# Water quality parameters and phytoplankton productivity and composition in the middle-Trinity River, TX during periods of high and low discharge

Final Report for:
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Final Report

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expressed in units considering oxygen (A, C) and carbon (B, D). Note that respiration is the difference between gross and net productivity.

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## Executive Summary

Field measurements reported here provide refined information on productivity at varied and extreme conditions (high and low river discharges) for the mid-reaches of the Trinity River, Texas. This information, when incorporated into hydrology models aiming to predict oxygen dynamics, will decrease uncertainty, enabling better predictions. Stated briefly, when river discharge was high the turbidity and sediment load was high and many parameters were very similar in value along this stretch of the river, which included pH, conductivity, DO, $NO_3/NO_2$ and TN, and $PO_4$ and TP. Also as expected, with a highly turbid environment the productivity was less and the compensation depth was shallower. Both these parameters showed decreasing trends along downstream locations, suggesting the river was becoming more turbid as it flowed through the landscape. Species richness was higher during the high discharge period, showing co-dominance of *Chlorella* sp. and *Pediastrum* spp. (both green algae) along with multiple species of diatom at station 1, with *Chlorella* sp. being solely dominant at the remaining stations. When river discharge was low, some observations were puzzling. For example, species richness was lower showing co-dominance of *Aulacoseira* sp. (diatom) and unknown taxa of centric diatom at station 1, with unknown taxa of centric diatom being solely dominant at the remaining stations. Why the taxonomic composition was dominated by green algae during high river discharge and diatoms during low river discharge, and why species richness was low with low river discharge are unknown. The diatom maxima observed at station 2 during the low-discharge period, which was nearly a full order of magnitude greater than biovolumes observed at other stations, is also puzzling. This biovolume maximum corresponded with the minimum observation of $NH_4$, but did not relate to other nutrients. Determining whether this correlation is causative would require further investigation. To refine estimates of oxygen dynamics in these hydrology models even more, it is recommended that monthly sampling of these same parameters be carried out over a two-year period. It is likely that these parameters change over shorter time periods than what was measured here, and it is likely that there is interannual variance, something that is not adequately accounted for in this limited sampling.

## Scope of work

Dissolved oxygen in river systems is strongly influenced by aeration, primary productivity and community respiration. Primary productivity's contribution to the oxygen budget is influenced by, in part, irradiance and phytoplankton assemblage composition. Water quality models seeking to estimate dissolved oxygen dynamics using formulations based on phytoplankton assemblage composition and irradiance will provide better predictions. In this research, primary productivity and community respiration in an important river system in south central USA, the Trinity River, was measured. In addition, phytoplankton were enumerated providing information on assemblage composition and biomass. Field sampling was conducted during periods of high and low river discharge.

## Description of research performed

The area of focus for this research encompassed mid-reaches of the Trinity River (Figure 1), with four sample stations visited in July 2015, a period of high river discharge (~17,000 cfs), and in June 2018, a period of low discharge (~850 cfs)(Figure 2). These sites were selected because historically Texas Commission on Environmental Quality has sampled them for other parameters. The locations and times of sampling of the four sites were:

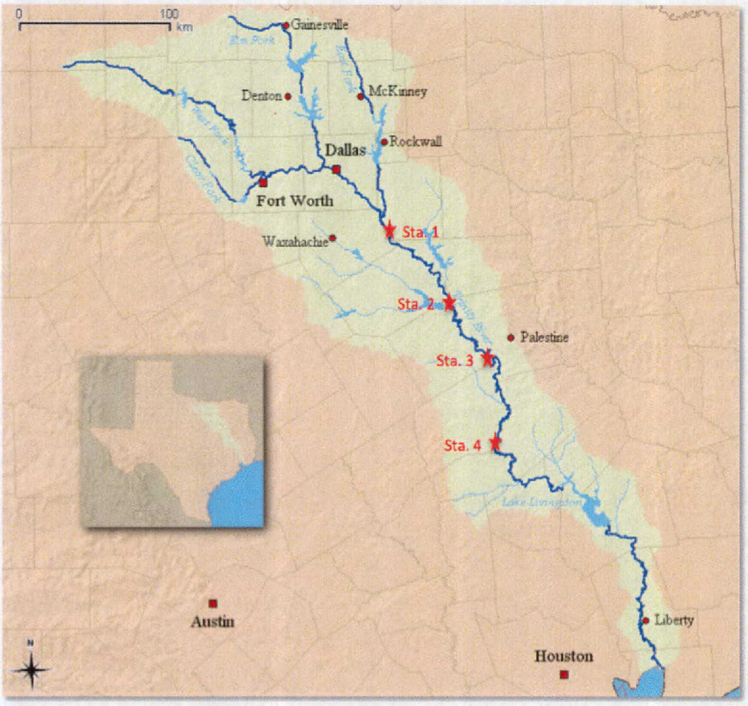


*Figure 1. Sampling sites along the Trinity River, Texas, which were: near the towns of Ennis and Rosser accessible near route 34 (station 1), just upstream from the confluence with the Richland Creek Reservoir discharge accessible at the route 287 overpass (station 2), near the town of Oakwood accessible at the routes 79 and 84 overpass (station 3), and near the town of Elwood accessible near the end of route 112 (station 4).*

Station 1 Located near the towns of Ennis and Rosser, accessing the river from a turnoff near route 34, latitude 32°25'24.8"N, longitude 96°27'16.8"W, this site was sampled on July 21, 2015 at 10:30 a.m. and on June 21, 2018 at 9:45 a.m.

Station 2 Located just upstream from the confluence with the Richland Creek Reservoir discharge, accessing the river from under the route 287 bridge, latitude 31°58'01.0"N, longitude 96°02'49.1"W, this site was sampled on July 22, 2015 at 10:35 a.m. and on June 20, 2018 at 10:00 a.m.

Station 3 Located near the town of Oakwood, accessing the river from under the routes 79 and 84 bridge, latitude 31°38'54.7"N, longitude 95°47'21.8"W, this site was sampled on July 23, 2015 at 10:20 a.m. and on June 19, 2018 at 10:00 a.m.

Station 4 Located near the town of Elwood, accessing the river from the of route 112, latitude 31°08'55.9"N, longitude 95°45'14.6"W, this site was sampled on July 24, 2015 at 10:25 a.m. and on June 18, 2018 at 10:00 a.m.

*Figure 2. Trinity sampling site near Oakwood (station 3) during July 2015 when discharge was 17,000 cfs (A) and June 2018 when discharge was 850 cfs (B). A common point of reference between the two sampling years (double-headed arrow line) and the high-water discharge height (dashed line) are shown.*

## Methods

Parameters measured and sampled for at each station encompassed abiotic, chemical and biological. Regarding abiotic parameters, irradiance, temperature, pH, oxygen-reduction potential (ORP, sampled in 2018 only), conductivity, dissolved oxygen (DO), turbidity, Secchi depth, and total suspended solids (TSS) were measured. Irradiance was measured at the start and end of productivity incubations using a handheld light meter (OMEGA Engineering™). Irradiance values reported here are the average of those measurements. Standard water quality parameters, i.e., temperature, pH, ORP (2018 only), conductivity, DO and turbidity, were measured with multiprobes, using a Quanta (HYDROLAB) during the July 2015 sampling (which did not have an ORP sensor) and a Mantra+ 30 (Eureka) during the June 2018 sampling (which had an ORP sensor). Note, HYDROLAB discontinued support of the Quanta in 2015, which require use of a different instrument during 2018 sampling. Secchi depth was determined using a traditional Secchi disk. Samples for TSS were collected by filtering quantitative volumes of river water through acid-washed, pre-weighed GF/F filters. TSS was then determined after dehydration in the laboratory (APHA-AWWA-WEF 2005).

Chemical parameters measured were nitrate ($NO_3$) and nitrite ($NO_2$), which are combined here, ammonium ($NH_4$), phosphate ($PO_4$), total nitrogen (TN), total phosphorus (TP) and total organic carbon (TOC). For $NO_3$ and $NO_2$ combined, $NH_4$ and $PO_4$, river water was filtered through acid-washed GF/F filters and filtrates frozen immediately, being thawed prior to laboratory analysis that occurred within 30 days of sampling. For TN, TP and TOC, unfiltered river water was frozen immediately, being thawed prior to laboratory analysis that occurred within 30 days of sampling. Using a Dionex ICS 2000 with an Ionpak AS20 and Ionpak AG20 analytical with guard columns (Dionex Corporation), $NO_3$, $NO_2$ and $PO_4$ were quantified. Separation was achieved with 35 mM KOH as eluent at a flow rate of 1 mL minute and an injection volume of 25 mL. Using the phenate hypochlorite method with sodium nitroprusside enhancement (US EPA Method 350.1, US Environmental Protection Agency 1993a), $NH_4$ was measured. Using high-temperature Pt-catalysed combustion with a Shimadzu TOC-VCSH and Shimadzu total measuring unit TNM-1 (Shimadzu Corporation), TN and TOC were measured. For TP, unfiltered samples were first digested using an acid persulfate technique (US EPA Method 365.3, US Environmental Protection Agency, 1978). Instrument detection limits for each constituent analyzed were 0.1 +/- 0.1 mg $L^{-1}$ DOC, 0.05 +/-0.05 mg $L^{-1}$ TN, 0.01 +/- 0.012 mg $L^{-1}$ $NH_4$ and 0.01 +/- 0.007 mg $L^{-1}$ NO3. Sample replicates, blanks, National Institute of Standards and Technology traceable and check standards were also run to monitor precision of instruments.

Biological parameters measured were chlorophyll *a*, phaeophytin *a*, phytoplankton biovolume and composition, net primary productivity and community respiration. For chlorophyll *a* and phaeophytin *a*, samples were collected by filtering quantitative volumes of river water through acid-washed GF/F filters, followed by extraction in 90% acetone and photometer measurement (Wetzel and Likens 2000). Phytoplankton samples were enumerated using a settling technique and inverted phase-contrast microscopy (Uttermohl 1958). Primary productivity and community respiration were determined by employing a light/dark bottle technique (Wetzel and Likens 2000). Regarding primary productivity, this was determined at the 100%, 50%, 20% and 5% light levels. This enabled a better approximation of the productivity integrated over the water column.

## Results

The days of sampling in July 2015 were fairly clear of clouds, contrasted with the days of sampling in June 2018, which were cloudy to partly cloudy. This resulted in variance in the average irradiance, ranging between ~1500 to ~ 2000 $\mu E\ m^{-2}\ s^{-1}$ in July 2015 and ~100 to ~1400 $\mu E\ m^{-2}\ s^{-1}$ in June 2018 (Figure 3a).

There was a general down-stream increase in temperature along the sites sampled for both sampling dates, increasing from ~28.3 to 29.3 °C in July 2015, and increasing from ~28.8 to 30.2 °C in June 2018 (Figure 3b).

Along the sites of sampling, pH was fairly conservative, being ~7.5 in July 2015 and ranging between 8.2 to ~9.0 in June 2018 (Figure 3c).

The Quanta multiprobe did not have a functional ORP sensor, so ORP measurements were performed during July 2015. During June 2018, ORP showed a decreasing trend with downstream location, decreasing from ~360 to ~200 (Figure 3d).

During the July 2015 sampling, conductivity was conservative along the sample sites, being ~0.350 mS $cm^{-1}$. During the June 2018 sampling, conductivity showed a decreasing trend with downstream locations, decreasing from ~0.850 to ~0.640 mS $cm^{-1}$ (Figure 3e).

During the July 2015 and June 2018 samplings, dissolved oxygen was fairly conservative along the sample sites, ranging from ~4.50 to ~5.00 mg $liter^{-1}$ in July 2015 and ranging between ~7.75 to 8.25 mg $liter^{-1}$ in June 2018 (Figure 3f).

Turbidity was very high during the July 2015 sampling, and very low during the June 2018 sampling. Turbidity showed an increasing trend with downstream locations, ranging from ~12000 to ~21000 NTUs. Turbidity was low during June 2018 sampling, being ~45 NTUs (Figure 4a).

Similarly, Secchi depth was shallower during the July 2015 sampling and deeper during the June 2018 sampling, with values ranging between ~0.10 and ~0.15 m in July 2015 and ranging between ~0.18 and ~0.30 m in June 2018 (Figure 4b).

Following suit, TSS was greater during the July 2015 sampling and less during the June 2018 sampling, with values ranging between ~0.25 and ~0.37 mg $liter^{-1}$ in July 2015 and ranging between ~0.03 and ~0.10 mg $liter^{-1}$ in June 2018 (Figure 4c).

Phytoplankton biovolume showed a decreasing trend with downstream location in July 2015, decreasing from ~2.50 $x10^9$ to ~1.00 $x10^9$ $\mu m^3$ $liter^{-1}$. Phytoplankton showed high variability in June 2018, with biovolume being very high at station 2, ~2.9 $x10^{10}$ $\mu m^3$ $liter^{-1}$, while ranging between ~2.50 $x10^9$ to ~4.90 $x10^9$ $\mu m^3$ $liter^{-1}$at other locations (Figure 4d).

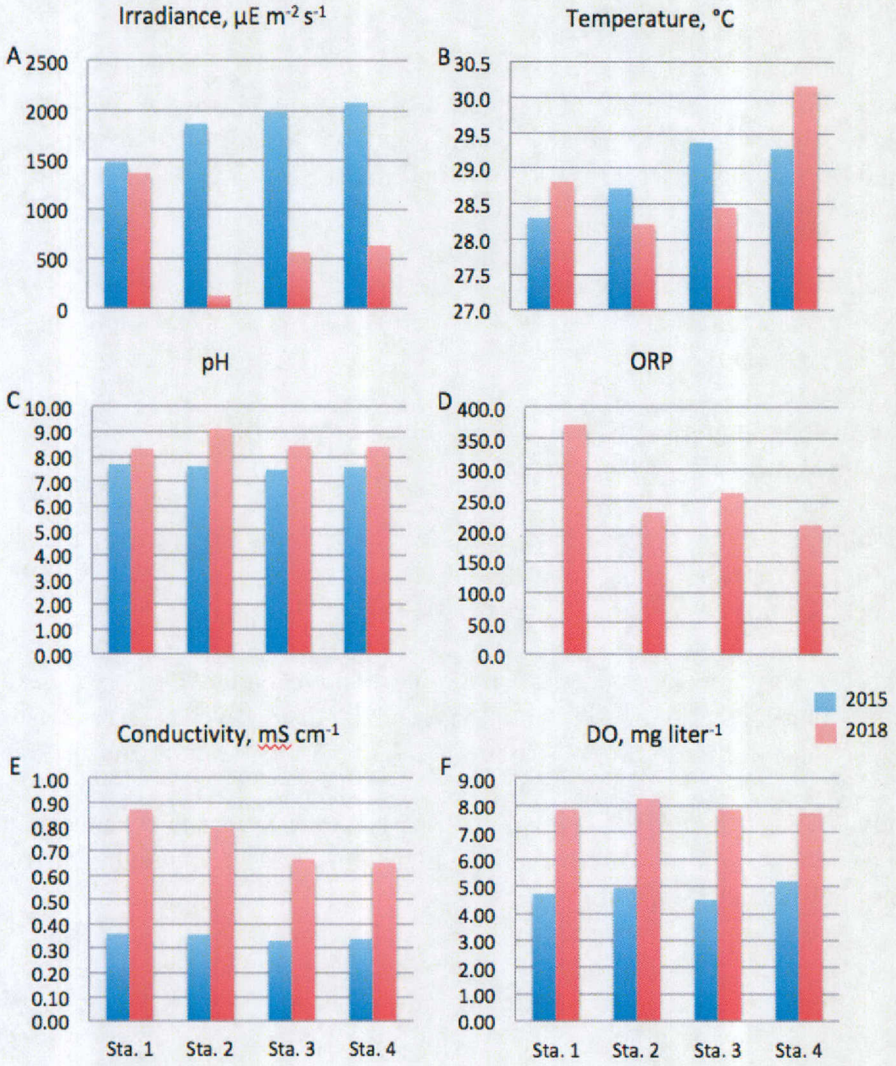


*Figure 3. Trinity River water quality parameters during periods of high discharge in July 2015 (blue bars) and low discharge in June 2018 (red bars) for irradiance (A), temperature (B), pH (C), oxygen-reduction potential (D), conductivity (E) and dissolved oxygen (F). Note that oxygen-reduction potential was only measured in 2018.*

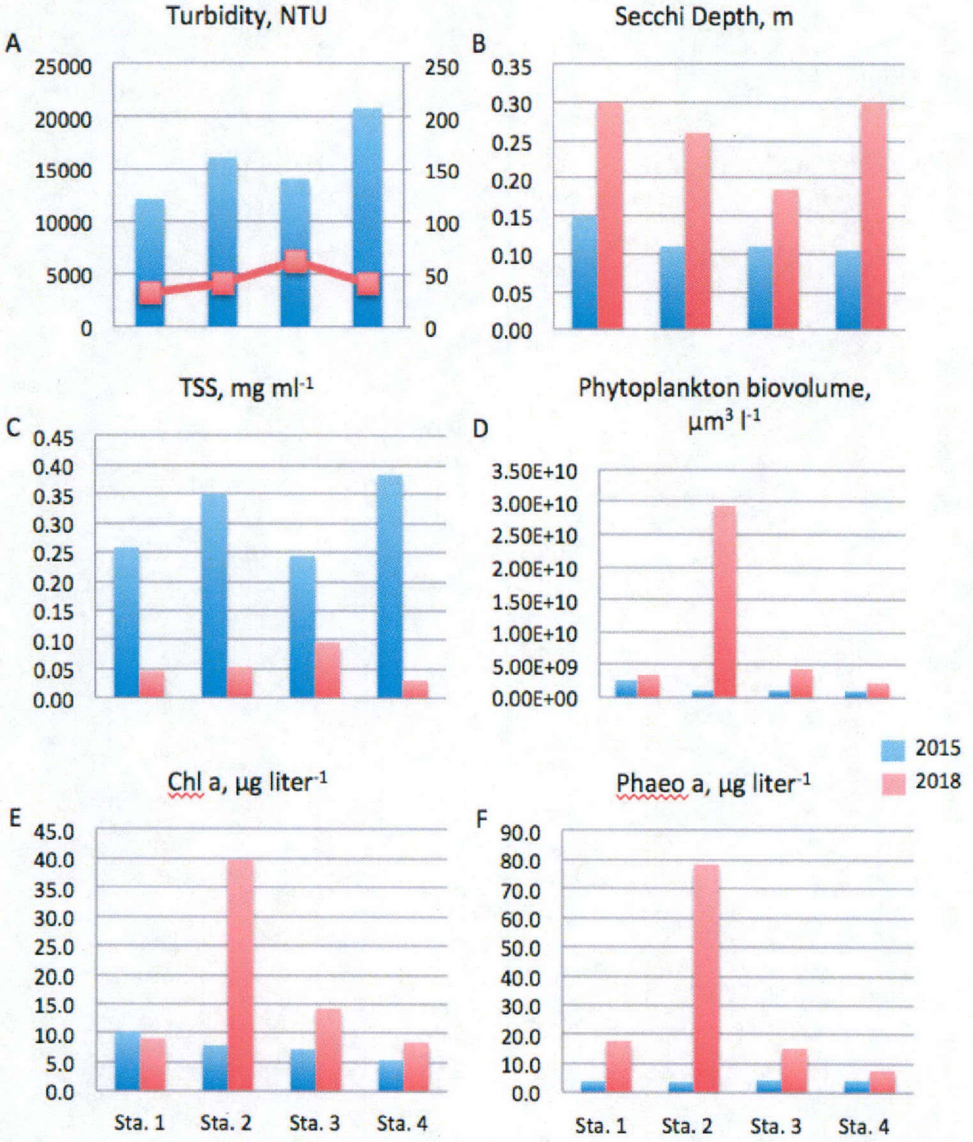


*Figure 4. Trinity River water quality parameters during periods of high discharge in July 2015 (blue bars) and low discharge in June 2018 (red bars or squares) for turbidity (A), Secchi depth (B), total suspended solids (C), phytoplankton biovolume (D), chlorophyll a (E) and phaeophytin a (F).*

Chlorophyll *a* concentration showed this same trend. It decreased with downstream location in July 2015, decreasing from ~10.0 to ~5.0 µg liter$^{-1}$. It showed high variability in June 2018, with concentration being very high at station 2, ~40.0 µg liter$^{-1}$, while ranging between ~8.0 to ~14.0 µg liter$^{-1}$at other locations (Figure 4e).

Phaeophytin *a* concentration was conservative in July 2015, being ~3.0 µg liter$^{-1}$. It showed high variability in June 2018, with concentration being very high at station 2, ~79.0 µg liter$^{-1}$, while ranging between ~8.0 to ~18.0 µg liter$^{-1}$ at other locations (Figure 4f).

Concentration of combined $NO_3$ and $NO_2$ was conservative in July 2015, being ~1.0 mg liter$^{-1}$. It showed a decreasing trend with downstream location in June 2018, decreasing from ~10.5 to 4.5 mg liter$^{-1}$ (Figure 5a).

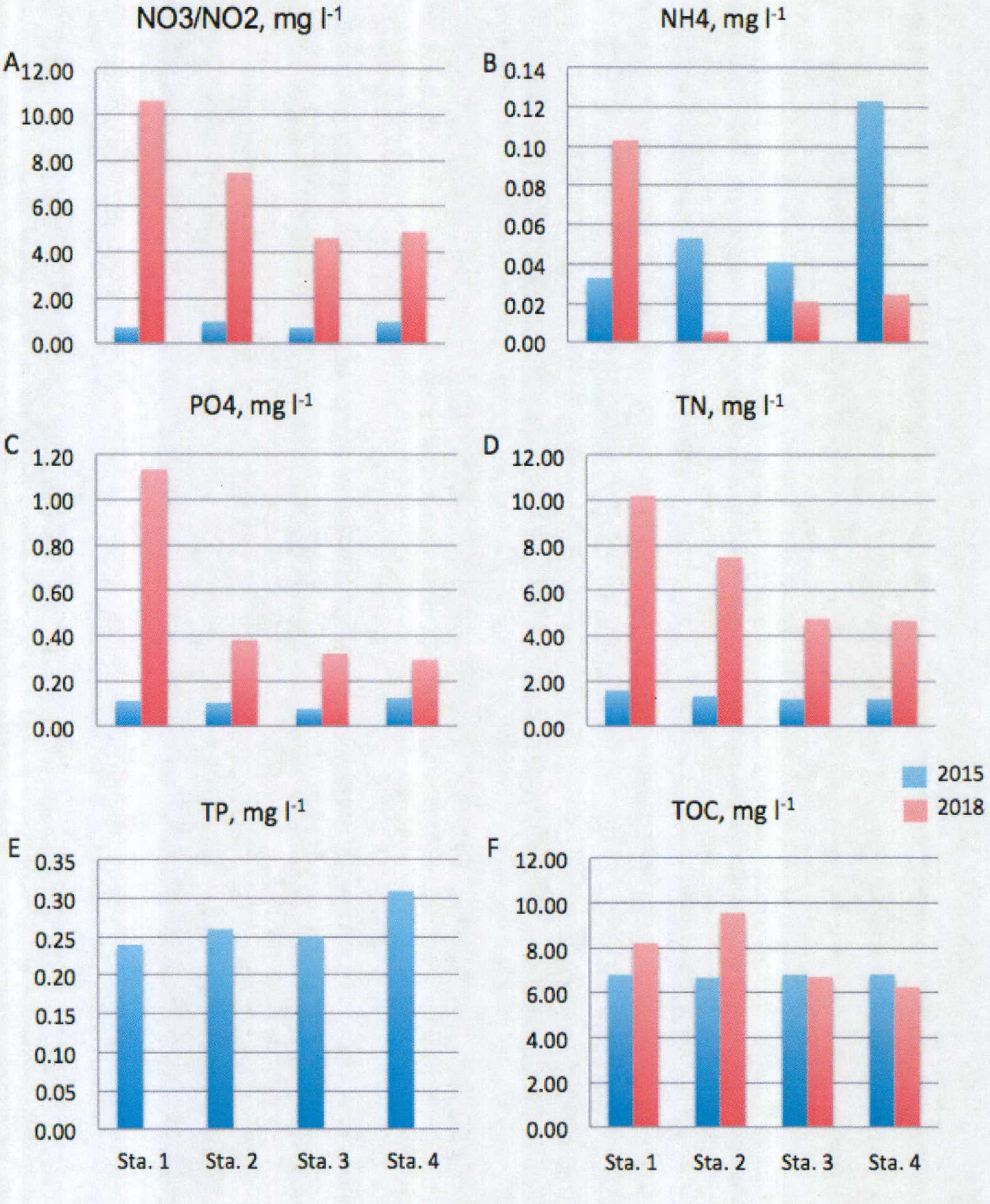


*Figure 5. Trinity River water quality parameters during periods of high discharge in July 2015 (blue bars) and low discharge in June 2018 (red bars) for nitrate and nitrite (A), ammonium (B), phosphate (C), total nitrogen (D), total phosphorus (E) and total organic carbon (F). Note that total phosphorus samples were lost in 2018.*

Concentration of $NH_4$ showed an increasing trend with downstream location in July 2015, increasing from ~0.03 to ~0.12 mg liter$^{-1}$. In June 2018, it was higher at station 1, being ~0.10 mg liter$^{-1}$, and variable downstream ranging between ~0.005 to ~0.02 µg liter$^{-1}$ (Figure 5b).

For $PO_4$, concentration was conservative in July 2015, being ~0.10 mg liter$^{-1}$. It showed a decreasing trend with downstream location in June 2018, decreasing from ~1.1 to 0.30 mg liter$^{-1}$ (Figure 5c).

Similarly, TN concentration was fairly conservative in July 2015, ranging between ~1.0 and ~1.5 mg liter$^{-1}$. It showed a decreasing trend with downstream location in June 2018, decreasing from ~10.5 to 4.5 mg liter$^{-1}$ (Figure 5d).

For TP, concentration showed an increasing trend with downstream location in July 2015, increasing from ~0.23 to 0.31 mg liter$^{-1}$ (Figure 5e). Samples were lost during collection in June 2018.

Concentration of TOC was conservative in July 2015, being ~6.5 mg liter$^{-1}$. It showed a decreasing trend with downstream location in June 2018, with values ~9.0 mg liter$^{-1}$ at stations 1 and 2, and ~6.25 mg liter$^{-1}$ at stations 3 and 4 (Figure 5f).

Productivity varied between the sampling dates and the sampling sites. At station 1, in July 2015 gross productivity was ~2.8 gC m$^{-3}$ d$^{-1}$ at the surface and the compensation depth was ~0.20 m, while in June 2018 gross productivity was ~10.0 gC m$^{-3}$ d$^{-1}$ at the surface and the compensation depth was ~0.62 m (Figure 6). At station 2, in July 2015 gross productivity was ~2.2 gC m$^{-3}$ d$^{-1}$ at the surface and the compensation depth was ~0.10 m, while in June 2018 gross productivity was ~10.5 gC m$^{-3}$ d$^{-1}$ at the surface and the compensation depth was ~0.35 m (Figure 7). At station 3, in July 2015 gross productivity was ~2.2 gC m$^{-3}$ d$^{-1}$ at the surface and the compensation depth was ~0.06 m, while in June 2018 gross productivity was ~10.5 gC m$^{-3}$ d$^{-1}$ at the surface and the compensation depth was ~0.35 m (Figure 8). At station 4, in July 2015 gross productivity was ~1.6 gC m$^{-3}$ d$^{-1}$ at the surface and the water column was net heterotrophic, while in June 2018 gross productivity was ~10.5 gC m$^{-3}$ d$^{-1}$ at the surface and the compensation depth was ~0.50 m (Figure 9).

Phytoplankton assemblage composition varied between the sampling dates and the sampling sites. At station 1, in July 2015 twenty-one taxa were observed with *Chlorella* spp., *Clamydomonus* sp., and *Pediastrum spp.* being dominant (green algae) along with multiple species of diatom, while in June 2018 eight taxa were observed with *Aulacoseira* sp. (diatom) and two unknown taxa of centric diatom were abundant (Table 1). At station 2, in July 2015 ten taxa were observed with a *Chlorella* sp. being solely dominant, while in June 2018 eleven taxa were observed with two unknown taxa of centric diatom dominant (Table 1). Similarly, at station 3 in July 2015, fifteen taxa were observed with a *Chlorella* sp. being solely dominant, while in June 2018 eleven taxa were observed with an unknown taxa of centric diatom solely dominant (Table 1). Finally, at station 4 in July 2015, eight taxa were observed with a *Chlorella* sp. being solely dominant, while in June 2018 six taxa were observed with an unknown taxa of centric diatom being solely dominant (Table 1).

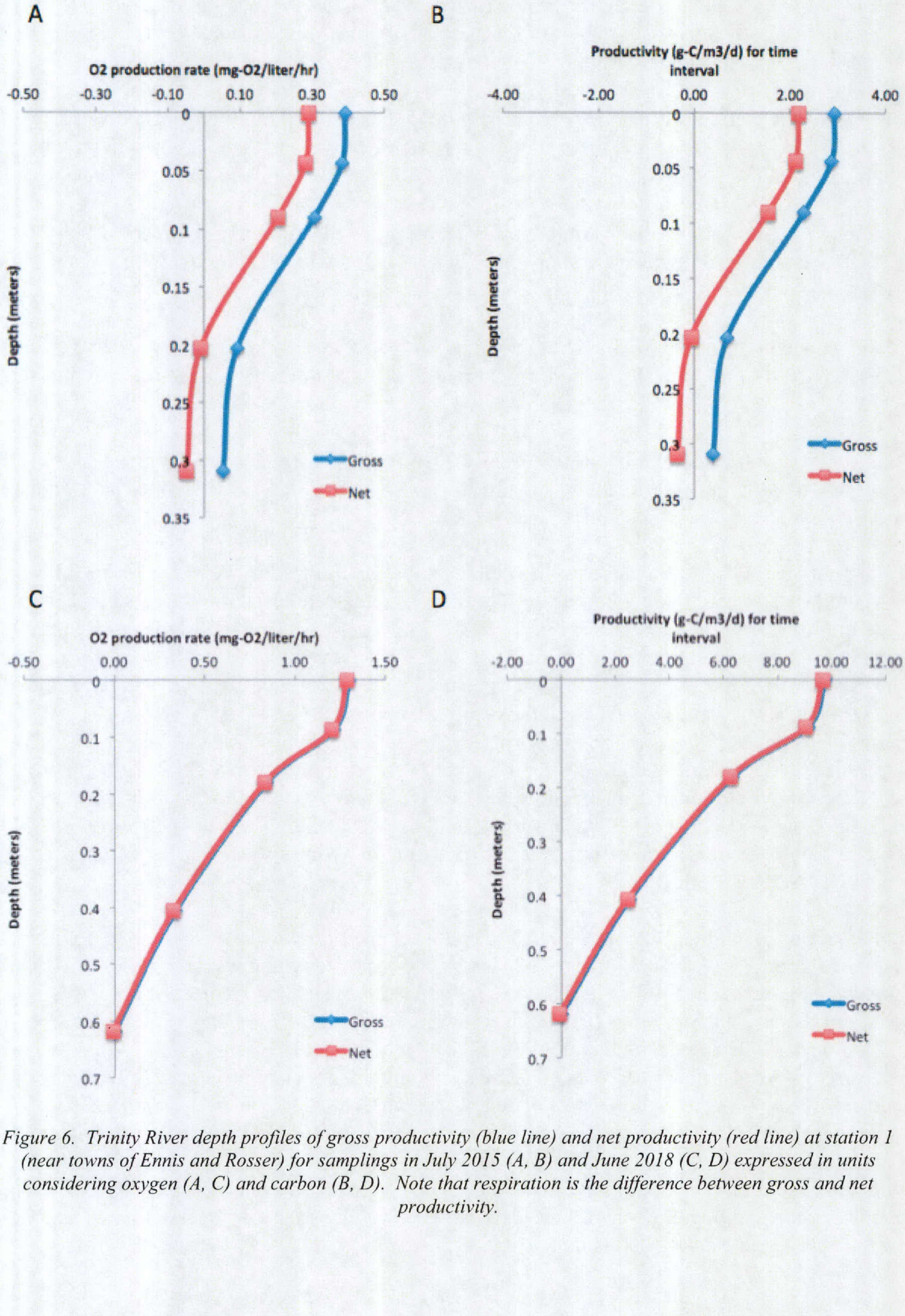


*Figure 6. Trinity River depth profiles of gross productivity (blue line) and net productivity (red line) at station 1 (near towns of Ennis and Rosser) for samplings in July 2015 (A, B) and June 2018 (C, D) expressed in units considering oxygen (A, C) and carbon (B, D). Note that respiration is the difference between gross and net productivity.*

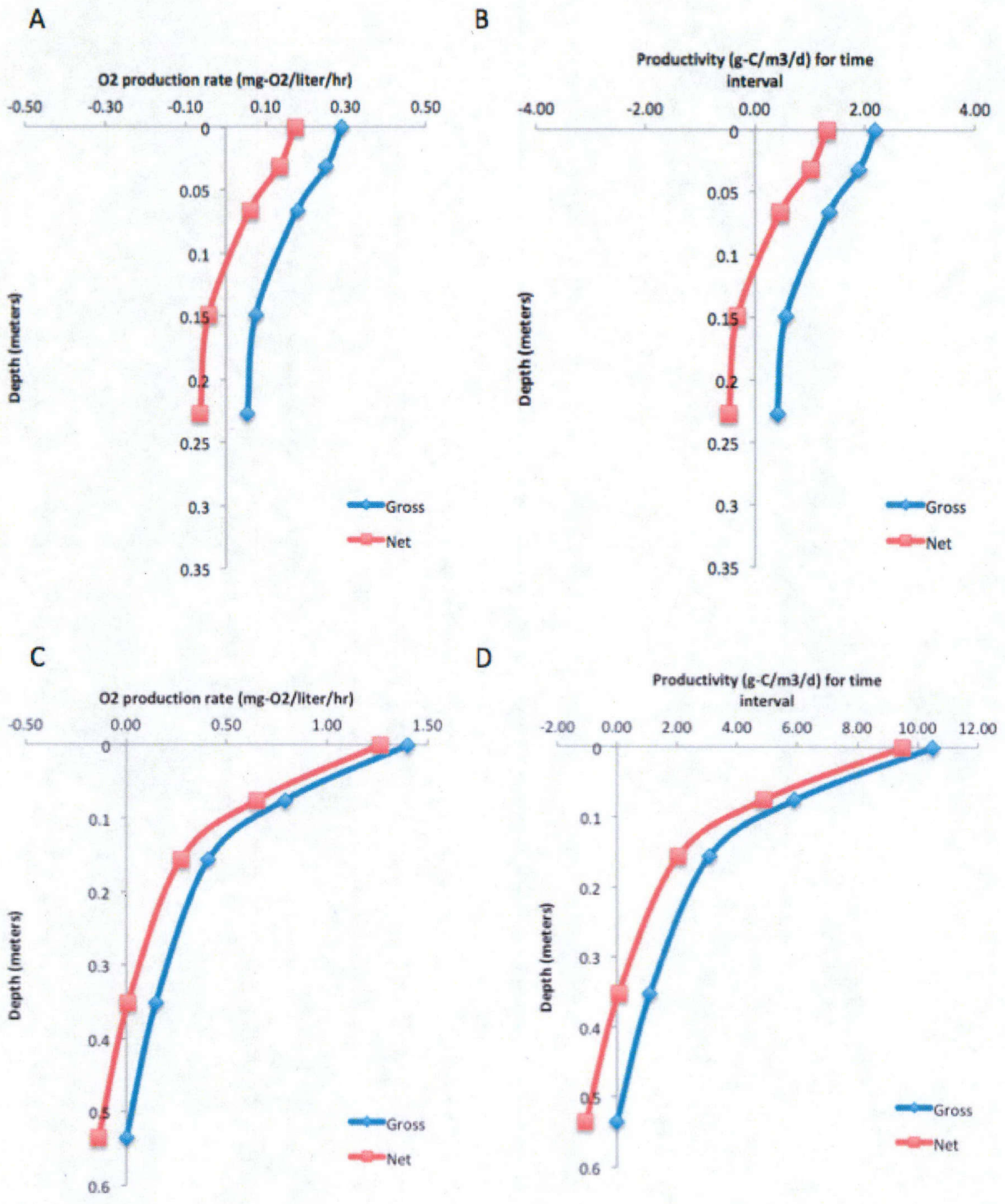


*Figure 7. Trinity River depth profiles of gross productivity (blue line) and net productivity (red line) at station 2 (just upstream from confluence with Richland Creek Reservoir discharge) for samplings in July 2015 (A, B) and June 2018 (C, D) expressed in units considering oxygen (A, C) and carbon (B, D). Note that respiration is the difference between gross and net productivity.*

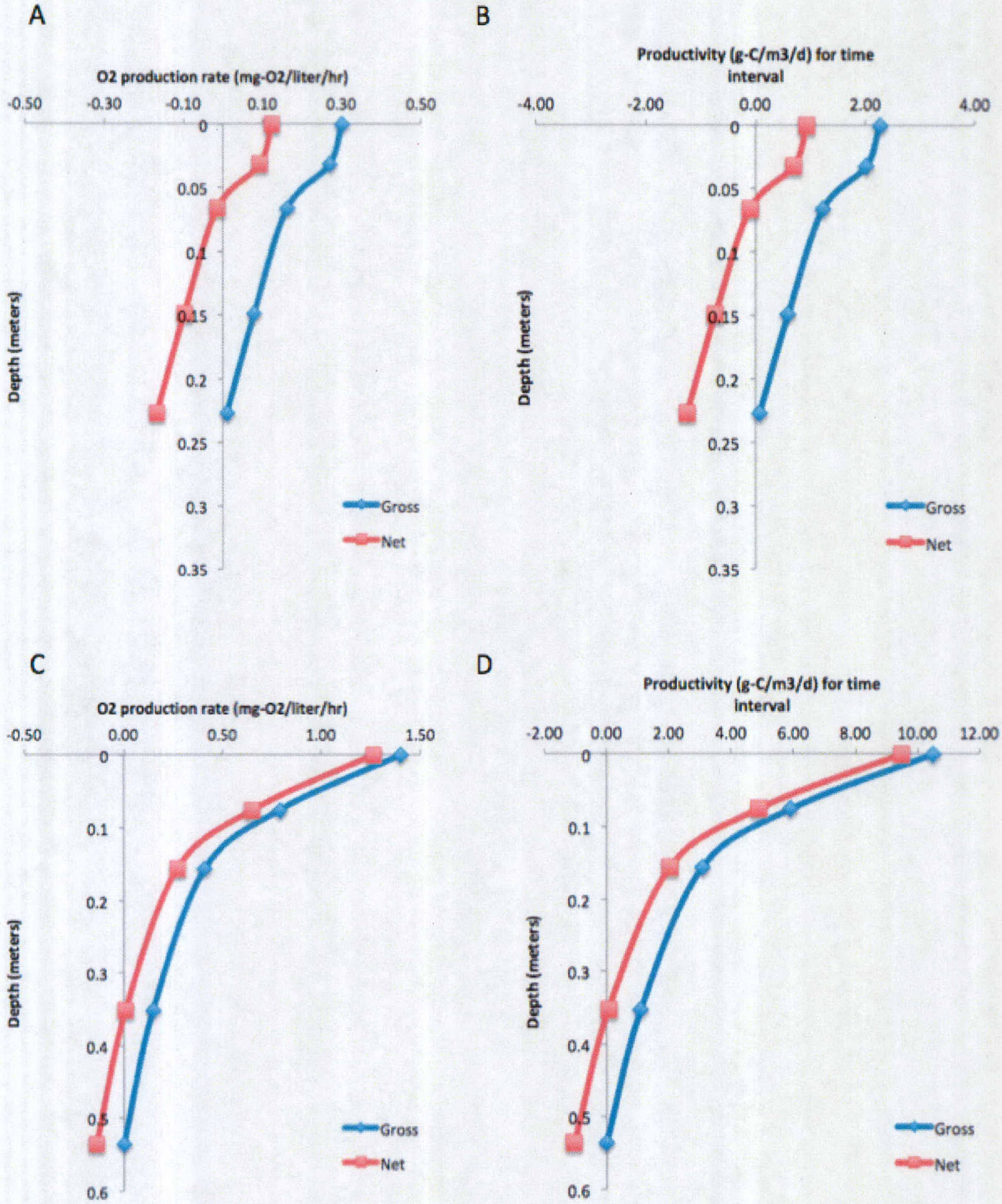


*Figure 8. Trinity River depth profiles of gross productivity (blue line) and net productivity (red line) at station 3 (near town of Oakwood) for samplings in July 2015 (A, B) and June 2018 (C, D) expressed in units considering oxygen (A, C) and carbon (B, D). Note that respiration is the difference between gross and net productivity.*

while in June 2018 gross productivity was ~10.5 gC $m^{-3}$ $d^{-1}$ at the surface and the compensation depth was ~0.50 m (Figure 9).

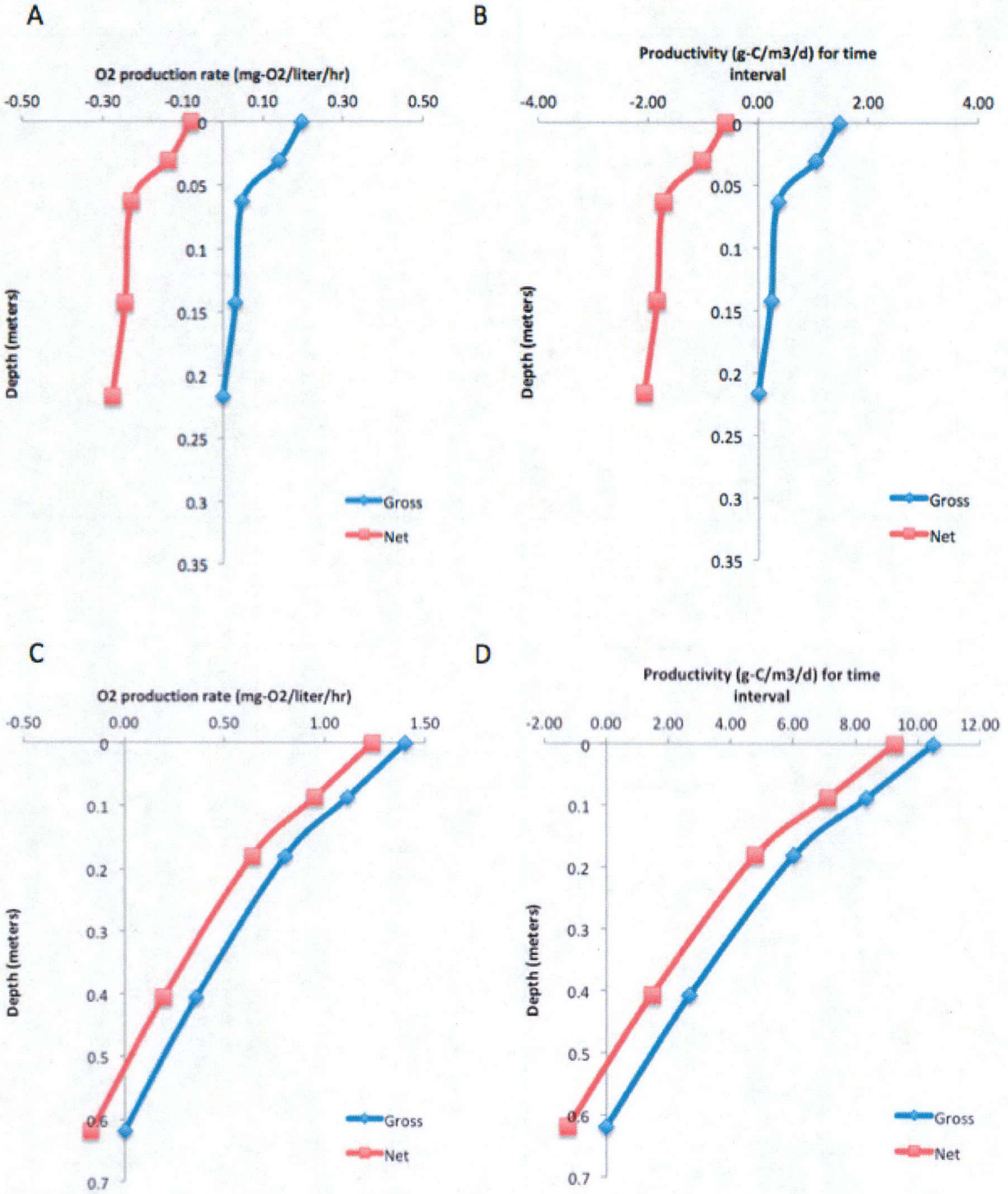


*Figure 9. Trinity River depth profiles of gross productivity (blue line) and net productivity (red line) at station 4 (near town of Elwood) for samplings in July 2015 (A, B) and June 2018 (C, D) expressed in units considering oxygen (A, C) and carbon (B, D). Note that respiration is the difference between gross and net productivity.*

Table 1. Trinity River phytoplankton composition at stations 1 through 4 for samplings in July 2015 and June 2018. Values shown in table are cellular biovolume concentration and are in units of $\mu m^3$ liter$^{-1}$.

| | | Chlorophytes | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| station | year | *Chlorella sp.1* | *Chlorella sp.2* | *Chlorella sp.3* | *Clamydomonus sp.* | *Kirchneriella lunaris* | *Oocystis sp.* | *Pediastrum duplex* | *Pediastrum simplex* | *Scenedesmus abundans* | *Scenedesmus arcuatatus* |
| 1 | 2015 | 5.98E+08 | 2.02E+07 | 6.83E+07 | 1.07E+08 | 9.87E+07 | 4.56E+07 | 6.07E+08 | 6.54E+05 | 0 | 0 |
| 1 | 2018 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8.83E+06 | 0 | 0 |
| 2 | 2015 | 5.72E+08 | 8.10E+07 | 0 | 1.07E+08 | 9.11E+07 | 7.97E+07 | 0 | 0 | 0 | 0 |
| 2 | 2018 | 0 | 0 | 0 | 0 | 0 | 0 | 1.77E+06 | 1.32E+07 | 0 | 5.96E+07 |
| 3 | 2015 | 5.89E+08 | 8.10E+07 | 0 | 0 | 9.62E+07 | 3.42E+07 | 0 | 2.12E+06 | 4.56E+07 | 0 |
| 3 | 2018 | 0 | 0 | 0 | 0 | 0 | 0 | 4.45E+06 | 4.61E+06 | 0 | 5.96E+07 |
| 4 | 2015 | 6.15E+08 | 4.05E+07 | 6.83E+07 | 0 | 8.86E+07 | 0 | 0 | 9.84E+06 | 0 | 0 |
| 4 | 2018 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8.71E+05 | 0 | 3.53E+05 |

Table 1 con't.

| | | Chlorophytes con't. | | Euglenophyta | | Bacillariophyta | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| station | year | *Spirogyra varians* | *unknown green algae* | *Trachelomonas sp.1* | *Trachelomonas sp.2* | *Aulacoseira granulata var.1* | *Aulacoseira sp.* | *Anomoeoneis sp.1* | *Anomoeoneis sp.2* | *centric diatom sp.1* | *centric diatom sp.2* |
| 1 | 2015 | 0 | 1.71E+08 | 4.15E+07 | 2.02E+07 | 0 | 2.84E+08 | 7.59E+06 | 1.82E+08 | 6.83E+07 | 0 |
| 1 | 2018 | 4.77E+06 | 0 | 0 | 0 | 0 | 1.32E+09 | 0 | 0 | 1.46E+09 | 4.38E+08 |
| 2 | 2015 | 0 | 1.37E+08 | 0 | 0 | 0 | 0 | 1.52E+07 | 0 | 0 | 0 |
| 2 | 2018 | 0 | 0 | 5.30E+05 | 0 | 7.20E+05 | 0 | 0 | 0 | 2.58E+10 | 2.64E+09 |
| 3 | 2015 | 3.90E+07 | 1.54E+08 | 0 | 0 | 0 | 0 | 3.29E+07 | 0 | 0 | 0 |
| 3 | 2018 | 0 | 0 | 5.01E+05 | 0 | 0 | 1.57E+08 | 0 | 0 | 3.22E+09 | 8.48E+07 |
| 4 | 2015 | 0 | 1.88E+08 | 0 | 0 | 0 | 0 | 3.42E+07 | 0 | 0 | 0 |
| 4 | 2018 | 0 | 0 | 0 | 0 | 3.97E+04 | 0 | 0 | 0 | 1.63E+09 | 3.40E+08 |

Table 1 con't.

| | | Bacillariophyta con't. | | | | | | Cryptophyta | | Cyanophyta | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| station | year | *Gyrosigma sp.* | *pennate diatom sp.* | *Pinnularia sp.* | *Synedra sp.* | *Tabellaria sp.1* | *Tabellaria sp.2* | *Cryptomonad sp.1* | *Cryptomonad sp.2* | *Merismopedia elegans* | *Oscillatoria sp.* |
| 1 | 2015 | | 1.71E+08 | 0 | 0 | 4.05E+07 | 3.80E+06 | 4.63E+07 | 8.10E+07 | 0 | 0 |
| 1 | 2018 | 1.12E+08 | 8.94E+07 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8.50E+05 |
| 2 | 2015 | | 0 | 0 | 0 | 3.80E+06 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2018 | | 3.52E+08 | 0 | 0 | 0 | 0 | 4.03E+08 | 0 | 3.51E+07 | 9.93E+05 |
| 3 | 2015 | | 0 | 0 | 0 | 0 | 0 | 9.25E+06 | 2.02E+07 | 0 | 0 |
| 3 | 2018 | | 1.49E+07 | 8.28E+08 | 2.98E+07 | 0 | 0 | 0 | 0 | 0 | 1.17E+05 |
| 4 | 2015 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 2018 | | 2.83E+08 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 1 con't.

| | | Cyanophyta con't. | | | |
|---|---|---|---|---|---|
| station | year | *Phormidium sp.* | *Raphidiopsis sp.1* | *Raphidiopsis sp.2* | *unknown cyanobacteria* |
| 1 | 2015 | 3.16E+07 | 0 | 0 | 0 |
| 1 | 2018 | 0 | 0 | 0 | 0 |
| 2 | 2015 | 3.92E+07 | 3.80E+06 | 0 | 0 |
| 2 | 2018 | 0 | 0 | 0 | 0 |
| 3 | 2015 | 3.54E+07 | 6.33E+06 | 1.90E+07 | 9.49E+06 |
| 3 | 2018 | 0 | 0 | 0 | 0 |
| 4 | 2015 | 1.14E+07 | 0 | 0 | 0 |
| 4 | 2018 | 0 | 0 | 0 | 0 |

## Conclusions

This project was only meant to provide a snapshot of the middle Trinity River at a period when river discharge was high and when it was low. So conclusions are limited in that regard. Even so, some conclusions can be made.

As expected, when river discharge was high the turbidity and sediment load was high and many parameters were very similar in value along this stretch of the river, which included pH, conductivity, DO, $NO_3/NO_2$ and TN, and $PO_4$ and TP. Also as expected, with a highly turbid environment the productivity was less and the compensation depth was shallower. Both these parameters showed decreasing trends along downstream locations, suggesting the river was becoming more turbid as it flowed through the landscape. Species richness was higher during the high discharge period, showing co-dominance of *Chlorella* sp. and *Pediastrum spp.* (both green algae) along with multiple diatom species at station 1, with *Chlorella* sp. being solely dominant at the remaining stations.

When river discharge was low, some observations were expected and others are puzzling. As expected, with a low turbidity environment the productivity was higher and the compensation depth was deeper. These parameters changed little along the middle Trinity River. Species richness was lower during the low discharge period, showing co-dominance of *Aulacoseira* sp. (diatom) and unknown taxa of centric diatom at station 1, with unknown taxa of centric diatom being solely dominant at the remaining stations. What is puzzling is why the taxonomic composition showed green algae dominance during the period of high river discharge and diatom dominance during the period of low river discharge, and why species richness was less during low river discharge. What is also puzzling is the diatom maxima observed at station 2, which was nearly a full order of magnitude greater than biovolumes observed at other stations. This biovolume maximum corresponded with the minimum observation of $NH_4$, but did not relate to other nutrients. Determining whether this correlation is causative would require further investigation.

## Recommendations

The project accomplished what it set out to do, which was to provide refined information on productivity at varied and extreme conditions (high and low river discharges). This information, when incorporated into hydrology models aiming to predict oxygen dynamics, will decrease uncertainty, enabling better predictions.

To refine estimates of oxygen dynamics in these hydrology models even more, it is recommended that monthly sampling of these same parameters be carried out over a two-year period. It is likely that these parameters change over shorter time periods than what was measured here, and it is likely that there is interannual variance, something that is not accounted for adequately in this limited sampling.

## References

APHA-AWWA-WEF (2005) Standard Methods for the Examination of Water and Wastewater. 21th Edition. New York, Total Solids Suspended, Method 2540 D, 2-55 a 2-59.

US Environmental Protection Agency (1993a). Method 350.1, Revision 2.0. Determination of ammonia nitrogen by semi-automated colorimetry. Revision 2.0 (Ed. J. W. O'Dell.) (US EPA, Office of Research and Development: Cincinnati, OH.) Available at https://www.epa.gov/sites/production/files/2015-06/documents/epa-350.1.pdf [Verified 19 May 2016].

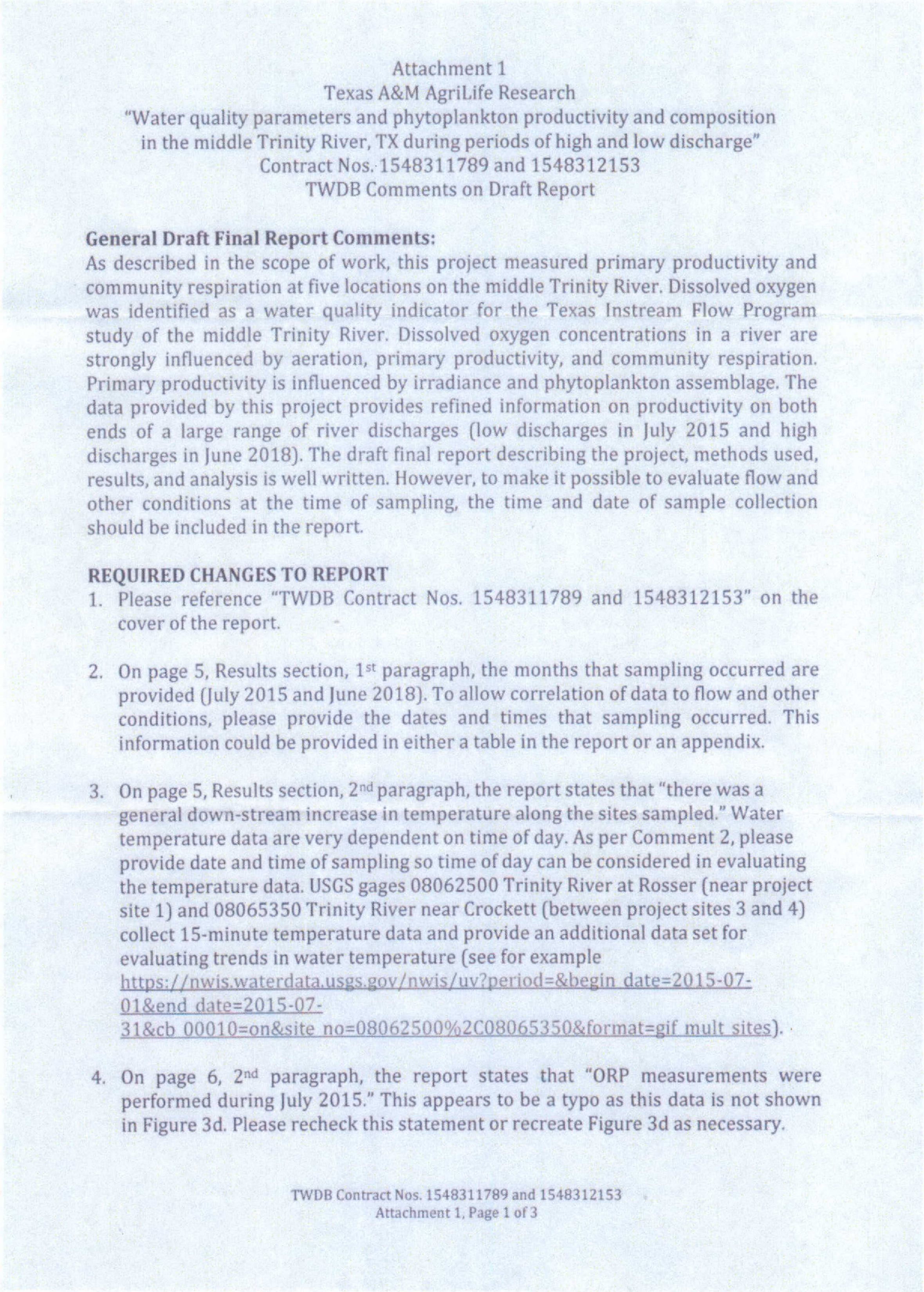
U.S. Environmental Protection Agency, Cincinnati, OH (1978). Method 365.3. All Forms of Phosphorus. Methods of Chemical Analysis of Water and Wastes. In CFR 136

Uttermohl, H., (1958). Zur vervollkominnung der quantitiven phytoplankton mothodik. Mitt. Int. Ver. Theoret. Ang. Limnol. 9, 1-38.

Wetzel, R. G., and Likens, G. E. (2000). 'Limnological Analysis', 2nd edn. (Springer-Verlag: New York.)

# Appendix A

Comments received from Texas Water Development Board on a previous iteration of this report.



Attachment 1
Texas A&M AgriLife Research
"Water quality parameters and phytoplankton productivity and composition
in the middle Trinity River, TX during periods of high and low discharge"
Contract Nos. 1548311789 and 1548312153
TWDB Comments on Draft Report

**General Draft Final Report Comments:**
As described in the scope of work, this project measured primary productivity and community respiration at five locations on the middle Trinity River. Dissolved oxygen was identified as a water quality indicator for the Texas Instream Flow Program study of the middle Trinity River. Dissolved oxygen concentrations in a river are strongly influenced by aeration, primary productivity, and community respiration. Primary productivity is influenced by irradiance and phytoplankton assemblage. The data provided by this project provides refined information on productivity on both ends of a large range of river discharges (low discharges in July 2015 and high discharges in June 2018). The draft final report describing the project, methods used, results, and analysis is well written. However, to make it possible to evaluate flow and other conditions at the time of sampling, the time and date of sample collection should be included in the report.

**REQUIRED CHANGES TO REPORT**

1. Please reference "TWDB Contract Nos. 1548311789 and 1548312153" on the cover of the report.

2. On page 5, Results section, 1st paragraph, the months that sampling occurred are provided (July 2015 and June 2018). To allow correlation of data to flow and other conditions, please provide the dates and times that sampling occurred. This information could be provided in either a table in the report or an appendix.

3. On page 5, Results section, 2nd paragraph, the report states that "there was a general down-stream increase in temperature along the sites sampled." Water temperature data are very dependent on time of day. As per Comment 2, please provide date and time of sampling so time of day can be considered in evaluating the temperature data. USGS gages 08062500 Trinity River at Rosser (near project site 1) and 08065350 Trinity River near Crockett (between project sites 3 and 4) collect 15-minute temperature data and provide an additional data set for evaluating trends in water temperature (see for example https://nwis.waterdata.usgs.gov/nwis/uv?period=&begin_date=2015-07-01&end_date=2015-07-31&cb_00010=on&site_no=08062500%2C08065350&format=gif_mult_sites).

4. On page 6, 2nd paragraph, the report states that "ORP measurements were performed during July 2015." This appears to be a typo as this data is not shown in Figure 3d. Please recheck this statement or recreate Figure 3d as necessary.

5. On page 6, 5th paragraph, the report describes turbidity data for June 2018 that is not shown in Figure 4a. Please check and recreate Figure 4a or modify the text as necessary. USGS gages 08062500 Trinity River at Rosser (near project site 1) and 08065350 Trinity River near Crockett (between project sites 3 and 4) collect 15-minute turbidity data and provide an additional data set for evaluating trends in turbidity (see for example https://nwis.waterdata.usgs.gov/nwis/uv?site_no=08065350%2C08062500&format=gif_mult_sites&PARAmeter_cd=63680&begin_date=2018-08-01&end_date=2018-08-31).

6. Figure 2 shows smaller reservoirs such as Bardwell Lake and Navarro Mills Lake near sampling site 2. However, the much larger Richland-Chambers Reservoir is not shown. Please recreate this map with the location of Richland-Chambers Reservoir displayed.

7. Please provide page numbers on the final report.

**SUGGESTED CHANGES TO REPORT**

8. The description of Station 2 on page 4 describes this station as "below the Richland Creek Reservoir" which is a bit confusing. The Lat/Long provided for Station 2 and the reference to the route 287 bridge place the site on the Trinity River upstream of the confluence with Richland Creek (on which Richland-Chambers Reservoir is located). When releases from Richland-Chambers Reservoir are low relative to the flow of the Trinity River, conditions in Richland Creek would have little influence on conditions at Station 2. Please consider alternative descriptions of Station 2 (perhaps "upstream of the confluence with Richland Creek") and/or including a figure that clearly shows the location of the site relative to Richland-Chambers Reservoir, Richland Creek, and the Trinity River.

9. As requested by Comment 8, please consider an alternative description for sampling site 2 in the caption for Figure 2. Perhaps "just above the confluence with Richland Creek accessible at the route 287 overpass" would be suitable.

10. It is difficult to compare Figures 10a and 10b. Please consider using a common legend for taxa displayed in Figure 10a and 10b (*e.g.* abundance of *Pediastrum simplex* would be shown with the same color in both figures). Same comment applies to Figures 11-13.

11. In the legend for Figure 10a, the taxa "Pediastrum simplex" and "Tabellaria sp." are listed twice. If appropriate, consider combining or designating as different species (*e.g.* "sp. 1" and "sp. 2").

12. It is unclear if the taxa "centric diatom sp." in Figure 10a is equivalent to either of the taxa "centric diatom sp. 1" and "centric diatom sp. 2" that appear in Figure

10b. If possible, please confirm that one of the "centric diatom sp." was present in both samples.

13. The taxa "oblong thing" appears in the legend for Figures 10-13. Please consider the use of a more technical term to describe the taxa.