend observed isn't positive, we are not making any measurable progress with our current development environment and it is one of the most critical drivers of long-term stream health.

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Appendix A. Watershed name, EII reach label, and sampling schedule for EII reaches considered in this report. Certain reaches were sampled in initial EII sampling events but were dropped from the project almost immediately and were not considered for this report (COW1, HUK1, DVS1).

Watershed	**EII Reach**	**Two-year Rotation**	**Watershed**	**EII Reach**	**Two-year Rotation**
Barton Creek	BAR1	Odd Years	Bee Creek	BEE1	Even Years
	BAR2	Odd Years		BEE2	Even Years
	BAR3	Odd Years		BEE3	Even Years
	BAR4	Odd Years	Bear Creek	BER1	Even Years
	BAR5	Odd Years		BER2	Even Years
	BAR6	Odd Years		BER3	Even Years
Bee Creek West*	BEW1	Odd Years	Bear Creek West	BRW1	Even Years
Blunn Creek	BLU1	Odd Years	Big Sandy Creek*	BSY1	Even Years
	BLU2	Odd Years	Bull Creek	BUL1	Even Years
	BLU3	Odd Years		BUL2	Even Years
Buttermilk Branch	BMK1	Odd Years		BUL3	Even Years
	BMK2	Odd Years		BUL4	Even Years
	BMK3	Odd Years		BUL5	Even Years
Boggy Creek	BOG1	Odd Years	Carson Creek	CAR1	Even Years
	BOG2	Odd Years		CAR2	Even Years
	BOG3	Odd Years	Commons Ford Creek	CMF1	Even Years
Country Club East	CCE1	Odd Years	Cuernavaca Creek	CRN1	Even Years
Country Club West	CCW1	Odd Years	Cottonmouth Creek	CTM1	Even Years
	CCW2	Odd Years	Cow Creek*	CWC1	Even Years
Decker Creek	DKR1	Odd Years	Dry Creek East	DRE1	Even Years
	DKR3	Odd Years		DRE2	Even Years
East Bouldin Creek	EBO1	Odd Years	Dry Creek North	DRN1	Even Years
	EBO2	Odd Years		DRN2	Even Years
	EBO3	Odd Years	Eanes Creek	EAN2	Even Years
Elm Creek	ELM1	Odd Years	Little Barton Creek	LBA1	Even Years
	ELM2	Odd Years		LBA2	Even Years
Fort Branch	FOR1	Odd Years		LBA3	Even Years
	FOR2	Odd Years	Little Bear Creek	LBR1	Even Years
	FOR3	Odd Years		LBR2	Even Years
	FOR4	Odd Years	Lick Creek*	LCK2	Even Years
Gilleland Creek	GIL1	Odd Years		LCK3	Even Years
	GIL2	Odd Years	Lake Creek	LKC1	Even Years
	GIL3	Odd Years		LKC2	Even Years
	GIL4	Odd Years		LKC3	Even Years
	GIL5	Odd Years	Marble Creek	MAR1	Even Years
	GIL6	Odd Years		MAR2	Even Years
Hamilton Creek*	HAM1	Odd Years	North Fork Dry Creek	NFD1	Even Years
Harper's Branch	HRP1	Odd Years	Onion Creek	ONI1	Even Years
Harris Branch	HRS1	Odd Years		ONI2	Even Years
	HRS2	Odd Years		ONI3	Even Years

Johnson Creek	JOH1	Odd Years		ONI4	Even Years
Little Bee Creek**	LBE1			ONI5	Even Years
Little Walnut Creek	LWA1	Odd Years		ONI6	Even Years
	LWA2	Odd Years	Panther Hollow	PAN1	Even Years
	LWA3	Odd Years	Rattan Creek	RAT1	Even Years
	LWA4	Odd Years		RAT2	Even Years
Maha Creek*	MAH2	Odd Years	Running Deer Creek	RDR1	Even Years
	MAH3	Odd Years	Rinard Creek	RIN1	Even Years
Shoal Creek	SHL1	Odd Years		RIN2	Even Years
	SHL2	Odd Years		RIN3	Even Years
	SHL3	Odd Years	South Boggy Creek	SBG1	Even Years
	SHL4	Odd Years		SBG2	Even Years
Tannehill Branch	TAN1	Odd Years	South Fork Dry Creek	SFD1	Even Years
	TAN2	Odd Years		SFD2	Even Years
	TAN3	Odd Years	Slaughter Creek	SLA1	Even Years
West Bouldin Creek	WBO1	Odd Years		SLA3	Even Years
	WBO2	Odd Years	Turkey Creek	TRK1	Even Years
	WBO3	Odd Years	Taylor Slough North	TYN1	Even Years
Wilbarger Creek*	WLB2	Odd Years	Taylor Slough South	TYS1	Even Years
	WLB3	Odd Years	West Bull Creek	WBL1	Even Years
Walnut Creek	WLN1	Odd Years		WBL2	Even Years
	WLN2	Odd Years			
	WLN3	Odd Years			
	WLN4	Odd Years			
	WLN5	Odd Years			
Waller Creek	WLR1	Odd Years			
	WLR2	Odd Years			
	WLR3	Odd Years			
Williamson Creek	WMS1	Odd Years			
	WMS2	Odd Years			
	WMS3	Odd Years			

*Travis County began sampling recently and less than 4 years of data are present for these watersheds.
**No longer currently sampled but consisted of enough years of data to perform trend analysis.

Appendix B. EII sub-index trends for all reaches sampled (Kendall tau test). Tau is significantly different from zero if the p-value is less than 0.05 and indicates a significant positive or negative trend (bold) over time depending on the sign of Kendall's tau.

EII Reach	Group	Statistic	Total EII	WQ	Sediment	AQL	Habitat	NCR	CR
BAR1	**Other**	tau	0	-0.22473	0.43193	0.228665	0.333333	-0.06667	-0.49441
		p-value	1	0.418962	0.104588	0.460597	0.251452	0.858028	0.059314
BAR2	**Other**	tau	0.38925	0.149592	0.261785	0.29359	0.425999	0.256892	**-0.51378**
		p-value	0.127389	0.582339	0.307076	0.241477	0.084857	0.310044	**0.035001**
BAR3	**Other**	tau	0.400066	0.512272	0.43193	0.264575	0.494413	0.340168	-0.14825
		p-value	0.212487	0.1203	0.104588	0.444833	0.059314	0.308325	0.706197
BAR4	**Other**	tau	-0.05557	-0.32098	-0.0748	**0.635764**	0.183494	0.146795	-0.46304
		p-value	0.875519	0.207317	0.813664	**0.009375**	0.482192	0.584648	0.060132
BAR5	**Other**	tau	0.138013	0.6	-0.4	0.690066	0.8	0.737865	0.2
		p-value	0.848312	0.220671	0.462433	0.085168	0.086411	0.129551	0.806496
BAR6	**Other**	tau	0.527046	0.119523	-0.4	0.4	0.527046	**1**	0
		p-value	0.312216	1	0.462433	0.462433	0.312216	**0.027486**	1
BEE1	**Other**	tau	0.171499	0	0.087039	0.30989	-0.08704	**0.591608**	-0.25355
		p-value	0.598161	1	0.831484	0.294507	0.831484	**0.036032**	0.401678
BEE2	**Other**	tau	0.114332	0.285831	0.087039	0.140859	0.057166	0.30989	-0.33333
		p-value	0.75183	0.342782	0.831484	0.674987	0.916051	0.294507	0.251452
BEE3	**Other**	tau	0.535264	0.235702	0.087039	0.422577	0.261116	0.478921	-0.36623
		p-value	0.059172	0.45383	0.831484	0.142213	0.394663	0.093493	0.208413
BER1	**Other**	tau	0.319142	0.253546	0.145065	0.388889	0.422577	0.166667	-0.1972
		p-value	0.289146	0.401678	0.671566	0.175308	0.142213	0.602168	0.529368
BER2	**Other**	tau	-0.4	0	-0.31623		-0.10541	-0.4	-0.33333
		p-value	0.462433	1	0.613354		1	0.462433	0.734095
BER3	**Other**	tau	**0.571662**	0.197203	0.145065	0.49322	0.197203	0.087039	-0.1972
		p-value	**0.045201**	0.529368	0.671566	0.088683	0.529368	0.831484	0.529368
BLU1	**Pre_Reg**	tau	**0.743161**	0.176777	-0.02817	**0.833333**	**0.647952**	0.294628	-0.47892
		p-value	**0.008408**	0.592628	1	**0.002499**	**0.021098**	0.335518	0.093493
BLU2	**Pre_Reg**	tau	-0.22866	0.057166	-0.02817	0.333333	0.277778	0.5	**-0.81698**
		p-value	0.460597	0.916051	1	0.251452	0.348083	0.076333	**0.003333**
BLU3	**Pre_Reg**	tau	0.084515	0.333333	-0.02817	0.514496	0.140859	0.30989	-0.47892
		p-value	0.833935	0.251452	1	0.07314	0.674987	0.294507	0.093493
BMK1	**Other**	tau	-0.08452	-0.25355	0.028172	0.5	-0.14086	0.166667	-0.47892
		p-value	0.833935	0.401678	1	0.076333	0.674987	0.602168	0.093493
BMK2	**Pre_Reg**	tau	-0.11433	**-0.68313**	0.028172	0.733333	0.084515	-0.1972	-0.55069
		p-value	0.75183	**0.048286**	1	0.060289	0.833935	0.529368	0.124306
BMK3	**Pre_Reg**	tau	0.264575	0.138013	0.142857	0.6	0.2965	-0.10911	0.430331
		p-value	0.444833	0.848312	0.710523	0.132855	0.37908	0.803089	0.36707
BOG1	**Pre_Reg**	tau	0.422577	0.518875	-0.1715	**0.691023**	0.478921	-0.02817	0.109109
		p-value	0.142213	0.102358	0.598161	**0.024822**	0.093493	1	0.803089
BOG2	**Pre_Reg**	tau	**0.628828**	-0.30989	-0.1715	**0.704295**	**0.833333**	0.166667	-0.22222
		p-value	**0.026857**	0.294507	0.598161	**0.011873**	**0.002499**	0.602168	0.465512
BOG3	**Pre_Reg**	tau	**0.591608**	0.140859	-0.1715	**0.760639**	**0.628828**	0.5	-0.12172
		p-value	**0.036032**	0.674987	0.598161	**0.00642**	**0.026857**	0.076333	0.742433

BRW1	**Other**	tau	0.342997	-0.30989	-0.25355	**0.628828**	**0.611111**	0.140859	-0.1715
		p-value	0.246252	0.294507	0.401678	**0.026857**	**0.028568**	0.674987	0.598161
BUL1	**Other**	tau	-0.43519	0.342997	-0.33333	0.478921	0.253546	-0.05717	**-0.61111**
BUL2	**Other**	tau	0.203091	**0.647952**	-0.33333	0.253546	0.535264	0.228665	-0.05556
		p-value	0.524777	**0.021098**	0.251452	0.401678	0.059172	0.460597	0.916965
BUL3	**Other**	tau	-0.21483	-0.06667	-0.2	-0.13801	0.552052	-0.13801	-0.6
		p-value	0.696727	1	0.707114	0.848312	0.1806	0.848312	0.132855
BUL4	**Other**	tau	0.6	0.105409	0.2	0	0.6	0.316228	0
		p-value	0.220671	1	0.806496	1	0.220671	0.613354	1
BUL5	**Other**	tau	0.241747	0.340168	-0.21429	0.472805	0.518875	-0.03637	-0.5
		p-value	0.506555	0.308325	0.536187	0.134625	0.102358	1	0.107762
CAR1	**Pre_Reg**	tau	0.057166	-0.05556	0.114332	0.444444	**0.647952**	0.117851	**-0.55556**
		p-value	0.916051	0.916965	0.75183	0.117851	**0.021098**	0.748196	**0.047604**
CAR2	**Other**	tau	**0.609272**	0.422577	0.114332	**0.816982**	0.5	0.342997	-0.11111
		p-value	**0.033339**	0.142213	0.75183	**0.003333**	0.076333	0.246252	0.754454
CCE1	**Pre_Reg**	tau	0.400163	0	-0.18185	0.4	**0.555556**	0.478921	-0.2
		p-value	0.170587	1	0.617989	0.462433	**0.047604**	0.093493	0.806496
CCW1	**Pre_Reg**	tau	0.140859	0.6	0.254588	0.8	0.140859	-0.14086	-0.2
		p-value	0.674987	0.132855	0.454427	0.086411	0.674987	0.674987	0.707114
CCW2	**Pre_Reg**	tau	0.514496	0.197203	0.254588	**0.833333**	**0.611111**	0.087039	**-0.72222**
		p-value	0.07314	0.529368	0.454427	**0.002499**	**0.028568**	0.831484	**0.009149**
CMF1	**Other**	tau	-0.02817	-0.05556	-0.343	0.333333	0.084515	0.028172	-0.38889
		p-value	1	0.916965	0.246252	0.367521	0.833935	1	0.175308
CRN1	**Other**	tau	0.486864	0.253546	-0.45733	**0.87831**	0.140859	0.400163	-0.1972
		p-value	0.100348	0.401678	0.113846	**0.009809**	0.674987	0.170587	0.529368
CTM1	**Other**	tau	0.366233	0.166667	0.30989	0.181848	0.333333	0.478921	-0.16667
		p-value	0.208413	0.602168	0.294507	0.617989	0.251452	0.093493	0.602168
DKR1	**Other**	tau	0.444444	0.228665	0.029013	0.254588	0.444444	0.253546	-0.22222
		p-value	0.117851	0.460597	1	0.454427	0.117851	0.401678	0.465512
DKR3	**Other**	tau	0.197203	0.370625	0.029013	0.6	-0.02817	-0.08452	-0.35714
		p-value	0.529368	0.258095	1	0.220671	1	0.833935	0.26551
DRE1	**Other**	tau	0.478921	**0.800327**	-0.30989	0.52381	0.140859	0.197203	**-0.61111**
		p-value	0.093493	**0.004426**	0.294507	0.133129	0.674987	0.529368	**0.028568**
DRE2	**Other**	tau	**0.609272**	0.277778	-0.30989	0.09759	**0.611111**	0.366233	-0.22222
		p-value	**0.033339**	0.348083	0.294507	0.879257	**0.028568**	0.208413	0.465512
DRN1	**Pre_Reg**	tau	**0.704295**	**0.760639**	0.028172	0.478921	**0.647952**	-0.20309	0.277778
		p-value	**0.011873**	**0.00642**	1	0.093493	**0.021098**	0.523217	0.348083
DRN2	**Pre_Reg**	tau	0.466667	**1**	-0.13801	0.6	0.690066	0.552052	-0.46667
		p-value	0.259656	**0.008535**	0.848312	0.132855	0.085168	0.1806	0.259656
EAN2	**Other**	tau	0.084515	0.145065	0.2	0.428571	0.235702	0.055556	-0.33333
		p-value	0.833935	0.671566	0.707114	0.173546	0.45383	0.916965	0.251452
EBO1	**Pre_Reg**	tau	0.454545	0.373979	0.43193	**0.777778**	**0.560968**	0.272727	**-0.52357**
		p-value	0.061707	0.135494	0.104588	**0.004879**	**0.022421**	0.275758	**0.033528**
EBO2	**Pre_Reg**	tau	0.418182	-0.36699	0.43193	**0.745455**	**0.527273**	0.236364	**-0.70909**
		p-value	0.086768	0.137902	0.104588	**0.001846**	**0.029273**	0.350201	**0.003093**

EBO3	**Pre_Reg**	tau	0.277825	0.40452	0.43193	**0.647952**	0.018522	-0.1667	-0.25006
		p-value	0.272832	0.126849	0.104588	**0.021098**	1	0.530916	0.367232
ELM1	**Other**	tau	0.197203		**-0.92857**	-0.66667	0.253546	0.422577	
		p-value	0.529368		**0.001982**	0.308179	0.401678	0.142213	
		p-value	0.529368	0.367521	**0.001982**	**0.027486**	0.093493	0.754454	0.763891
FOR1	**Pre_Reg**	tau	-0.0367	0.472805	-0.11367	0.5	0.29359	-0.29918	-0.42857
		p-value	0.937759	0.134625	0.718348	0.107762	0.241477	0.237625	0.173546
FOR2	**Pre_Reg**	tau	-0.0734	0.400066	-0.11367	**0.642857**	0.463042	-0.11219	-0.5
		p-value	0.814783	0.212487	0.718348	**0.035448**	0.060132	0.69444	0.107762
FOR3	**Pre_Reg**	tau	-0.37398	0.047619	-0.11367	**0.611111**	0.13217	-0.29359	**-1**
		p-value	0.13469	1	0.718348	**0.028568**	0.635608	0.241477	**0.002667**
FOR4	**Pre_Reg**	tau	-0.01852	0.256892	-0.11367	**0.6**	-0.01852	-0.23636	-0.25689
		p-value	1	0.310044	0.718348	**0.020045**	1	0.350201	0.310044
GIL1	**Other**	tau	-0.11111	-0.11433	0.114332	0.366233	0.171499	0.377168	-0.30989
		p-value	0.754454	0.75183	0.75183	0.208413	0.598161	0.201677	0.294507
GIL2	**Other**	tau	0.111111	0.176777	0.114332	0.140859	**0.611111**	0.197203	-0.11433
		p-value	0.754454	0.592628	0.75183	0.674987	**0.028568**	0.529368	0.75183
GIL3	**Other**	tau	-0.2357	-0.1715	0.114332	0.444444	0.228665	-0.1972	-0.47892
		p-value	0.45383	0.598161	0.75183	0.117851	0.460597	0.529368	0.093493
GIL4	**Other**	tau	0.388889	**0.591608**	0.114332	0.619048	0.253546	0.333333	-0.44444
		p-value	0.175308	**0.036032**	0.75183	0.071505	0.401678	0.251452	0.117851
GIL5	**Other**	tau	0	-0.43519	0.114332	0.071429	0.111111	0.114332	-0.47892
		p-value	1	0.13781	0.75183	0.901539	0.754454	0.75183	0.093493
GIL6	**Other**	tau	0.235702	-0.06086	0.114332	0.444444	0	**0.591608**	**-0.76064**
		p-value	0.455545	0.913457	0.75183	0.117851	1	**0.036032**	**0.00642**
HRP1	**Pre_Reg**	tau	0.253546	-0.14086	0.166667	0.422577	0.478921	0.366233	**-0.60927**
		p-value	0.401678	0.674987	0.602168	0.142213	0.093493	0.208413	**0.033339**
HRS1	**Other**	tau	0.253546	0.087039	0.029013	**0.555556**	0.422577	**0.571662**	-0.27778
		p-value	0.401678	0.831484	1	**0.047604**	0.142213	**0.045201**	0.348083
HRS2	**Other**	tau	**0.647952**	**0.760639**	0.029013	**0.771517**	**0.766032**	**0.722222**	-0.1972
		p-value	**0.021098**	**0.00642**	1	**0.014713**	**0.007469**	**0.009149**	0.529368
JOH1	**Pre_Reg**	tau	0.222222	0.29277	0.428571	0.400066	-0.1972	0.222222	-0.33333
		p-value	0.465512	0.447521	0.173546	0.212487	0.529368	0.465512	0.367521
LBA1	**Other**	tau	0.435194	-0.20309	**-0.57166**	**0.571662**	**0.611111**	0.222222	0.111111
		p-value	0.136333	0.524777	**0.045201**	**0.045201**	**0.028568**	0.465512	0.754454
LBA2	**Other**	tau	0.166667	-0.14086	**-0.57166**	0.422577	0.057166	0	-0.16667
		p-value	0.602168	0.674987	**0.045201**	0.142213	0.916051	1	0.602168
LBA3	**Other**	tau	0.197203	0.028172	**-0.57166**	0.5	0.366233	0.400163	-0.08452
		p-value	0.529368	1	**0.045201**	0.076333	0.208413	0.170587	0.833935
LBE1	**Other**	tau	-0.2	-0.66667	-0.4		0.4	0.2	-0.66667
		p-value	0.806496	0.308179	0.462433		0.462433	0.806496	0.308179
LBR1	**Other**	tau	**0.555556**	**0.609272**	-0.1715	**0.618284**	0.422577	0.5	-0.1715
		p-value	**0.047604**	**0.033339**	0.598161	**0.046063**	0.142213	0.076333	0.598161
LBR2	**Other**	tau	0.087039	0.370625	-0.1715	0.277778	0.333333	0.342997	-0.14286
		p-value	0.832107	0.258095	0.598161	0.348083	0.251452	0.246252	0.710523
LKC1	**Other**	tau	0.117851	**0.591608**	0.084515	0.166667	0.145065	0.114332	-0.36623

		p-value	0.749119	**0.036032**	0.833935	0.602168	0.670402	0.75183	0.208413
LKC2	**Other**	tau	0.444444	0.551246	0.084515	0.197203	**0.666667**	0.30989	-0.16667
		p-value	0.117851	0.055469	0.833935	0.529368	**0.016489**	0.294507	0.602168
LKC3	**Other**	tau	0.30989	0.478921	0.084515	0.478921	0.111111	0.166667	-0.14086
LWA1	**Pre_Reg**	tau	0.253546	0.055556	-0.40016	0.333333	0.478921	0.084515	-0.11111
		p-value	0.401678	0.916965	0.170587	0.251452	0.093493	0.833935	0.754454
LWA2	**Pre_Reg**	tau	0.30989	-0.28583	-0.40016	**0.722222**	0.535264	0.377168	-0.44444
		p-value	0.294507	0.342782	0.170587	**0.009149**	0.059172	0.201677	0.117851
LWA3	**Pre_Reg**	tau	0.071611	-0.2	-0.35806	0.214834	0.138013	0.333333	-0.2
		p-value	1	0.707114	0.435695	0.696727	0.848312	0.45237	0.707114
LWA4	**Pre_Reg**	tau	0.235702	0.261116	-0.40016	0.366233	-0.05556	0.028172	0.057166
		p-value	0.45383	0.396439	0.170587	0.208413	0.916965	1	0.916051
MAR1	**Other**	tau	0.329276	0.45733	0.253546	**0.555556**	0.140859	**0.707107**	**-0.72222**
		p-value	0.281818	0.113846	0.401678	**0.047604**	0.674987	**0.013849**	**0.009149**
MAR2	**Other**	tau	**0.648181**	0.545545	0.253546	0.2	0.388889	0.45733	-0.40007
		p-value	**0.024631**	0.080905	0.401678	0.707114	0.175308	0.113846	0.212486
NFD1	**Other**	tau	0.478921	**0.722222**	0.171499	0.29277	0.444444	0.111111	0.055556
		p-value	0.093493	**0.009149**	0.598161	0.447521	0.117851	0.754454	0.916965
ONI1	**Other**	tau	0.5	-0.11433	0.057166	0.535264	**0.555556**	0.5	-0.5145
		p-value	0.076333	0.75183	0.916051	0.059172	**0.047604**	0.107762	0.07314
ONI2	**Other**	tau	0.285831	0.084515	0.057166	0.342997	**0.571662**	0.222222	-0.38889
		p-value	0.342782	0.833935	0.916051	0.246252	**0.045201**	0.465512	0.175308
ONI3	**Other**	tau	0.089803	-0.10911	0.222375	0.285831	0.545545	**0.618284**	**-0.61828**
		p-value	0.829573	0.803089	0.52982	0.342782	0.080905	**0.046063**	**0.046063**
ONI4	**Other**	tau	**0.589256**	0.084515	0.057166	**0.591608**	0.377168	0.277778	-0.1972
		p-value	**0.04204**	0.833935	0.916051	**0.036032**	0.201677	0.348083	0.529368
ONI5	**Other**	tau	0.471405	0.319142	0.057166	-0.11433	0.444444	-0.29463	-0.16667
		p-value	0.108472	0.287333	0.916051	0.75183	0.117851	0.335518	0.602168
ONI6	**Other**	tau	0.203091	-0.02817	0.057166	0.028172	0.285831	-0.14086	-0.25355
		p-value	0.523217	1	0.916051	1	0.342782	0.674987	0.401678
PAN1	**Other**	tau	-0.08452	-0.1972	-0.1715	0	0.055556	0.055556	-0.1972
		p-value	0.833935	0.529368	0.598161	1	0.916965	0.916965	0.529368
RAT1	**Other**	tau	-0.1972	**0.68313**	-0.39036	0	-0.36623	0.111111	-0.58554
		p-value	0.529368	**0.048286**	0.287611	1	0.208413	0.754454	0.094718
RAT2	**Other**	tau	0.45733	-0.06667	-0.39036	-0.39036	0.422577	0.400163	-0.13801
		p-value	0.113846	1	0.287611	0.287611	0.142213	0.170587	0.848312
RDR1	**Other**	tau	-0.08452	**-0.55556**	**-0.68599**	0.5	0.145065	0.366233	-0.38889
		p-value	0.833935	**0.047604**	**0.015333**	0.076333	0.670402	0.208413	0.175308
RIN1	**Other**	tau	0.121716	-0.02901	**0.824958**	0.478921	0.277778	0.176777	**-0.64795**
		p-value	0.744397	1	**0.003863**	0.093493	0.348083	0.592628	**0.021098**
RIN2	**Other**	tau	**0.591608**	**0.760639**	**0.824958**	**0.866667**	0.14825	0.109109	-0.05717
		p-value	**0.036032**	**0.00642**	**0.003863**	**0.024171**	0.706197	0.803089	0.916051
RIN3	**Other**	tau	0.414039	0.6	**0.824958**	0.333333	0.138013	-0.27603	-0.4
		p-value	0.338888	0.220671	**0.003863**	0.734095	0.848312	0.56609	0.462433
SBG1	**Other**	tau	0.203091	0.514496	-0.08452	0.388889	0.222222	-0.1972	-0.05556
		p-value	0.523217	0.07314	0.833935	0.175308	0.465512	0.529368	0.916965

SBG2	**Pre_Reg**	tau	-0.16667	0.366233	-0.08452	0.253546	-0.22222	-0.1715	**-0.64795**
		p-value	0.602168	0.208413	0.833935	0.401678	0.465512	0.598161	**0.021098**
SFD1	**Other**	tau	**0.777778**	**0.591608**	0.319142	**0.714286**	0.478921	**0.648181**	-0.02817
		p-value	**0.004879**	**0.036032**	0.287333	**0.035498**	0.093493	**0.024631**	1
		p-value	**0.036032**	0.173546	0.287333	0.065134	0.465512	0.602168	0.444833
SHL1	**Pre_Reg**	tau	0.440386	0.373979	0.129652	**0.587181**	0.127273	0.345455	-0.16262
		p-value	0.072495	0.135494	0.638386	**0.015491**	0.640429	0.161125	0.564144
SHL2	**Pre_Reg**	tau	0.454545	0.454545	0.129652	**0.563636**	0.240782	**0.6**	-0.30909
		p-value	0.061707	0.061707	0.638386	**0.019518**	0.347262	**0.012731**	0.212912
SHL3	**Pre_Reg**	tau	0.381385	**0.486172**	0.129652	**0.587181**	**0.490909**	-0.36699	-0.40369
		p-value	0.132267	**0.04904**	0.638386	**0.015491**	**0.04296**	0.137902	0.101042
SHL4	**Pre_Reg**	tau	-0.12965	0.373979	0.129652	**0.53936**	0.166695	0.256892	-0.41818
		p-value	0.638386	0.13469	0.638386	**0.038879**	0.530916	0.310044	0.086768
SLA1	**Other**	tau	**0.591608**	**0.611111**	0.145065	**0.591608**	0.114332	-0.14086	0.222222
		p-value	**0.036032**	**0.028568**	0.670402	**0.036032**	0.75183	0.674987	0.465512
SLA3	**Other**	tau	0.228665	-0.30989	0.145065	**0.591608**	-0.11111	-0.28583	-0.11111
		p-value	0.460597	0.294507	0.670402	**0.036032**	0.754454	0.342782	0.754454
TAN1	**Pre_Reg**	tau	0.222222	0.055556	-0.16667	**0.777778**	**0.816982**	0.171499	**-0.68599**
		p-value	0.465512	0.916965	0.602168	**0.004879**	**0.003333**	0.598161	**0.015333**
TAN2	**Pre_Reg**	tau	0.49322	-0.08452	-0.16667	**0.647952**	**0.611111**	0.277778	-0.5
		p-value	0.088683	0.833935	0.602168	**0.021098**	**0.028568**	0.348083	0.076333
TAN3	**Pre_Reg**	tau	**0.741249**	0.5	0	**0.815374**	0	0.142857	0.254588
		p-value	**0.016965**	0.107762	1	**0.00832**	1	0.710523	0.454427
TRK1	**Other**	tau	-0.1715	-0.53526	-0.35283	**0.611111**	0.366233	-0.1972	-0.44444
		p-value	0.598161	0.059172	0.262556	**0.028568**	0.208413	0.529368	0.117851
TYN1	**Pre_Reg**	tau	**0.722222**	**0.628828**	**0.816982**	**0.722222**	**0.777778**	0.30989	0.084515
		p-value	**0.009149**	**0.026857**	**0.003333**	**0.009149**	**0.004879**	0.294507	0.833935
TYS1	**Pre_Reg**	tau	0	-0.17678	0.197203	0.514496	0.422577	0.197203	**-0.72222**
		p-value	1	0.594032	0.529368	0.07314	0.142213	0.529368	**0.009149**
WBL1	**Other**	tau	-0.343	-0.33333	-0.05556	0.222222	-0.11111	-0.14086	-0.38889
		p-value	0.246252	0.251452	0.916965	0.465512	0.754454	0.674987	0.175308
WBL2	**Other**	tau	**0.667298**	0.422577	-0.05556	0.444444	**0.760639**	0.140859	-0.44444
		p-value	**0.019244**	0.142213	0.916965	0.117851	**0.00642**	0.674987	0.117851
WBO1	**Pre_Reg**	tau	0.5		0.181848	0.333333	0.30989	0.277778	
		p-value	0.076333		0.617989	0.734095	0.294507	0.348083	
WBO2	**Pre_Reg**	tau	0.422577	**-0.87333**	0.181848	0.5	**0.555556**	0.366233	**-0.85749**
		p-value	0.142213	**0.001662**	0.617989	0.076333	**0.047604**	0.208413	**0.002237**
WBO3	**Pre_Reg**	tau	**0.591608**	0	0.181848	**0.904762**	0.535264	0.366233	-0.54554
		p-value	**0.036032**	1	0.617989	**0.006864**	0.059172	0.208413	0.080905
WLN1	**Pre_Reg**	tau	0.45733	**0.647952**	-0.25355	0.388889	**0.647952**	0.114332	-0.16667
		p-value	0.113846	**0.021098**	0.401678	0.175308	**0.021098**	0.75183	0.602168
WLN2	**Other**	tau	0.114332	0.055556	-0.25355	0.285831	0.277778	0.028172	-0.1972
		p-value	0.75183	0.916965	0.401678	0.342782	0.348083	1	0.529368
WLN3	**Other**	tau	0.029013	0.30989	-0.25355	0.400163	0.333333	0.222222	**-0.61111**
		p-value	1	0.294507	0.401678	0.170587	0.251452	0.465512	**0.028568**
WLN4	**Other**	tau	0.050063	-0.58554	0.19518	0.142857	0.29277	-0.19518	0.142857

		p-value	1	0.094718	0.648582	0.763891	0.447521	0.648582	0.763891
WLN5	**Other**	tau	0.276026	-0.06667	0	0	0.276026	-0.06667	0.414039
		p-value	0.56609	1	1	1	0.56609	1	0.338888
WLR1	**Pre_Reg**	tau	0.478921	0.166667	-0.1715	**0.611111**	**0.743161**	0.222222	0.111111
WLR2	**Pre_Reg**	tau	0.333333	-0.38889	-0.1715	**0.783349**	0.366233	0.422577	**-0.7303**
		p-value	0.251452	0.175308	0.598161	**0.005851**	0.208413	0.142213	**0.011751**
WLR3	**Pre_Reg**	tau	-0.25355	-0.02817	-0.1715	**0.785714**	-0.5	-0.27778	-0.42601
		p-value	0.401678	1	0.598161	**0.009375**	0.076333	0.348083	0.154424
WMS1	**Pre_Reg**	tau	-0.15913	-0.15913	-0.15913	0.422222	0.179787	0.224733	-0.44947
		p-value	0.588506	0.588506	0.588506	0.107405	0.529599	0.418962	0.087961
WMS2	**Other**	tau	0.314627	0.071429	-0.15913	0.5	**0.53936**	0.340997	-0.35714
		p-value	0.243035	0.901539	0.588506	0.107762	**0.038879**	0.206827	0.26551
WMS3	**Other**	tau	-0.04495	-0.21429	-0.15913	0.109109	0.089893	0.066667	-0.57143
		p-value	0.928444	0.536187	0.588506	0.803089	0.787616	0.858028	0.063487