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Austin Creek and Beaver Creek Sampling Project

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Background Information

Beaver Creek and Austin Creek were sampled intensively on November 20, 2004 to measure temperature, dissolved oxygen, turbidity, total nitrogen, total phosphorus, total suspended solids, and fecal coliforms. The objective was to assess the amount of variability that can be expected for water quality measurements collected from these creeks at different times during the day and in different locations within the Austin Creek and Beaver Creek watersheds.

Water quality data were collected every 30 minutes at three stationary or "fixed" sites in upper and lower Austin Creek and Beaver Creek, beginning at 8:00 am and ending at 16:00 (4 pm). During this same period, individual samples were collected at 24 additional "creek walk" sites within the Austin Creek and Beaver Creek watersheds (Figure 1, page 8). The creek walk sites included 8 sites in Austin Creek, 8 sites in Beaver Creek, 5 small tributaries to Austin Creek, and 3 small tributary to Beaver Creek. Table 1 (page 6) describes the approximate location for each site.

The weather during sampling was cloudy and cool. Approximately 2 inches of rain was recorded at the Smith Creek weather station during the week prior to sampling (Table 2, page 7), with heavy rain occurring on November 18 (1.12 in). The water was visibly more turbid on November 19 than on November 20 at the lower Austin Creek fixed sampling site (R. Matthews, field observations).

Results/Discussion

Water Temperature and Dissolved Oxygen

A calibrated YSI field meter was used to measure temperature and dissolved oxygen at all creek walk sites and at the Beaver Creek and upper Austin Creek fixed sites. A YSI meter was not available for use at the lower Austin Creek fixed site until the field sampling was completed (12:30 pm). Until that time, temperature was measured using a hand-held thermometer and dissolved oxygen was measured using the Winkler method. Concurrent temperature readings from the thermometer and the YSI meter revealed a ΔT of 0.5°C, which accounts for the abrupt change in temperature in the lower Austin Creek data (Figure 2, page 9).

If the earlier temperature values (i.e., thermometer readings) are adjusted for this difference, the water temperatures at all three stationary sites were very similar (Figure 3, page 10). Temperatures at the fixed sites increased slowly throughout the day.

Figures 4 and 5 (pages 11 and 12) show the water temperature results for the creek walk samples, plotted by collection time and overlaid on the fixed site results.[1] The creek walk samples are plotted using symbols and colors that correspond to the appropriate fixed reference site. Figure 4 shows the sample identification number from Table 1 and Figure 5 indicates whether the sample was collected in the main channel of Austin Creek or Beaver Creek (y) or from small tributaries or inlet pipes flowing into the creeks (n).

Unusually warm samples were collected from small tributaries to lower Austin Creek (Sites 5, 72, 73, and 74). The sample from Site 5 was collected from the Lake Louise outflow pipe, which also explains the higher temperature for Site 4, which was collected in the mixing zone downstream from the outflow.

Dissolved oxygen was measured using either a calibrated YSI meter or by the Winkler method. Dissolved oxygen concentrations were similar at all three fixed sites, decreasing during the day due to warmer water temperatures (Figure 6, page 13). Approximately 10% of the YSI measurements were duplicated using the Winkler method to provide quality control data (see quality control discussion beginning on page 36). Comparisons of the Winkler and YSI data indicate that both methods produced similar results. The median absolute difference between the YSI and Winkler oxygen results was 0.38 mg/L.

Most of the creek walk sites had dissolved oxygen concentrations that were similar to the results from the fixed sites (Figures 7 and 8, pages 14 and 15). Sites 5, 72, 73, and 74 had lower oxygen levels, probably due to the higher temperatures in these small tributaries. The sample from Site 79 was collected from a pipe flowing into Beaver Creek and may have lower oxygen due to lack of turbulence and biological oxygen consumption.

[1] Adjusted temperature data were used in Figures 4 and 5.

Total Suspended Solids and Turbidity

The fixed sites in Beaver Creek and lower Austin Creek had higher total suspended solids and turbidity levels than upper Austin Creek (Figures 9 and 10, pages 16 and 17). The total suspended solids and turbidity concentrations decreased significantly[2] throughout the day at all fixed sites. This was probably due to decreasing amounts of storm runoff following the heavy precipitation on November 18.

The total suspended solids and turbidity results from the creek walk sites were more variable than at the fixed sites (Figures 11–14, pages 18–21). The lowest total suspended solids levels were collected at sites located in upper Austin Creek (Sites 89 and 92), upper Beaver Creek (Site 80), and from small tributaries to Austin or Beaver Creeks (Sites 5, 72, 73, 78, and 79). Similarly, the lowest turbidities were associated with sites in upper Austin Creek (Sites 89 and 92), upper Beaver Creek (Site 80), and tributaries to Austin or Beaver Creeks (Sites 5, 74, 78, 79). The turbidity at Site 4 was relatively low for an in-stream sample, but it was collected immediately downstream from the Lake Louise outflow pipe (Site 5), and may have been diluted by low turbidity lake water.

Most of the total suspended solids and turbidity levels in the creek walk samples from Beaver Creek were lower than those from the Beaver Creek fixed site. Beaver Creek appeared to be picking up sediment as it flows through Sudden Valley. The upper portion of the Beaver Creek watershed (Sites 78 and 80) had the lowest sediment concentrations, and the sites closest to the confluence of Beaver and Austin Creeks (Sites 77 and 91) had relatively high turbidity and total suspended solids levels. This can be seen by sorting the creek walk samples by position in the watershed, beginning with the samples collected farthest upstream near the Sudden Valley campground (Figure 15, page 22). Both total suspended solids and turbidity were significantly correlated with watershed position.[3]

Turbidity is often used as a surrogate for the more labor-intensive total suspended solids analysis. Figure 16 (page 23) shows that total suspended solids and turbidity were highly correlated[3] and there was no bias relating to site. Three unusually high total suspended solids values were paired with relatively low turbidity results. This can occur if heavy particles increase the total suspended solids concentration but settle too quickly to be measured by the turbidimeter. It can also represent field variability between duplicate samples, as well as sampling and analytical error.

[2]Least squares regression, p-value <0.05; TSS outlier omitted.
[3]Pearson's r correlation, p-value <0.05.

Total Nitrogen and Total Phosphorus

Total nitrogen and total phosphorus concentrations at the fixed sites followed patterns similar to total suspended solids and turbidity, with higher concentrations in Beaver Creek and lower Austin Creek compared to upper Austin Creek (Figures 17 and 18, pages 24 and 25). Nitrogen concentrations decreased significantly during the day in lower Austin Creek and Beaver Creek, but not upper Austin Creek. Phosphorus concentrations decreased significantly during the day in Beaver Creek and *upper* Austin Creek, but not in lower Austin Creek.

The highest nitrogen concentration was measured at Site 72, which was collected from a small tributary flowing into lower Austin Creek (Figure 19, page 26). The lowest nitrogen concentrations were from Site 79, a pipe flowing into Beaver Creek, and Site 5, the outflow from Lake Louise. In general, samples collected in the main channels of Austin or Beaver Creeks were fairly similar to their fixed site references (Figure 20, page 27).

The total phosphorus patterns for the creek walk samples were not as predictable as other parameters (Figures 21 and 22, pages 28 and 29). Phosphorus was low in both samples from upper Austin Creek (Sites 89 and 92), and in one of the tributaries to Beaver Creek (Site 78), but not at Site 80. The sample collected at the Lake Louise outlet (Site 5) had a low phosphorus concentration, but the sample immediately downstream in Austin Creek (Site 4) had the highest concentration of all samples collected. Nevertheless, the Beaver Creek total phosphorus concentrations were related to location in the watershed (Figure 23, page 30), which is likely due to the relationship between sediments and phosphorus.

Not surprisingly, the total phosphorus and total nitrogen concentrations were correlated to total suspended solids and turbidity concentrations (Figures 25 and 24, pages 32 and 31). The nutrient correlations with turbidity were higher than with total suspended solids, due, at least in part, to the outlier total suspended solids value. The correlation between total phosphorus and turbidity (or total suspended solids) was expected because phosphorus is often transported with particulates in storm runoff. The correlation with total nitrogen may indicate that there was an increased amount of nitrogen associated with suspended organic particles, or may have been due to leaching of soluble nitrogen compounds from the watershed during the preceeding storm events.

Coliforms

Fecal coliform counts were quite variable, but followed the same general pattern as the other parameters (Figures 26–28, pages 33–35). All counts from the fixed sites were $\leq$20 cfu/100 mL, and the fixed sites on Beaver Creek and lower Austin Creek had higher counts than upper Austin Creek. The highest counts were measured in tributaries to lower Austin Creek (Sites 5 and 72) and in the mixing zone downstream from Lake Louise (Site 4). Site 1 also had a fairly high count. This site was located near the mouth of Austin Creek and is easily accessible to waterfowl and dogs. The relatively low counts in the main channel of lower Austin Creek is consistent with historic data from the Lake Whatcom monitoring project that indicate that Austin Creek coliform counts are lower in the winter than in the summer.

Quality Control

Separate field duplicates were collected and analyzed for fecal coliforms[4], total nitrogen, total phosphorus, total suspended solids, and turbidity. In addition, approximately 10% of the YSI dissolved oxygen results were verified against paired Winkler dissolved oxygen samples. The median absolute difference between field duplicates indicated good replication (Figure 29, page 36).

Additional quality control data were collected as part of the on-going Lake Whatcom monitoring project. These additional results, along with detailed methods descriptions, will be included in the 2006 Final Report.

[4]Data provided by the City of Bellingham

ID	Creek	Sampling Location
89	Upper Austin Creek	Right fork above Y and downstream from end of Tumbling Water Ln.
92	Upper Austin Creek	Main channel at Tumbling Water Dr.
1	Lower Austin Creek	Near mouth of Austin Creek
2	Lower Austin Creek	Near barn on 9th tee
3	Lower Austin Creek	Downstream from Lake Louise input pipe
4	Lower Austin Creek	Mixing zone from Lake Louise input into Austin Creek
6	Lower Austin Creek	Upstream from Lake Louise input pipe
75	Lower Austin Creek	First bend upstream from Lake Whatcom Blvd.
5	Lower Austin Creek tributary	Outflow pipe from Lake Louise
71	Lower Austin Creek tributary	Tributary on right bank near Austin Creek Ln.
72	Lower Austin Creek tributary	Tributary from house on hill near Austin Creek Ct. N
73	Lower Austin Creek tributary	Storm water drain from Lake Whatcom Blvd.
74	Lower Austin Creek tributary	Tributary on left bank near Austin Creek Ln.
77	Beaver Creek	Downstream side of culvert over Creekside Ln east bridge
80	Beaver Creek	Beaver Creek fork across from camp ground gate by large cedar
84	Beaver Creek	Downstream from bridge at Polo Park Dr/Western Ct South
85	Beaver Creek	Upstream from bridge at Polo Park Dr. and Lost Lake Ln.
88	Beaver Creek	Upstream from bridge at fork on Western Ln.
91	Beaver Creek	Bridge to Area Z on south leg of Strawberry Ct.
93	Beaver Creek	Downstream from bridge over Polo Park Dr.
96	Beaver Creek	Upstream from bridge over Beaver Ct.
79	Beaver Creek tributary	Pipe upstream from Polo Park bridge (upstream from 93)
78	Beaver Creek tributary	Tributary upstream from Gate 13 on Lake Louise Rd.
86	Beaver Creek tributary	Tributary across Lake Louise Rd. between bridge and road
†	Upper Austin Creek	Fixed site upstream from confluence with Beaver Creek (upper Austin Creek fixed site)
†	Lower Austin Creek	Fixed site upstream from bridge over Lake Whatcom Blvd. (lower Austin Creek fixed site)
†	Beaver Creek	Fixed site upstream from confluence with Austin Creek

†Multiple sample IDs for all fixed sites.

Table 1: Site descriptions for the creek walk and fixed site samples collected on November 20, 2004.

Date	Precip (in)	Date	Precip (in)
Nov 1	0.58	Nov 11	0.01
Nov 2	0.69	Nov 12	0.01
Nov 3	0.02	Nov 13	0.04
Nov 4	0.01	Nov 14	0.21
Nov 5	0.00	Nov 15	0.55
Nov 6	0.80	Nov 16	0.22
Nov 7	0.04	Nov 17	0.04
Nov 8	0.01	Nov 18	1.12
Nov 9	0.00	Nov 19	0.02
Nov 10	0.00	Nov 20	0.01

Table 2: Precipitation at the Smith Creek weather station, November 1–20, 2004.

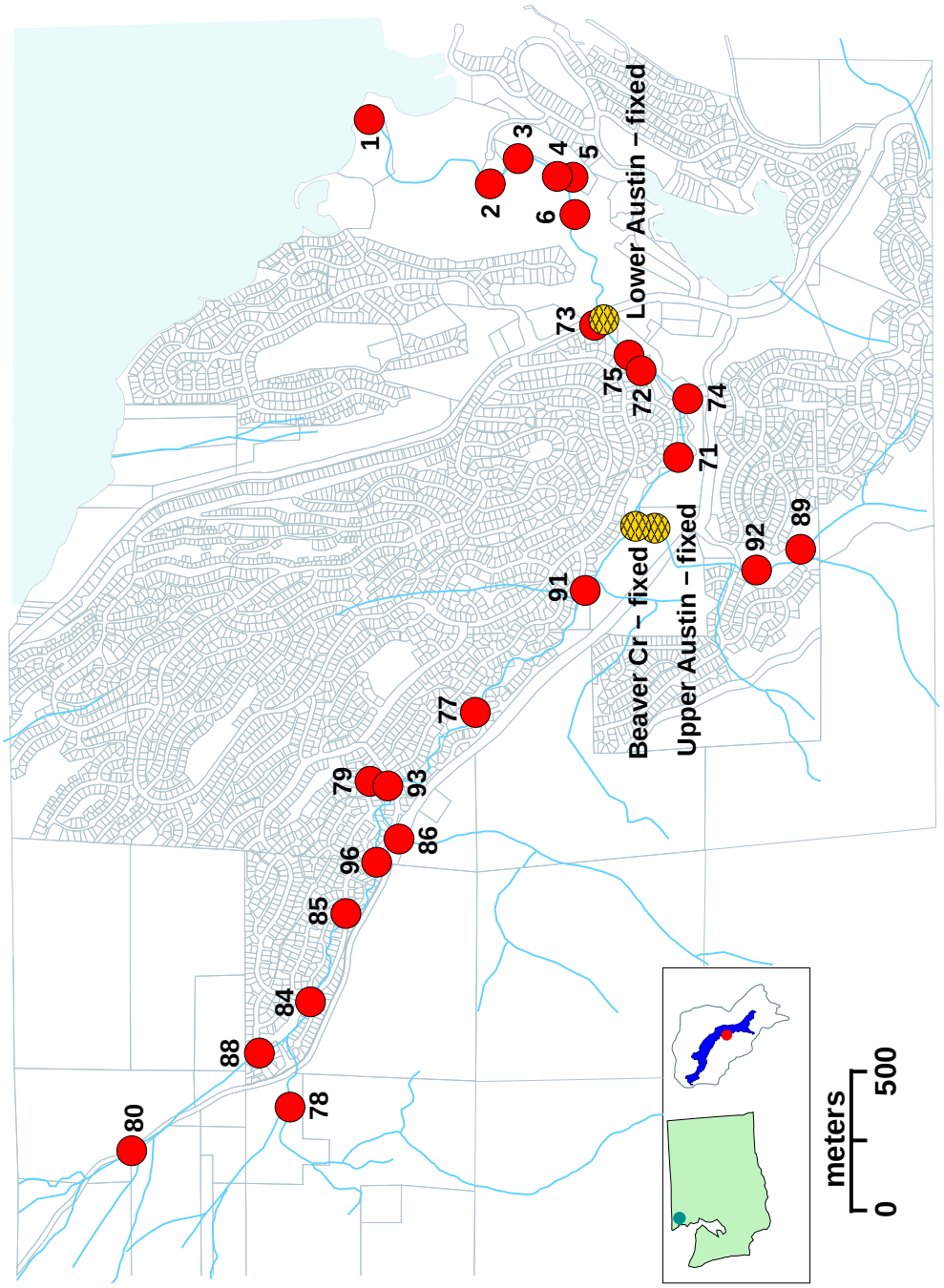


Figure 1: Sampling sites in the Austin Creek and Beaver Creek watersheds, November 20, 2004. Figure modified from source map created by Gerry Gabrisch, Oct 3, 2005. Data: Western Washington University, Skagit County GIS, Nooksack Tribe, and the City of Bellingham. Datum and Projection: NAD83 UTM 10 N.

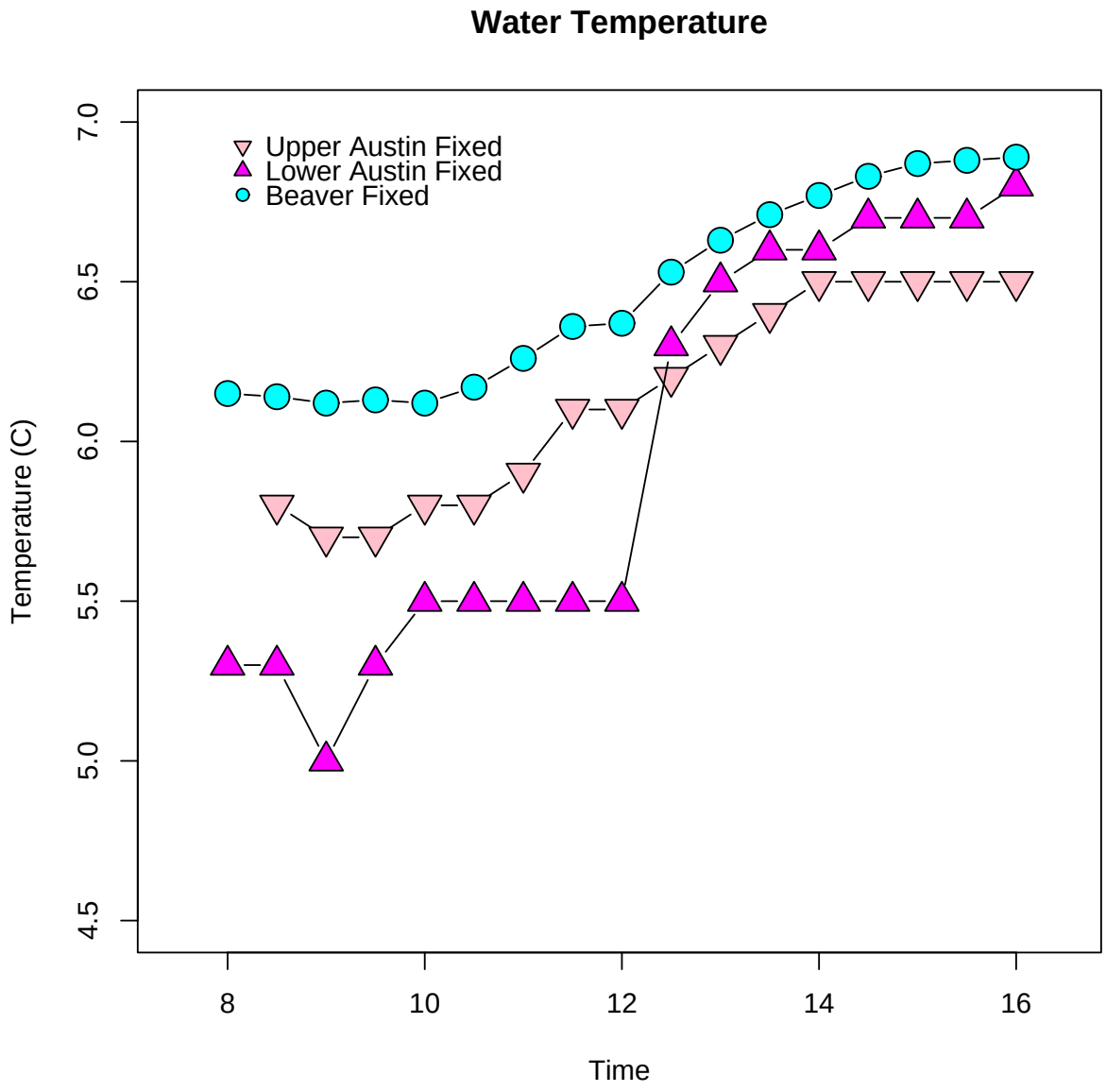


Figure 2: Water temperature results from the fixed sites on Austin and Beaver Creeks. The abrupt temperature change at the lower Austin Creek site was caused by changing to the YSI field meter. See Figure 3 for adjusted temperature results.

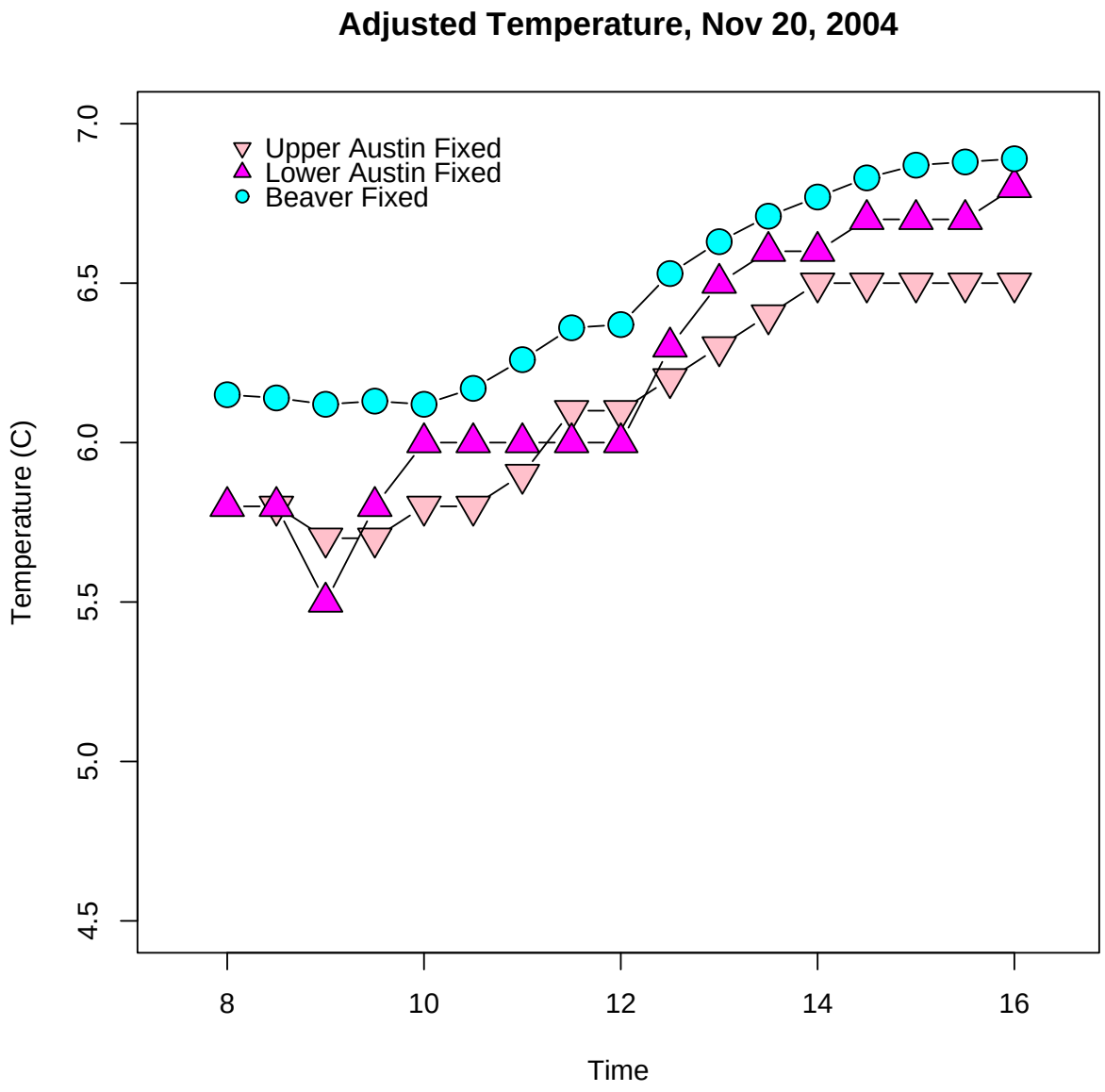


Figure 3: Adjusted water temperature results from the fixed sites on Austin and Beaver Creeks. Lower Austin Creek thermometer readings from 8:00–12:00 have been increased by 0.5° to align with YSI values collected from 12:30–16:00.

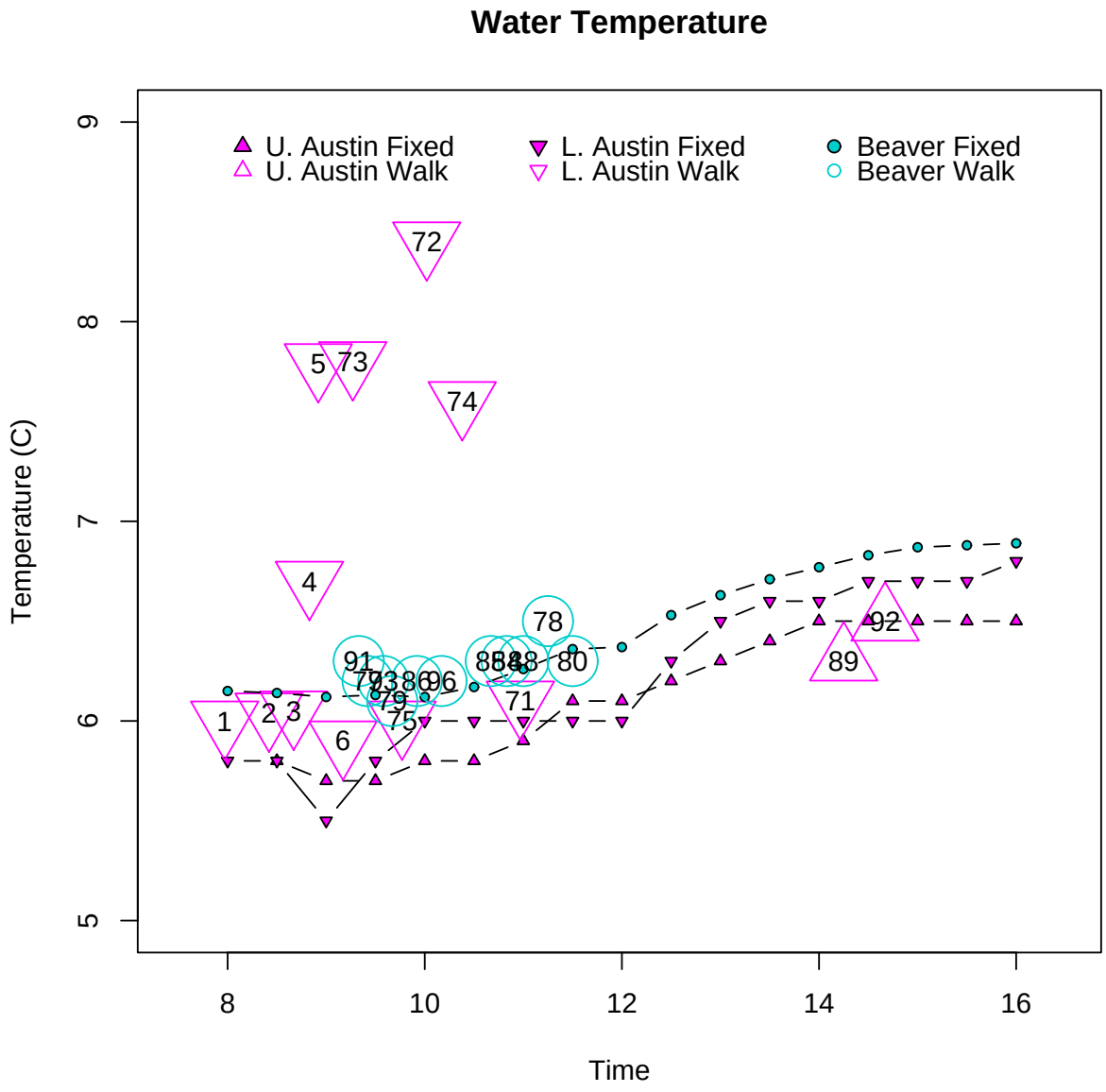


Figure 4: Water temperature results from all sites sampled in Austin and Beaver Creeks. Sample identification numbers have been added to show site locations. Lower Austin Creek fixed site temperatures are adjusted as described in the text.

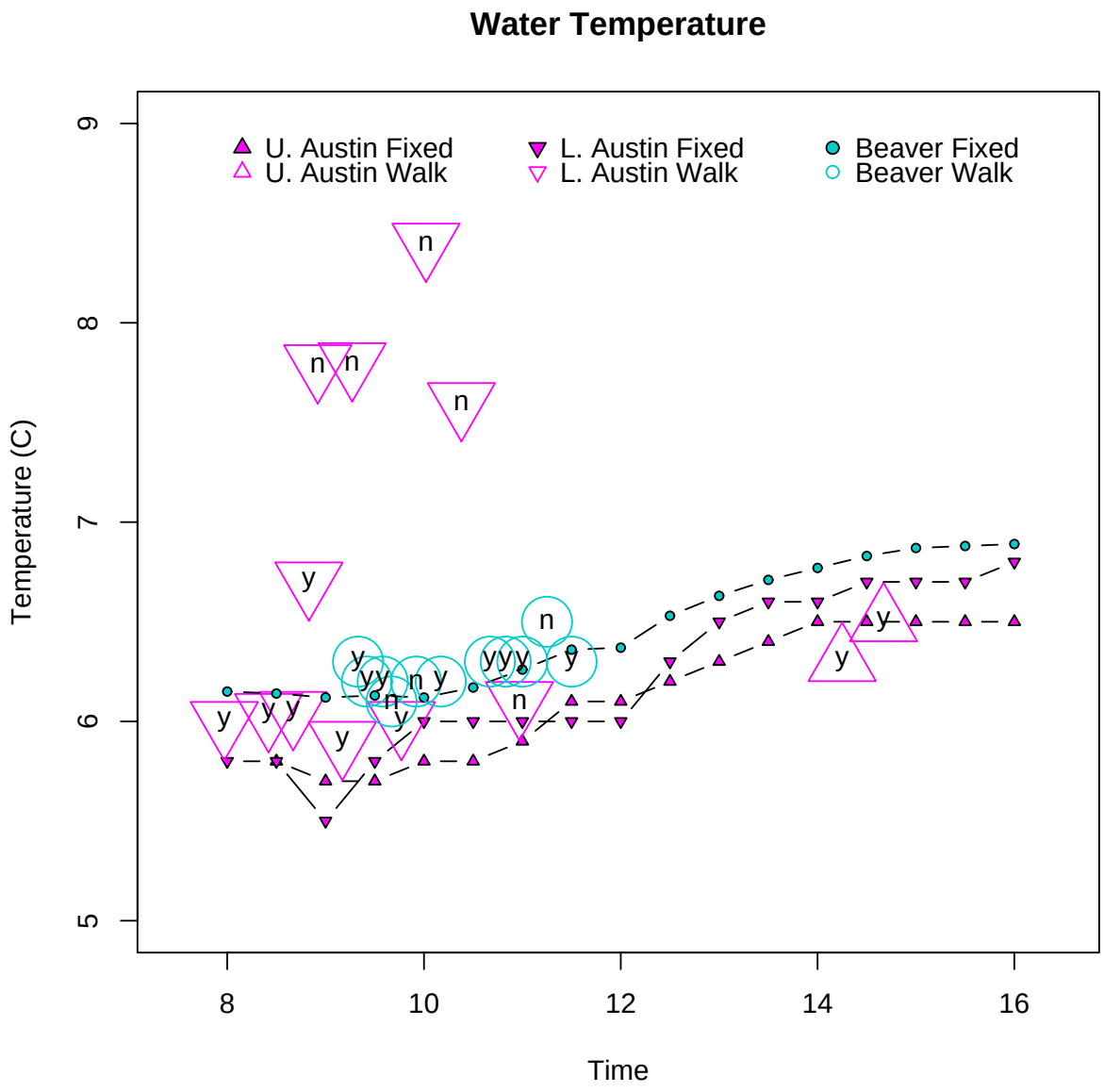


Figure 5: Water temperature results from all sites sampled in Austin and Beaver Creeks. Samples indicate whether they were collected in the main channels of Austin or Beaver Creeks (y) or from small inlet pipes or tributaries (n). Lower Austin Creek fixed site temperatures are adjusted as described in the text.

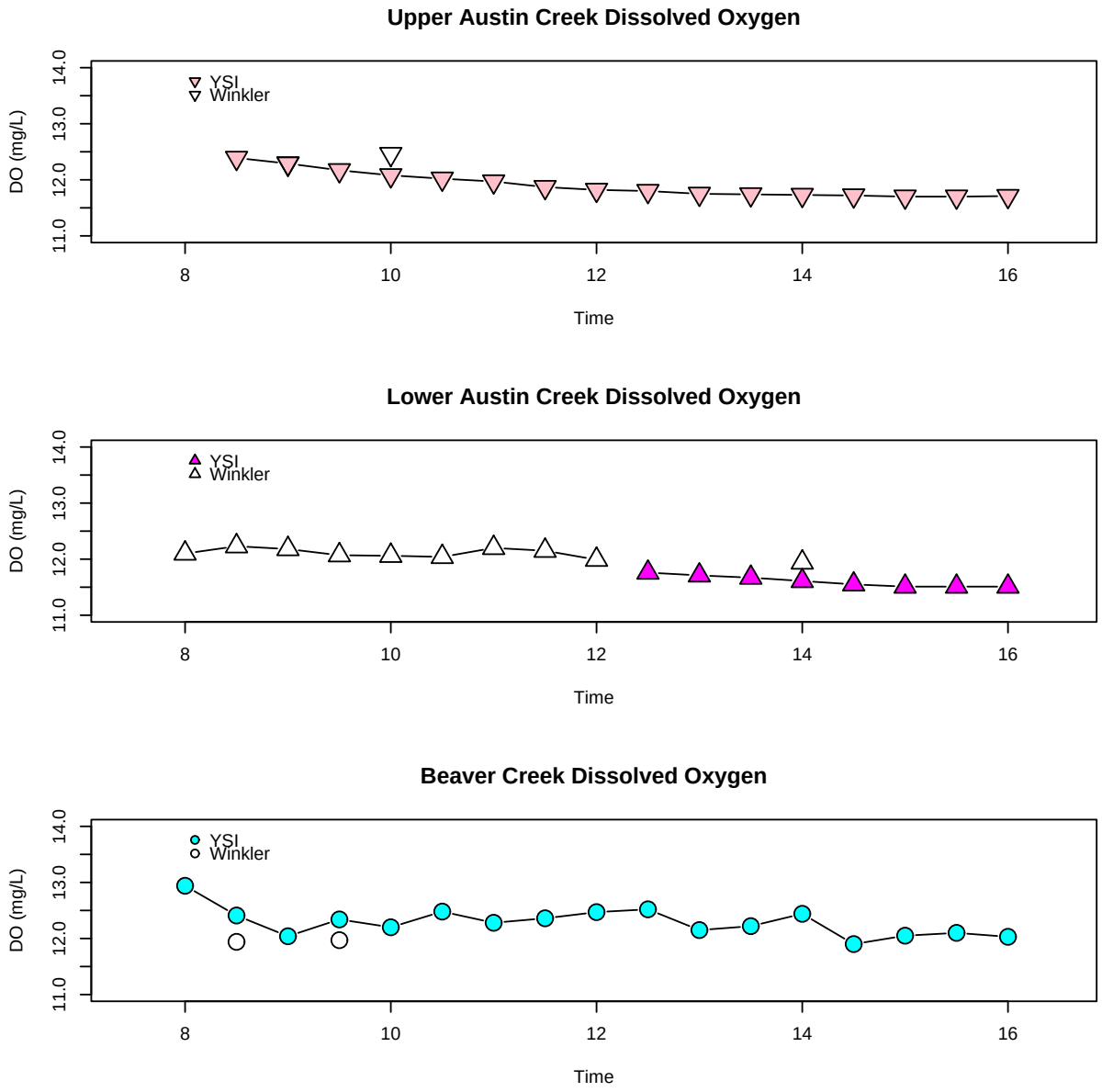


Figure 6: Dissolved oxygen results (YSI and Winkler) from the fixed sites on Austin and Beaver Creeks.

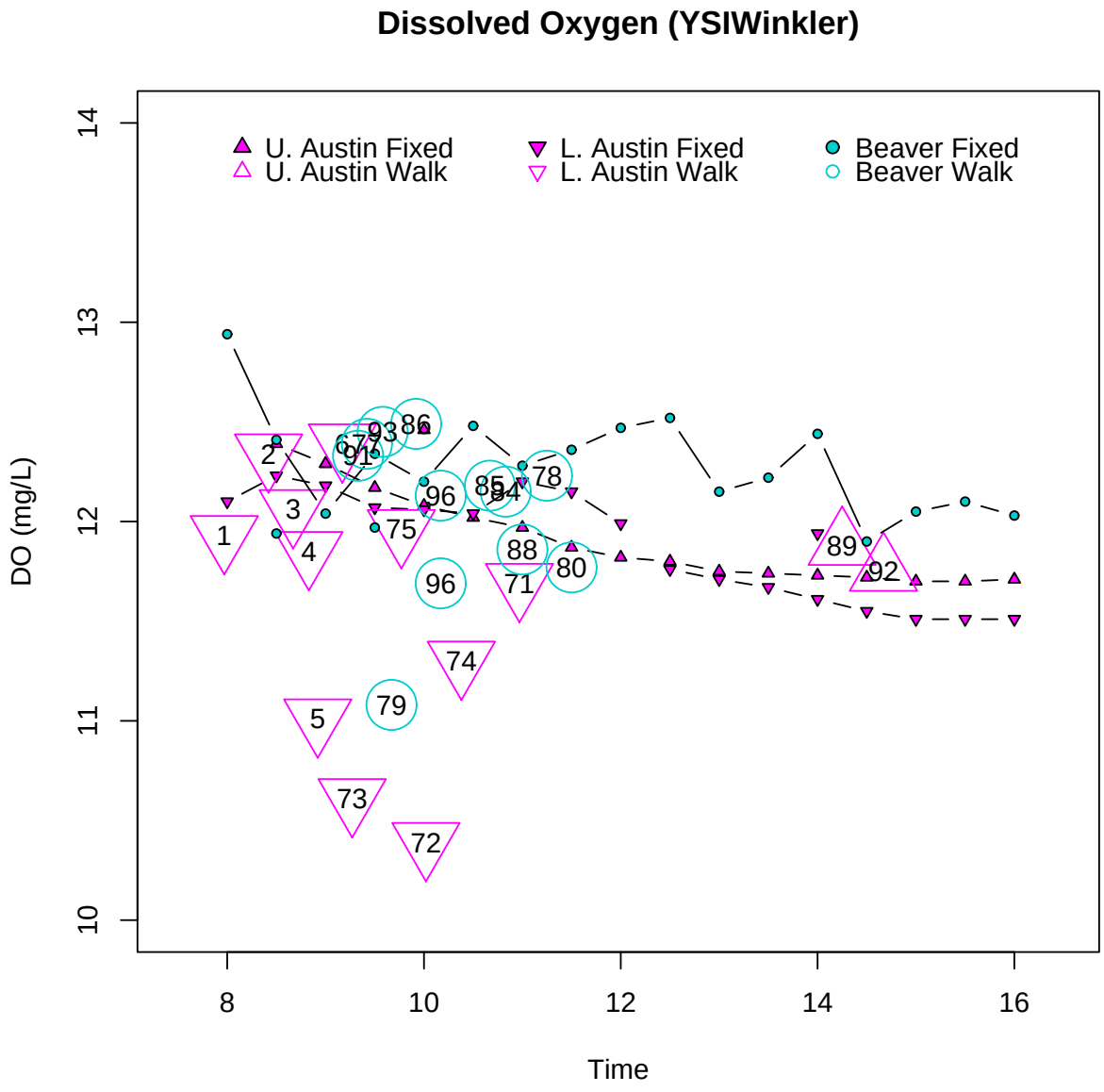


Figure 7: Dissolved oxygen results (YSI and Winkler) from all sites sampled in Austin and Beaver Creeks. Sample identification numbers have been added to show site locations.

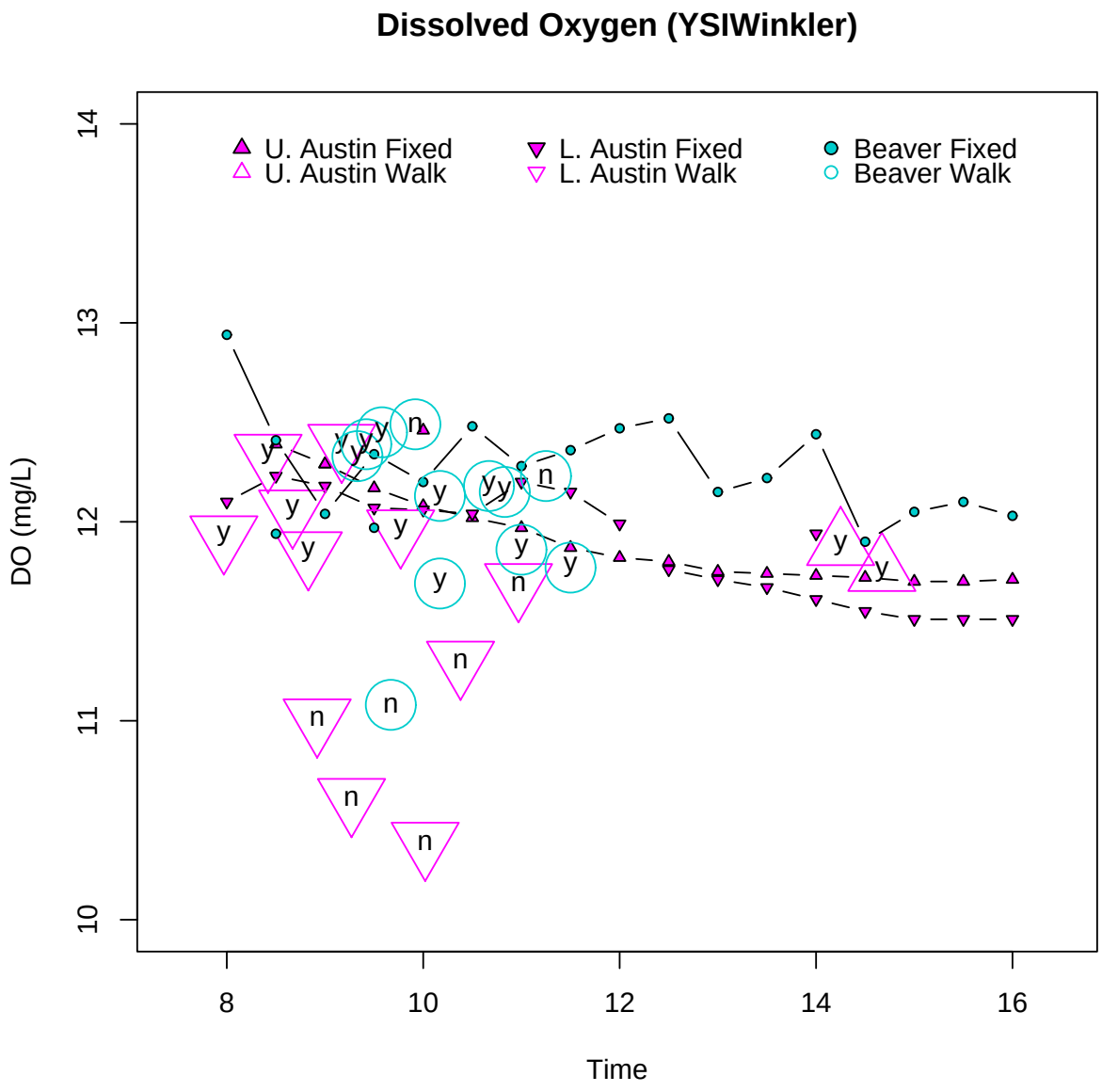


Figure 8: Dissolved oxygen results (YSI and Winkler) from all sites sampled in Austin and Beaver Creeks. Samples indicate whether they were collected in the main channels of Austin or Beaver Creeks (y) or from small inlet pipes or tributaries (n).

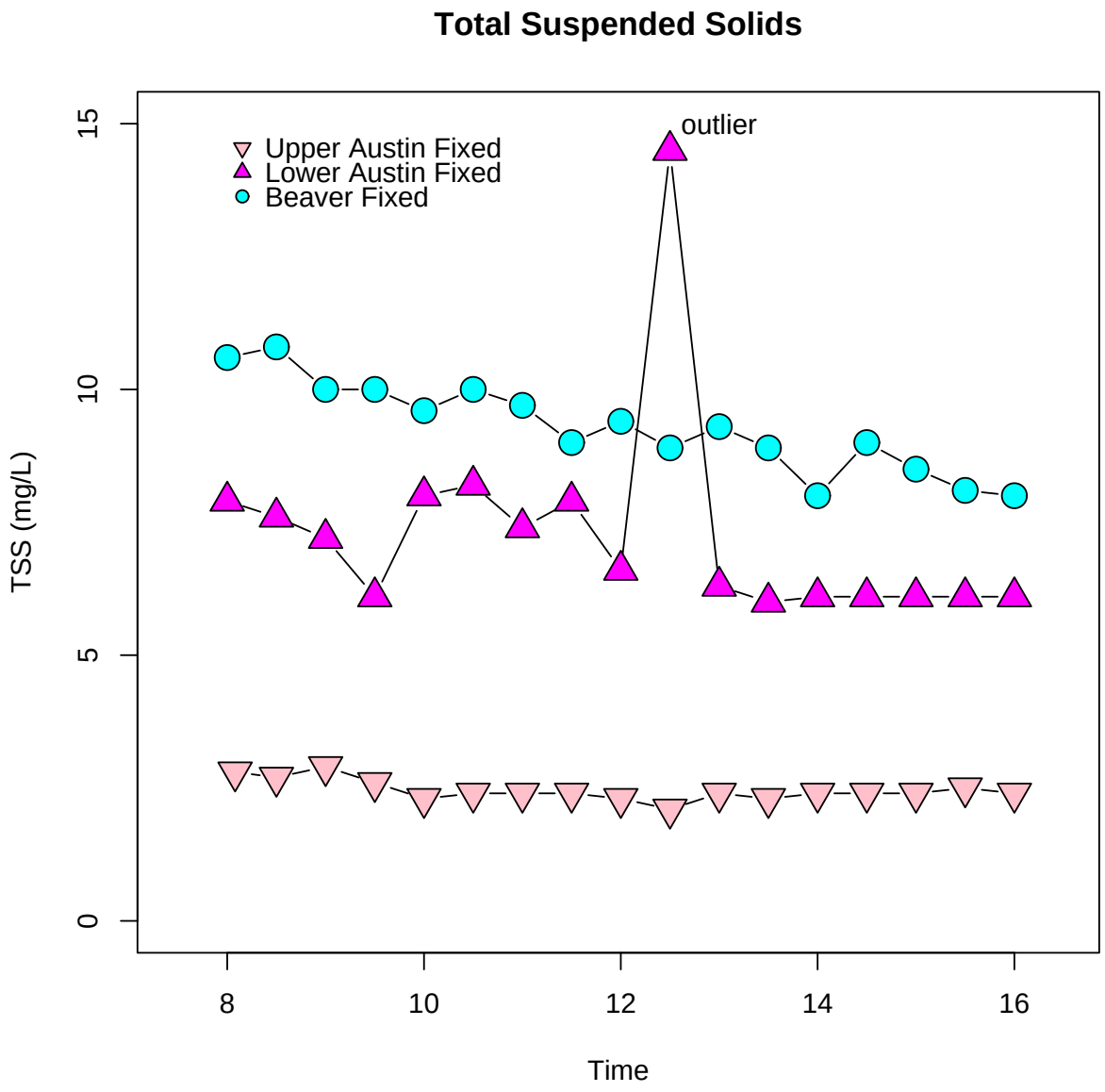


Figure 9: Total suspended solids results from the fixed sites on Austin and Beaver Creeks. The outlier from lower Austin Creek may have been caused by sampling or analytical error.

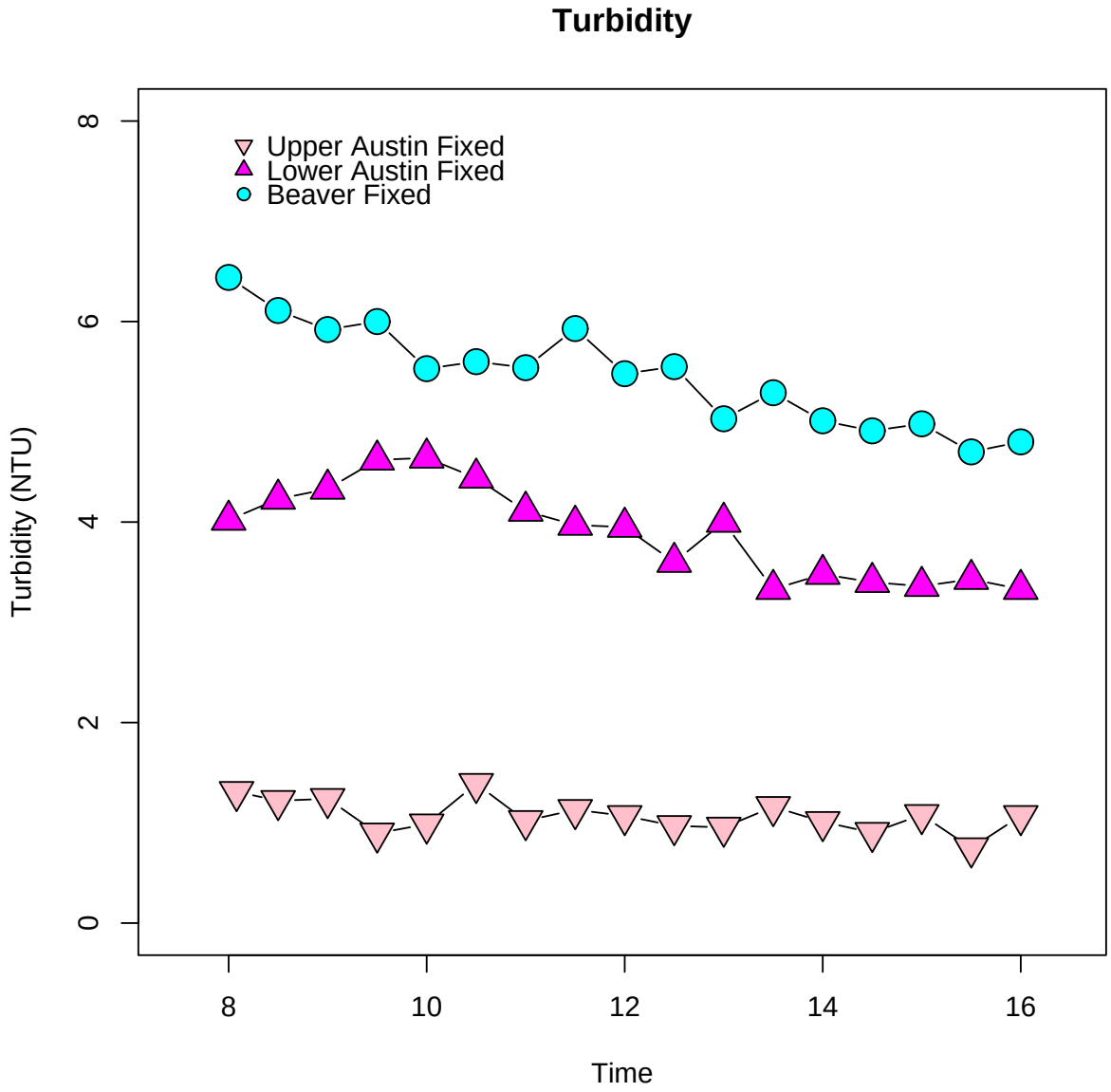


Figure 10: Turbidity results from the fixed sites on Austin and Beaver Creeks.

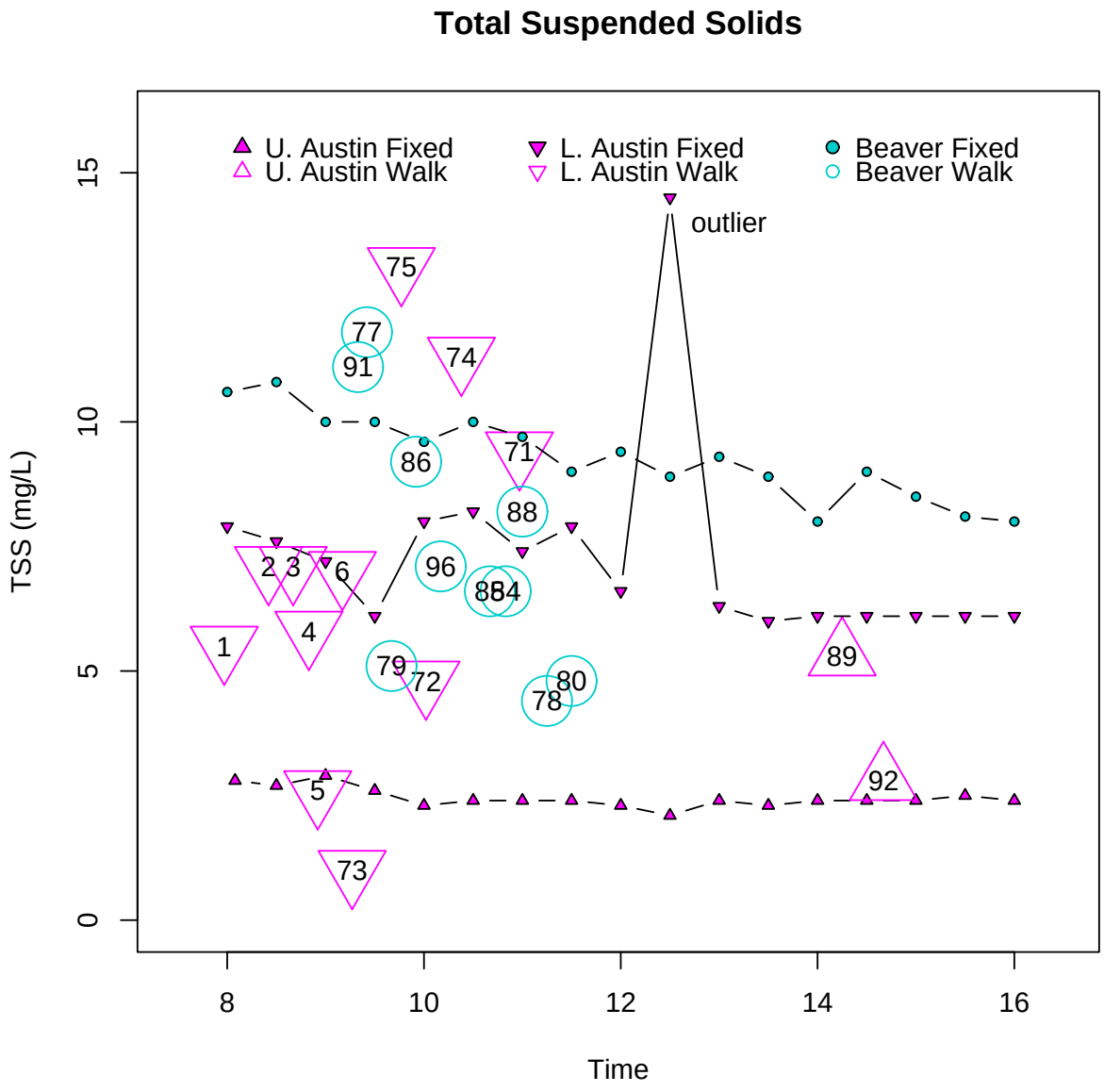


Figure 11: Total suspended solids results from all sites sampled in Austin and Beaver Creeks. Sample identification numbers have been added to show site locations.

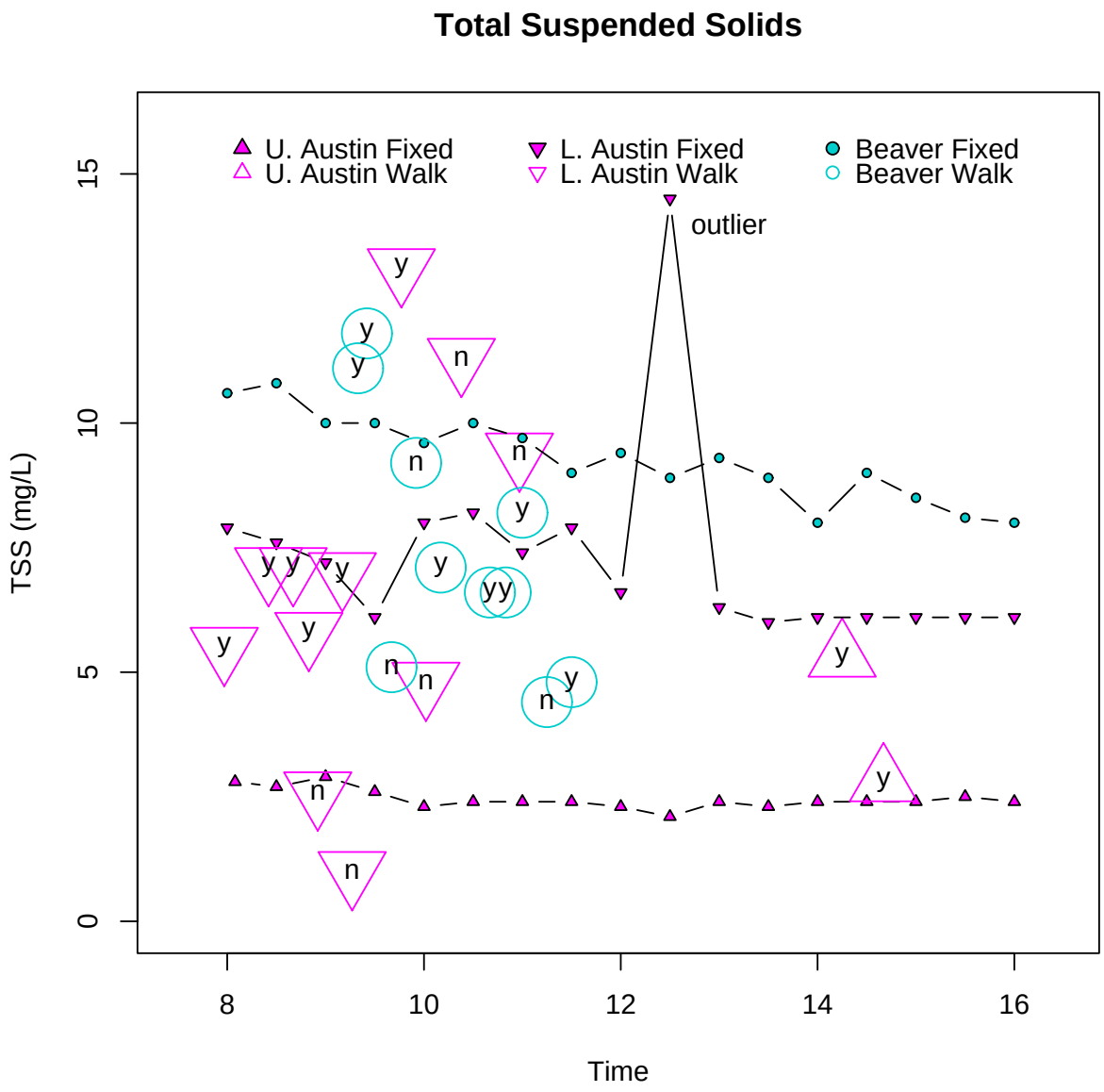


Figure 12: Total suspended solids results from all sites sampled in Austin and Beaver Creeks. Samples indicate whether they were collected in the main channels of Austin or Beaver Creeks (y) or from small inlet pipes or small tributaries (n).

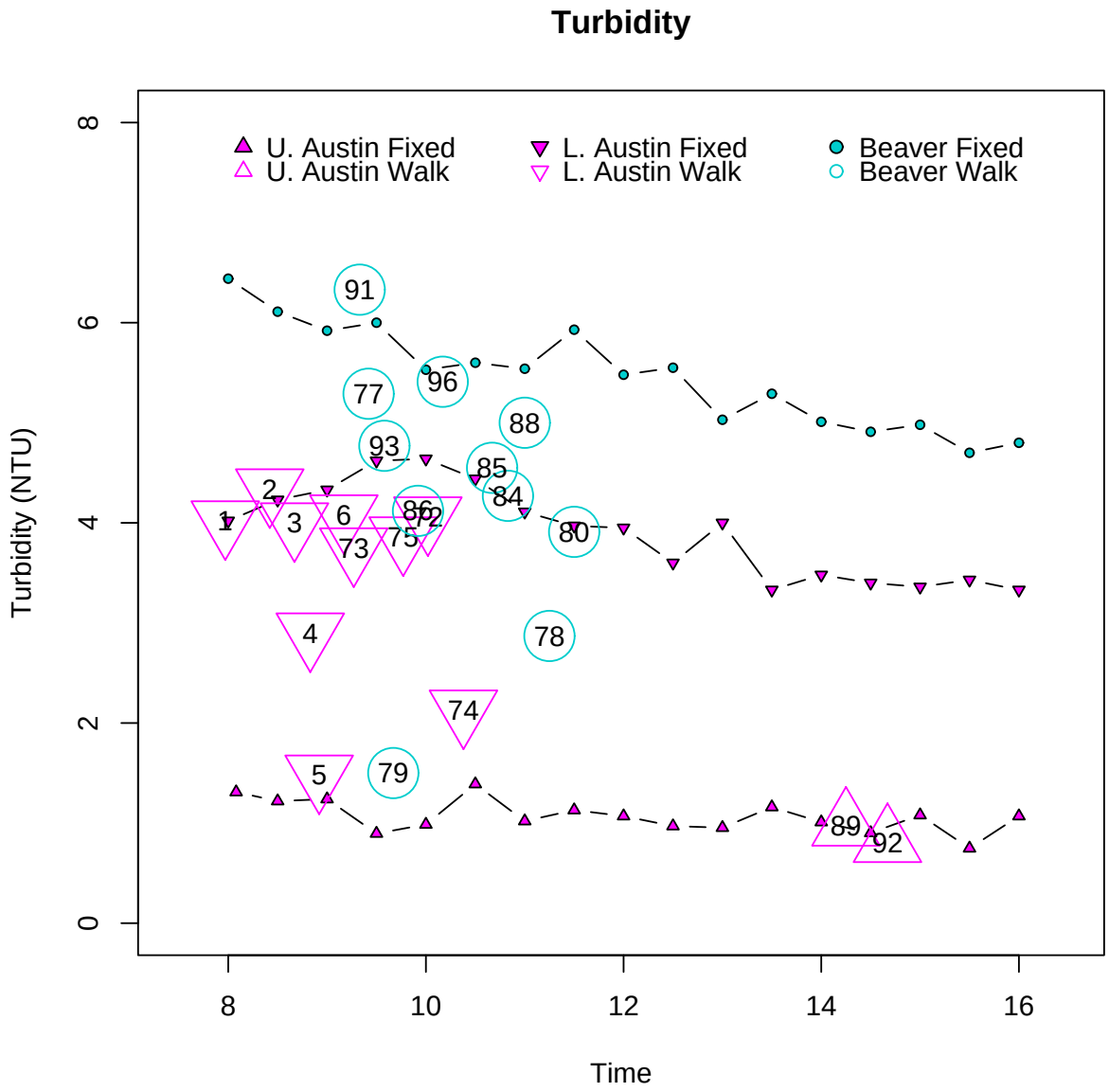


Figure 13: Turbidity results from all sites sampled in Austin and Beaver Creeks. Sample identification numbers have been added to show site locations.

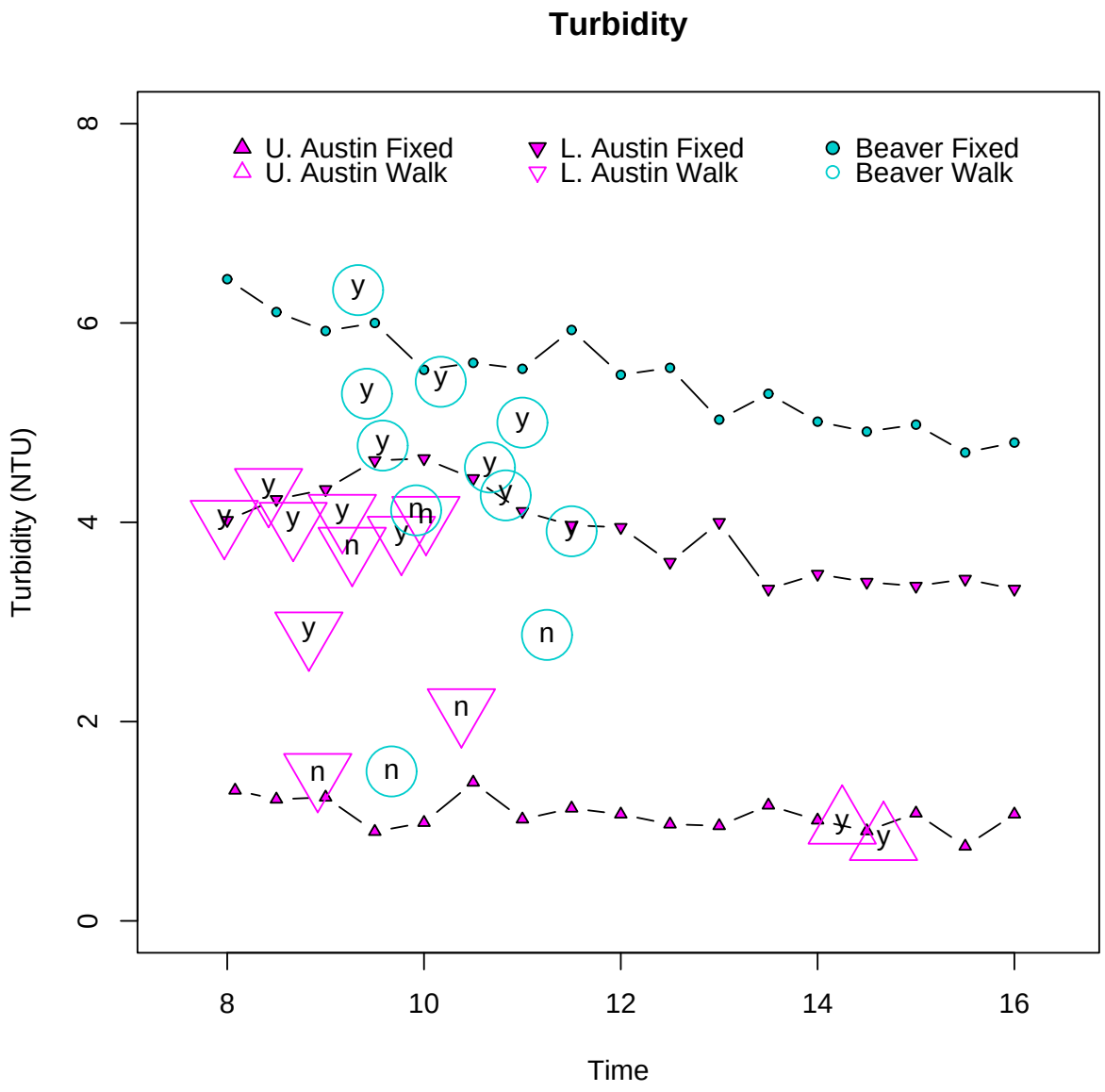


Figure 14: Turbidity results from all sites sampled in Austin and Beaver Creeks. Samples indicate whether they were collected in the main channels of Austin or Beaver Creeks (y) or from small inlet pipes or tributaries (n).

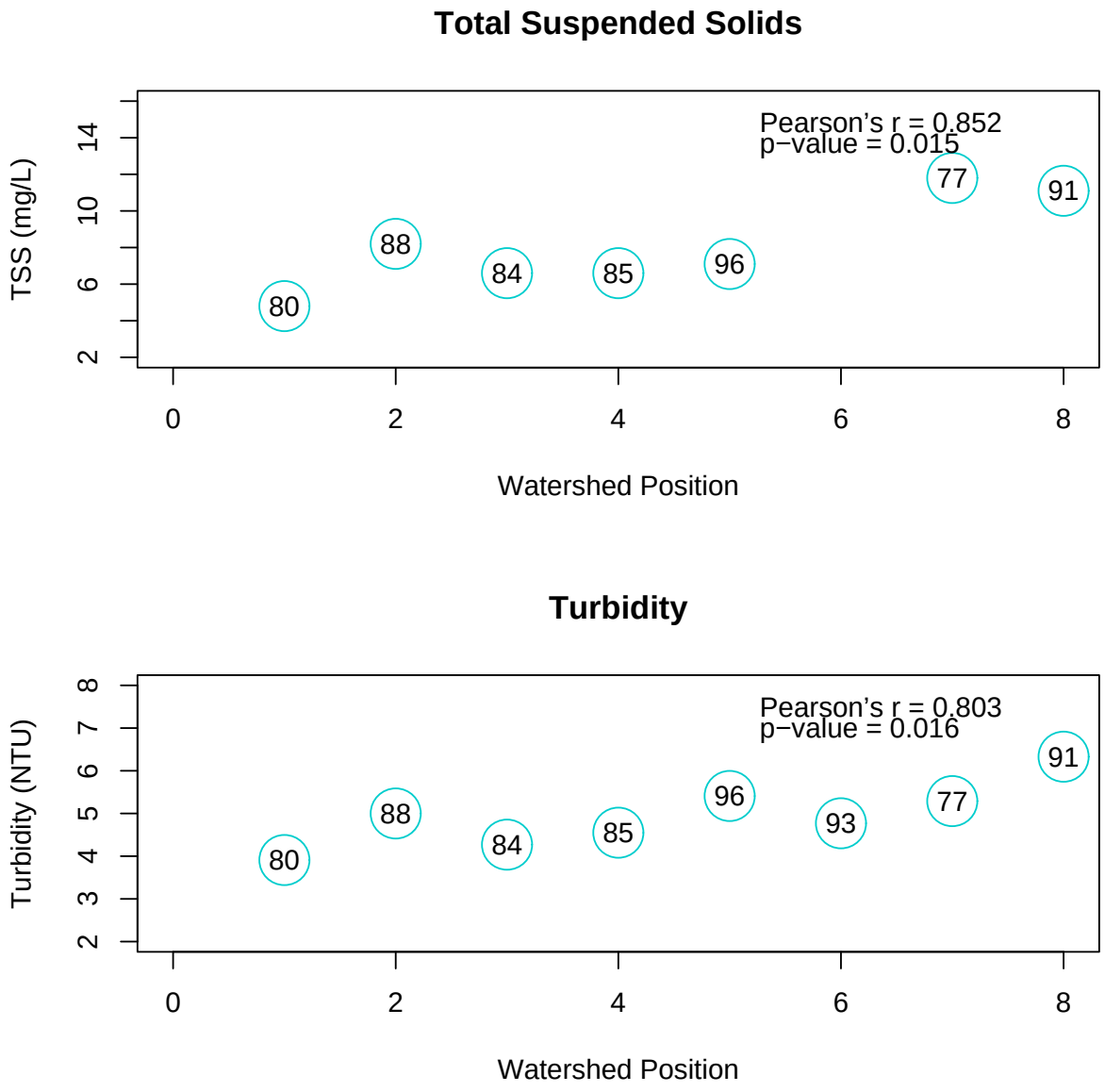


Figure 15: Relationship between total suspended solids, turbidity levels, and location in the Beaver Creek watershed. Samples were sorted by watershed position, beginning at the Sudden Valley campground, so position numbers increase near the confluence of Beaver and Austin Creeks.

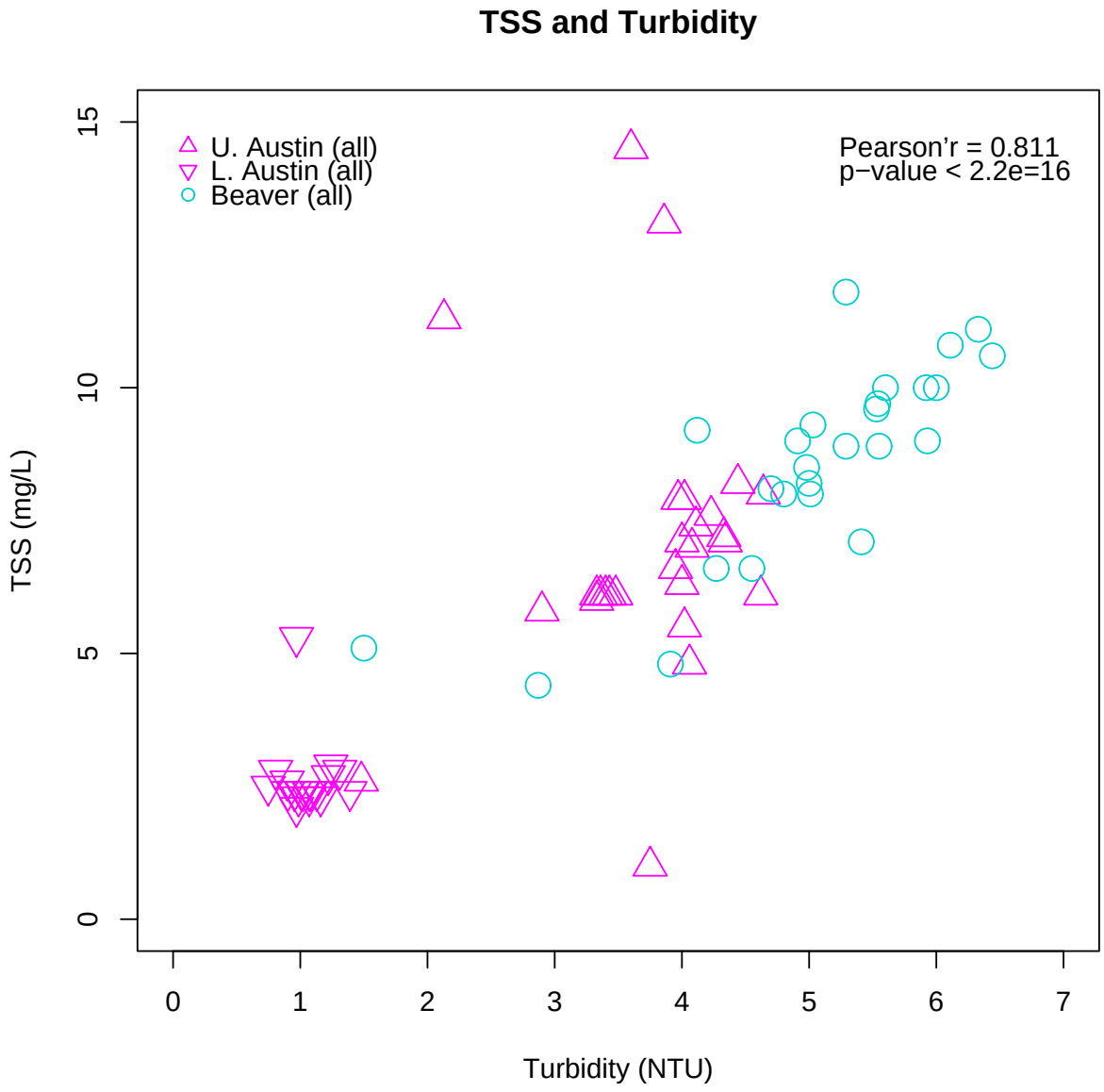


Figure 16: Relationship between total suspended solids and turbidity results from all Austin Creek and Beaver Creek samples.

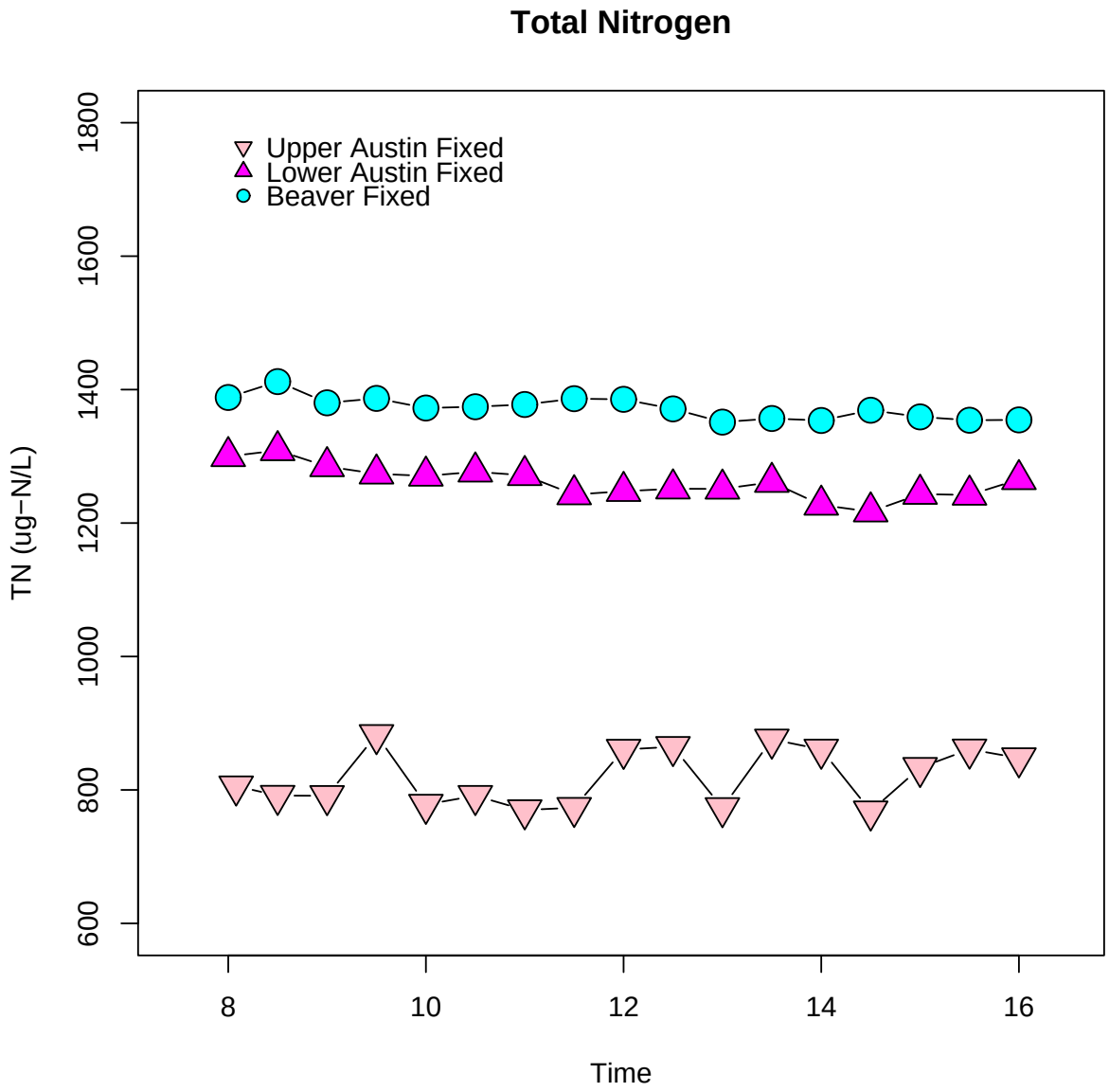


Figure 17: Total nitrogen results from the fixed sites on Austin and Beaver Creeks.

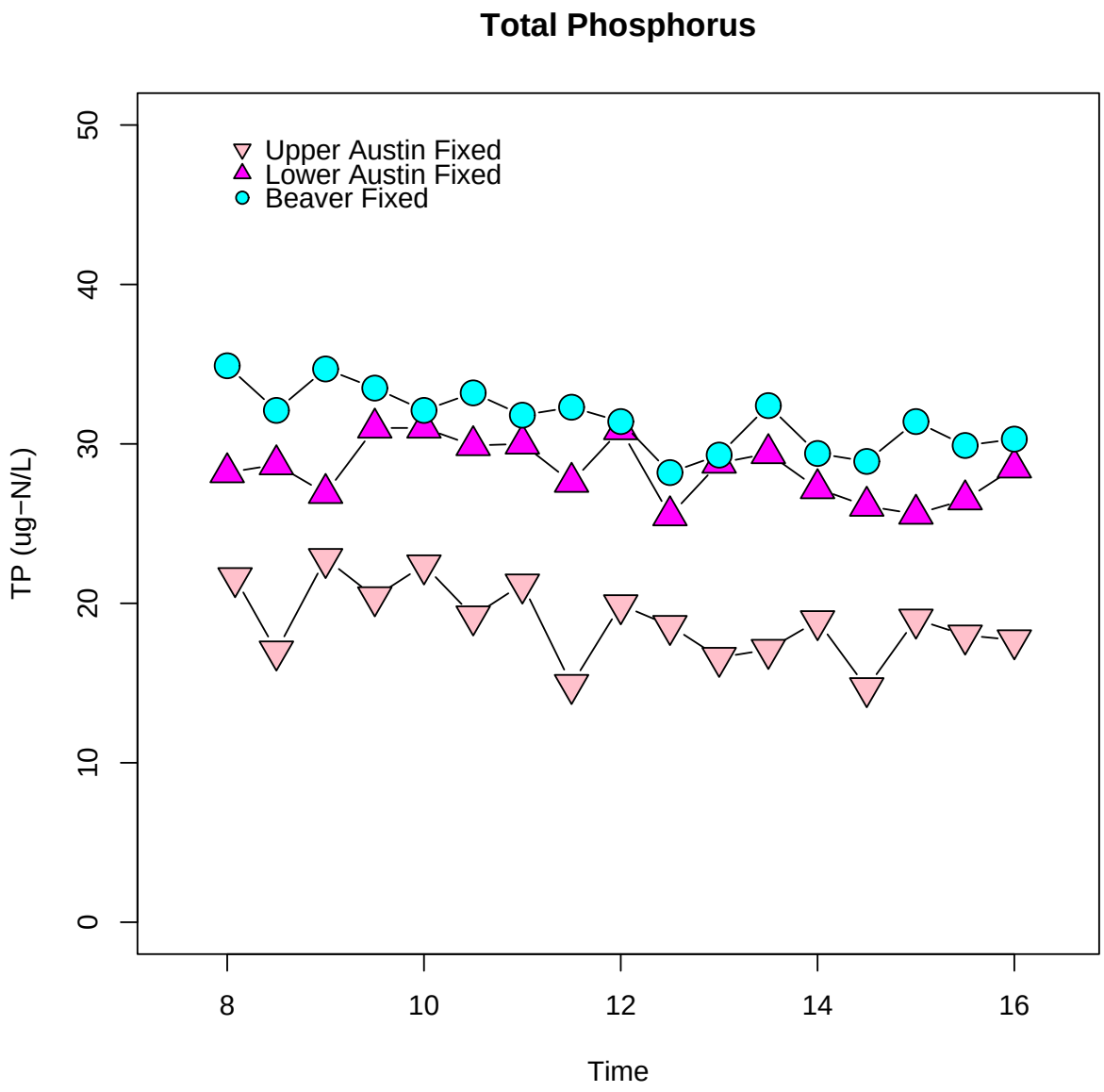


Figure 18: Total phosphorus results from the fixed sites on Austin and Beaver Creeks.

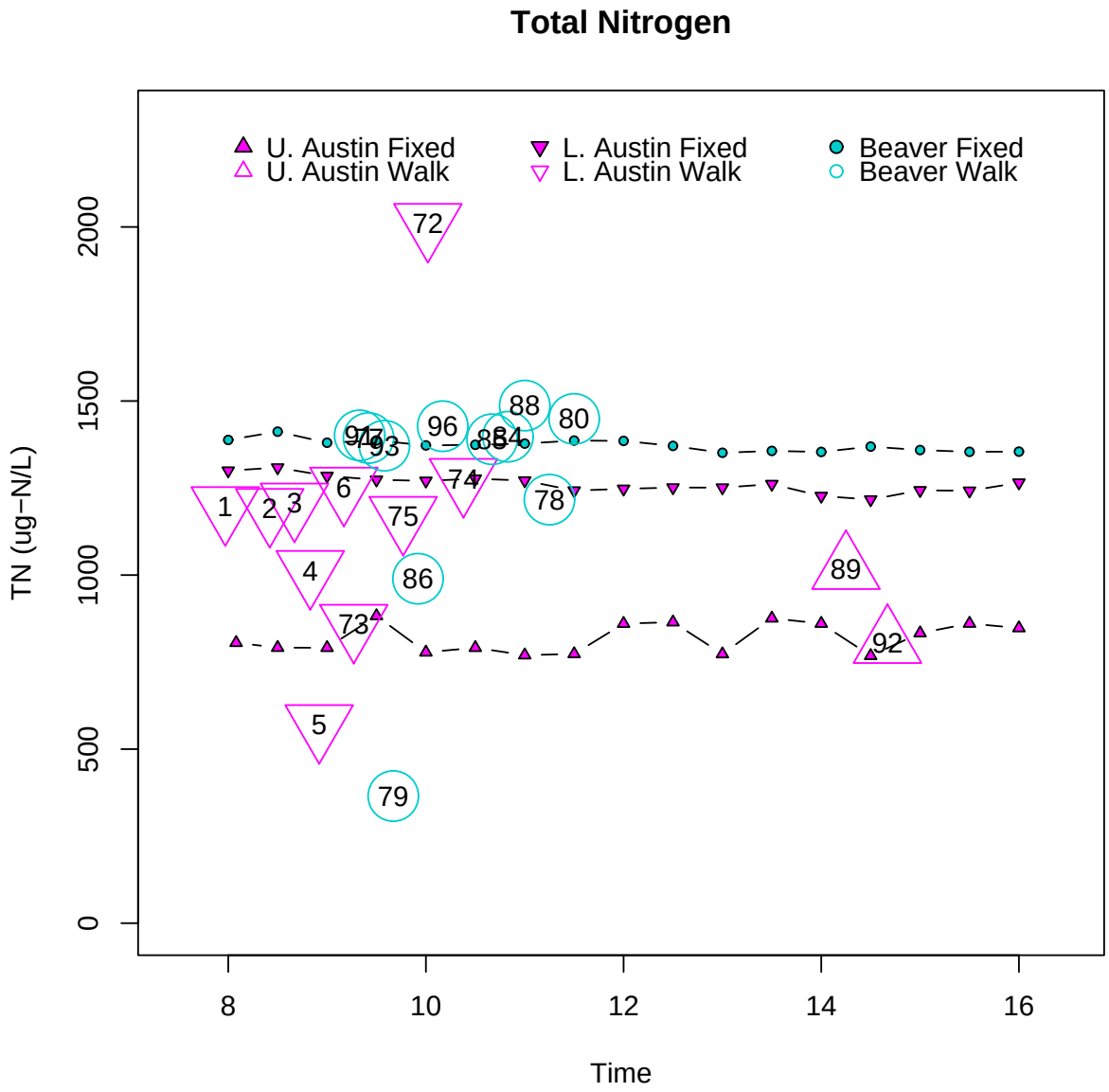


Figure 19: Total nitrogen results from all sites sampled in Austin and Beaver Creeks. Sample identification numbers have been added to show site locations.

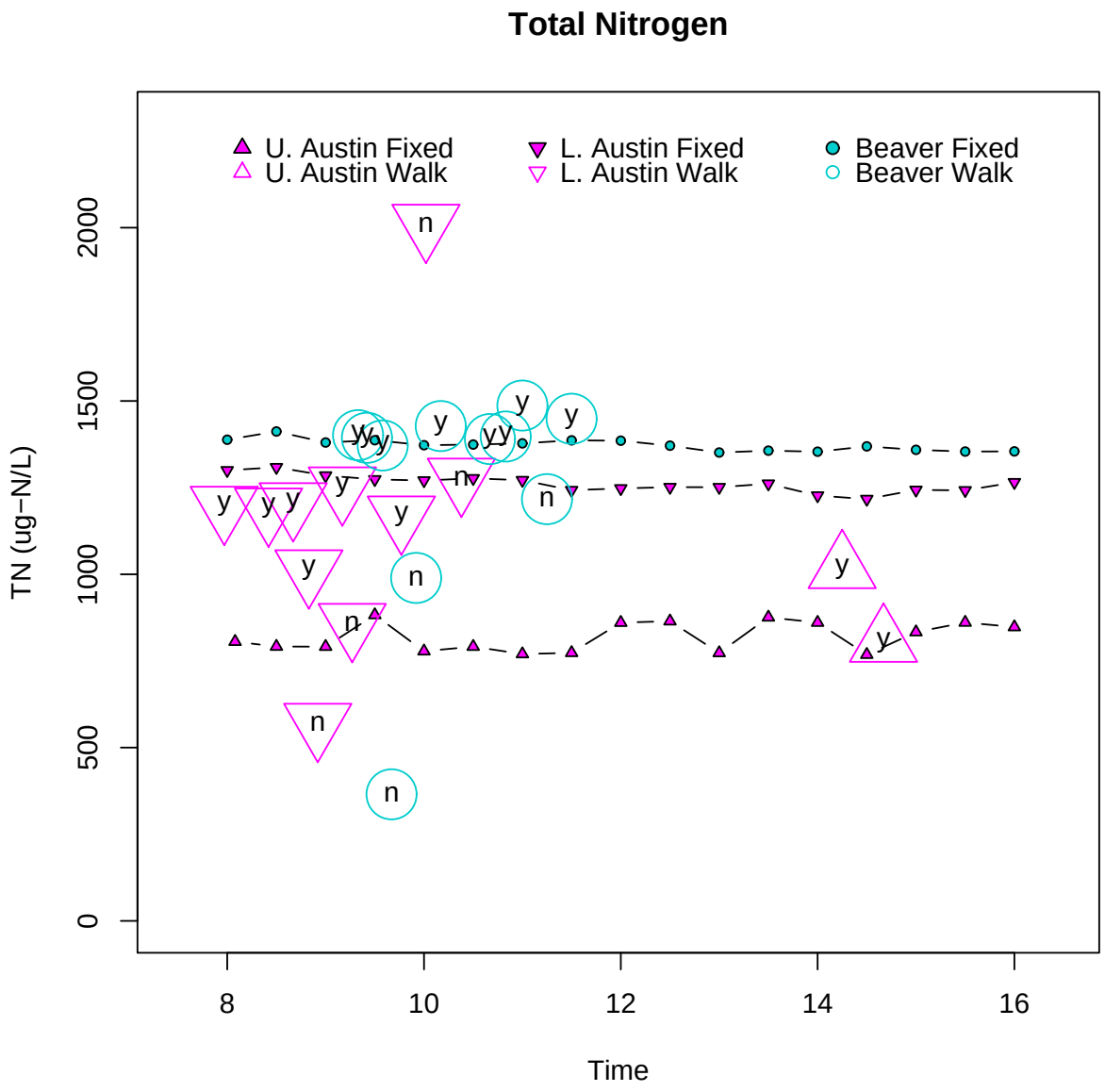


Figure 20: Total nitrogen results from all sites sampled in Austin and Beaver Creeks. Samples indicate whether they were collected in the main channels of Austin or Beaver Creeks (y) or from small inlet pipes or tributaries (n).

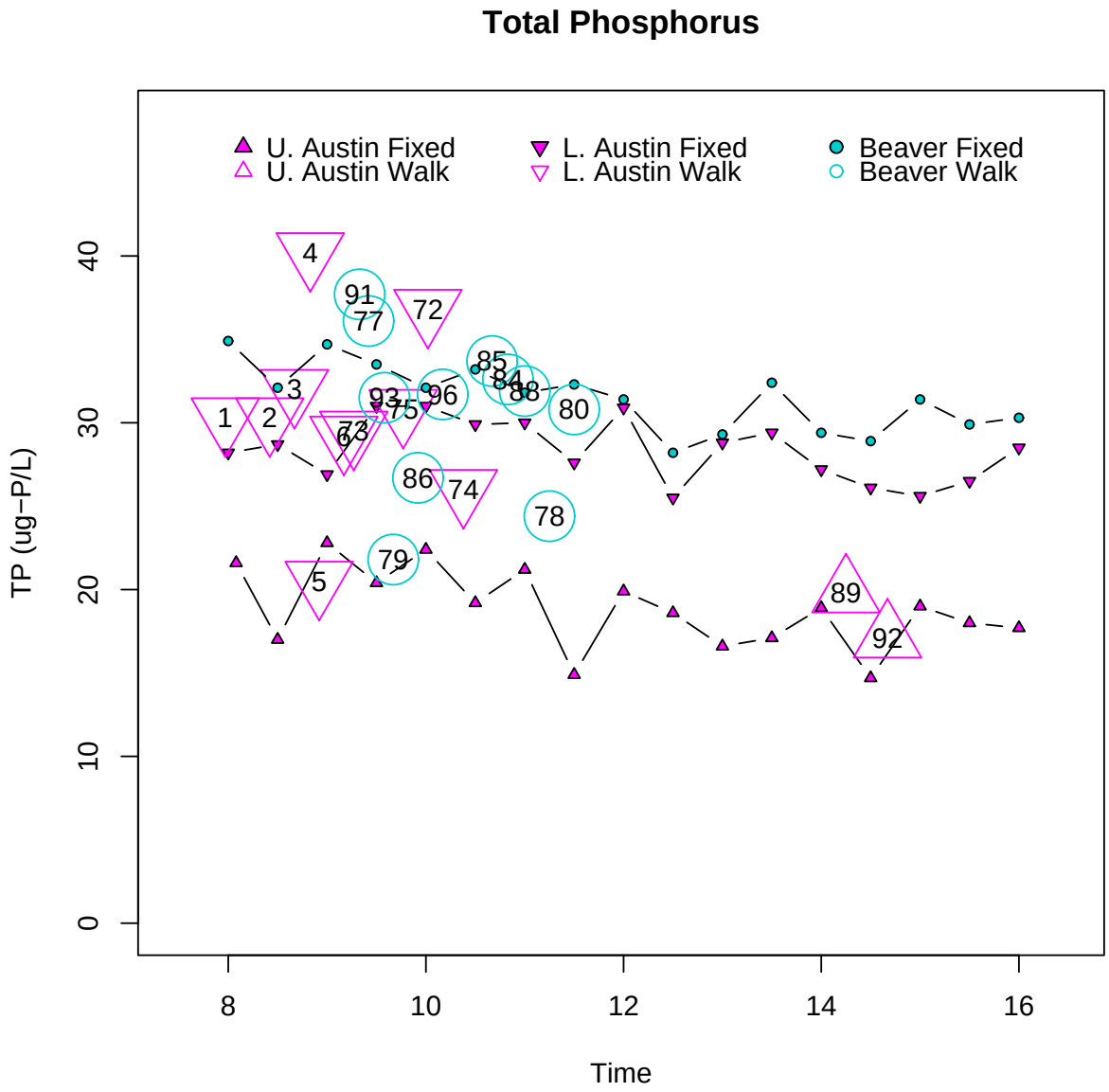


Figure 21: Total phosphorus results from all sites sampled in Austin and Beaver Creeks. Sample identification numbers have been added to show site locations.

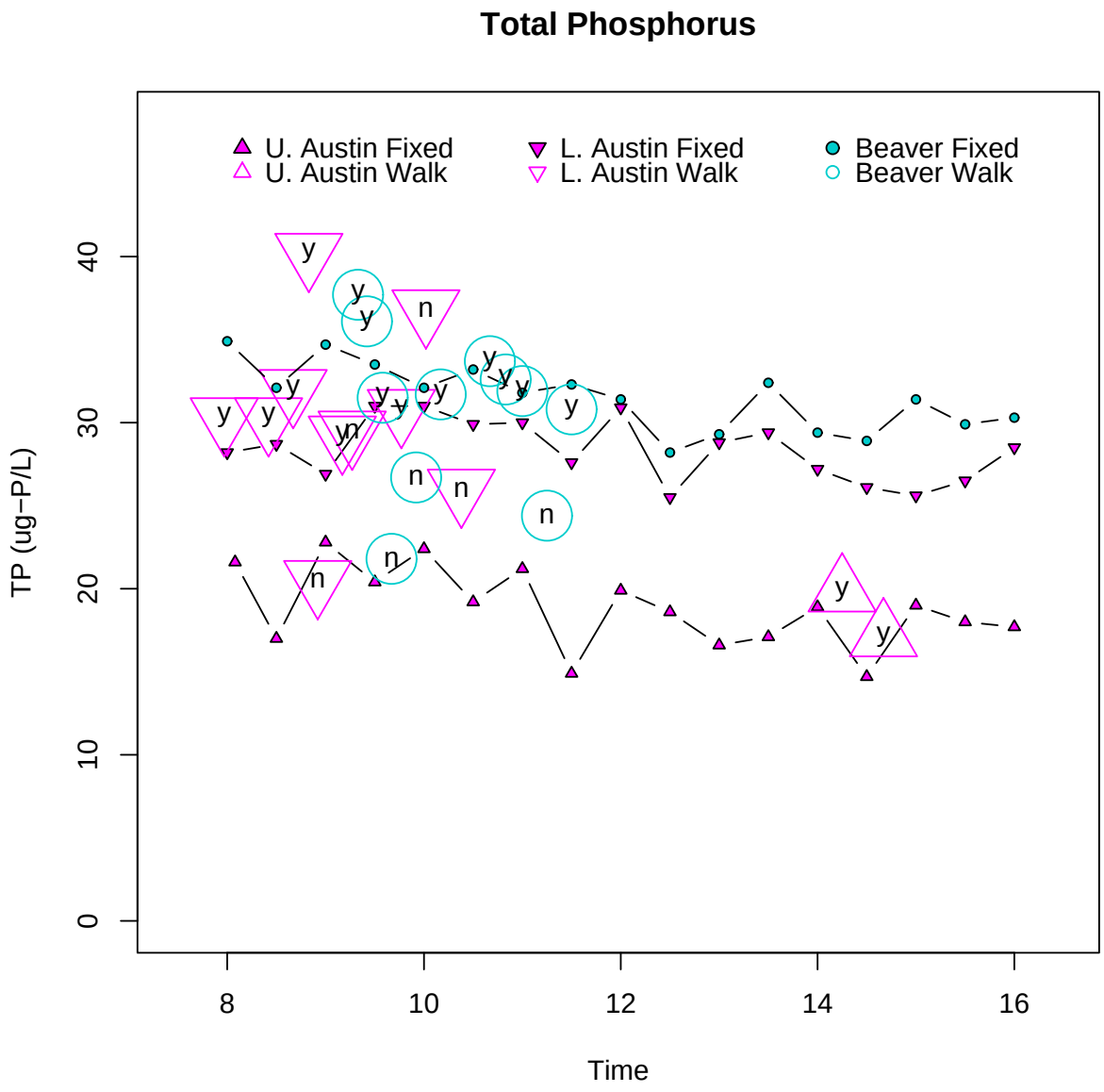
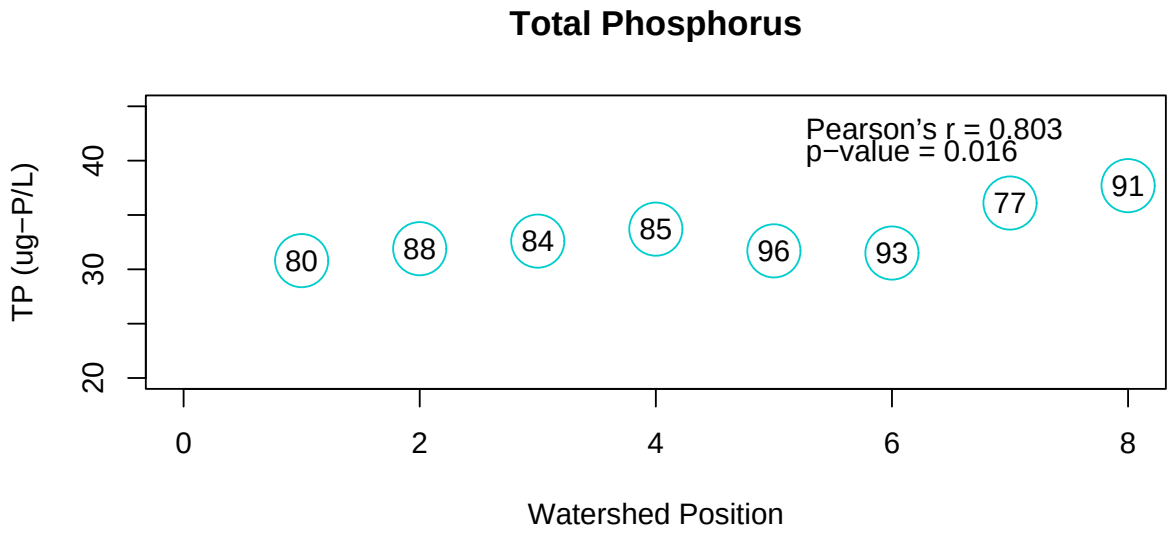


Figure 22: Total phosphorus results from all sites sampled in Austin and Beaver Creeks. Samples indicate whether they were collected in the main channels of Austin or Beaver Creeks (y) or from small inlet pipes or tributaries (n).



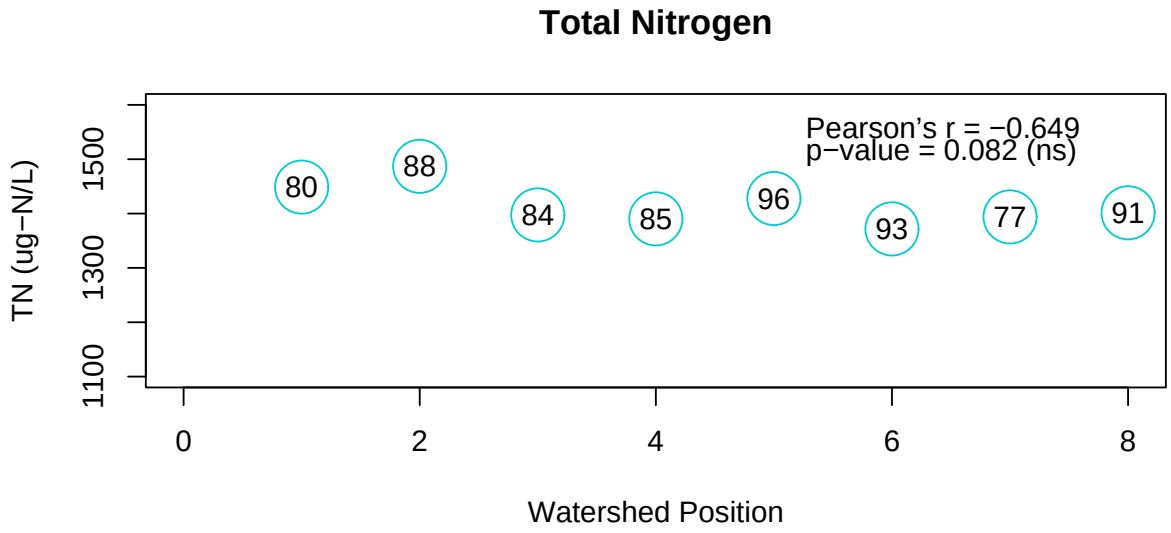


Figure 23: Relationship between total phosphorus, total nitrogen, and location in the Beaver Creek watershed. Samples were sorted by watershed order, beginning at the Sudden Valley campground, so order increases as you approach the confluence of Beaver and Austin Creeks. Only the total phosphorus relationship is stastistically significant.

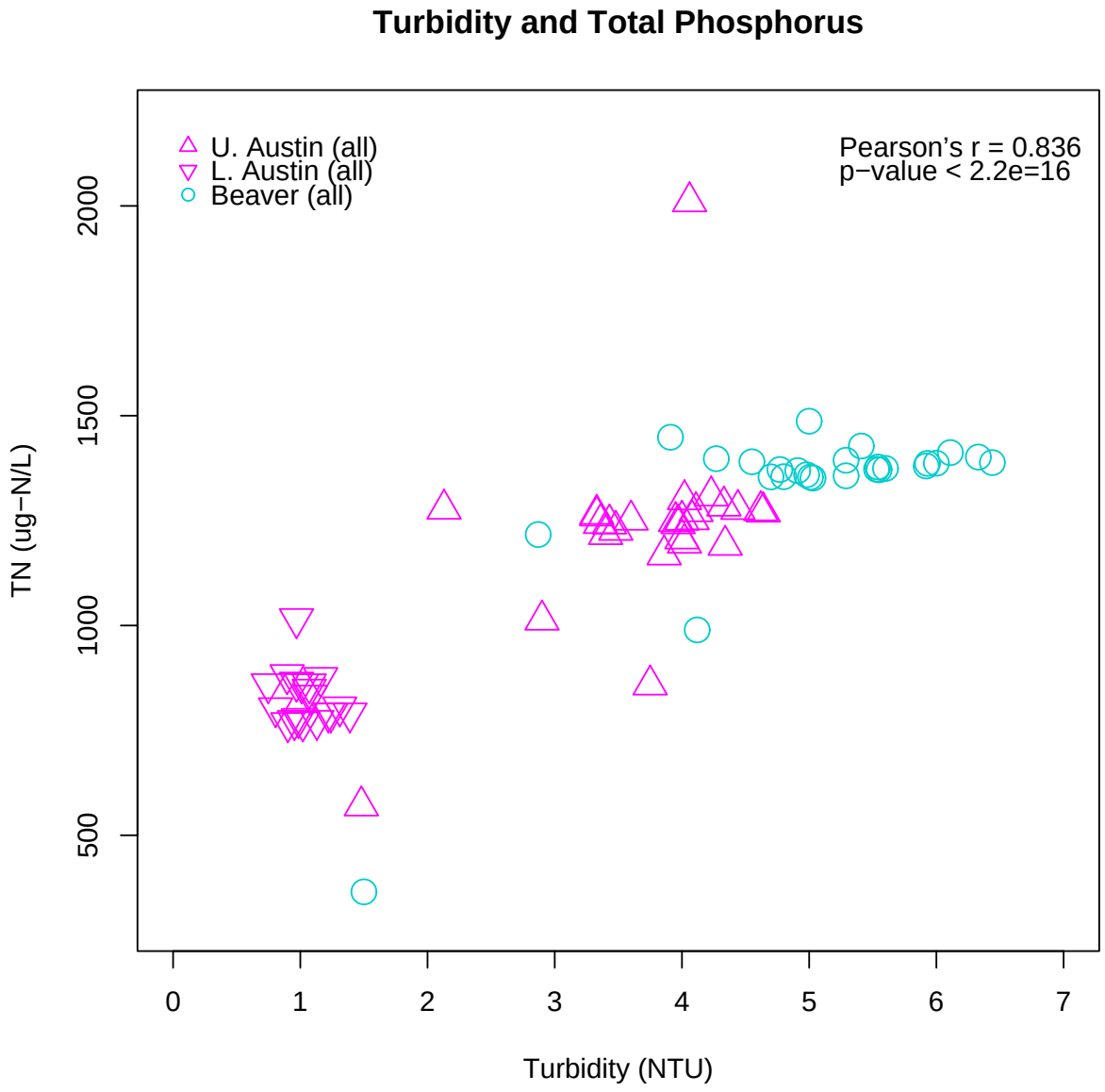


Figure 24: Relationship between total nitrogen and turbidity results from all Austin Creek and Beaver Creek samples.

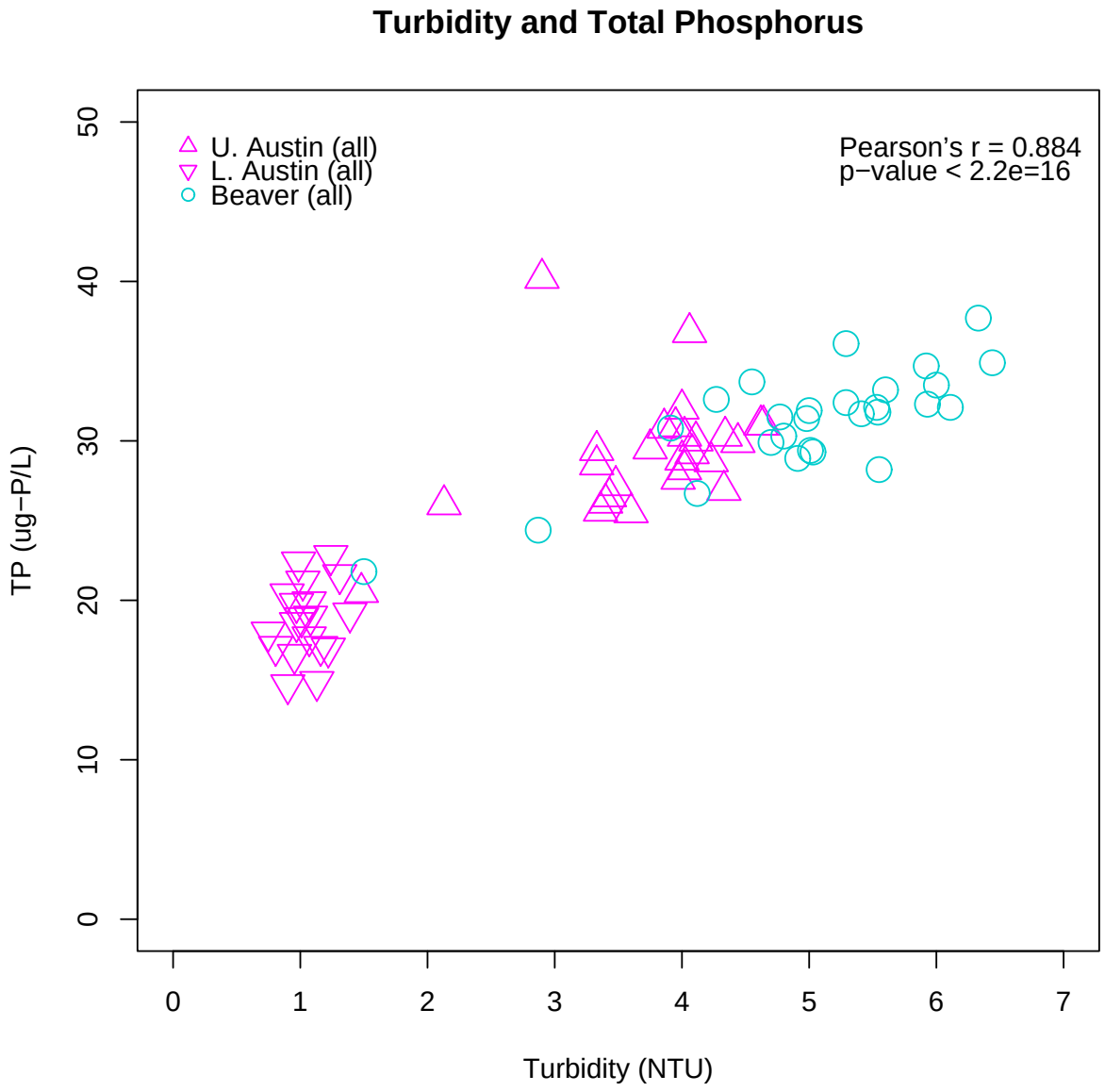


Figure 25: Relationship between total phosphorus and turbidity results from all Austin Creek and Beaver Creek samples.

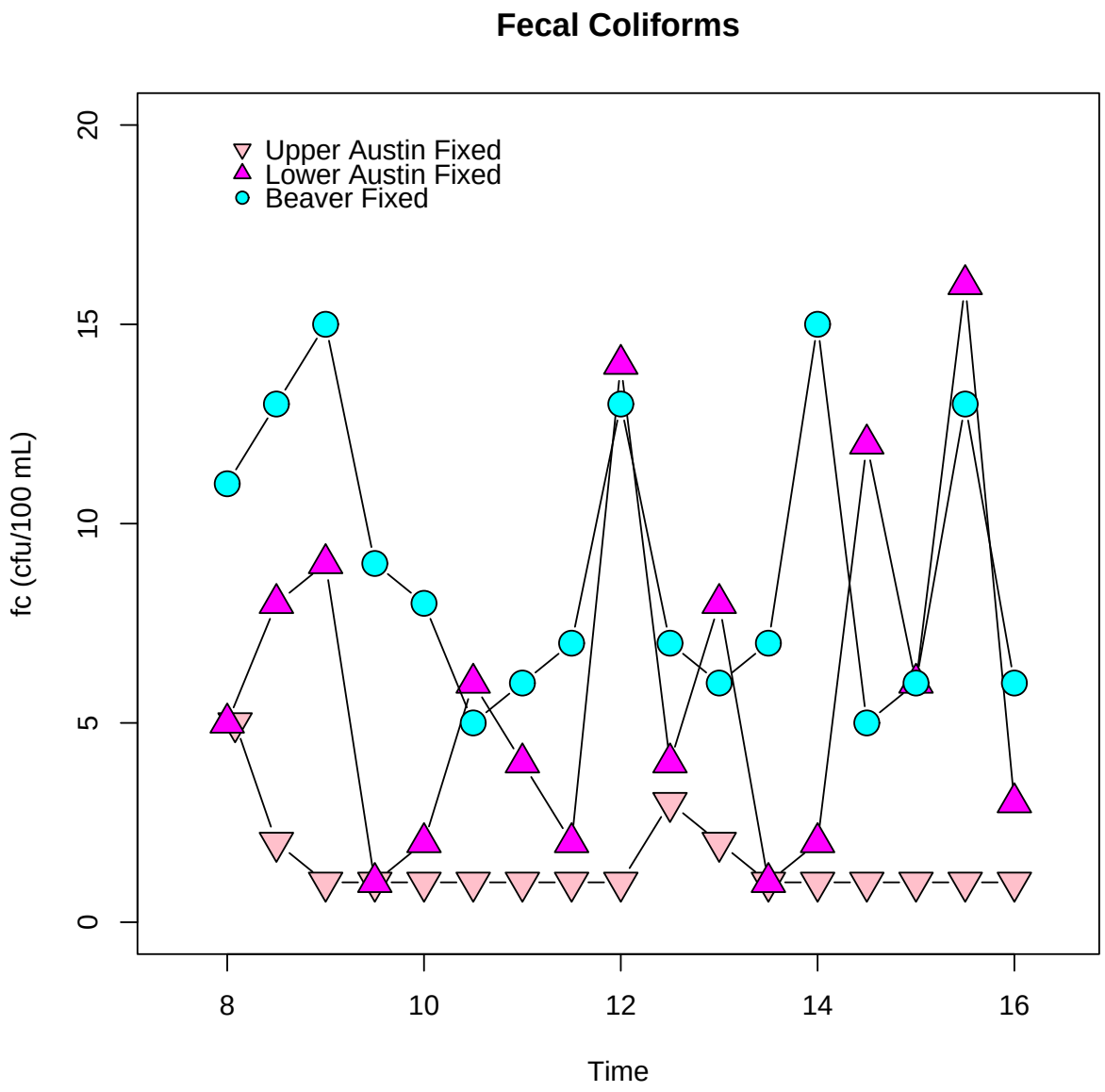


Figure 26: Fecal coliform results from the fixed sites on Austin and Beaver Creeks.

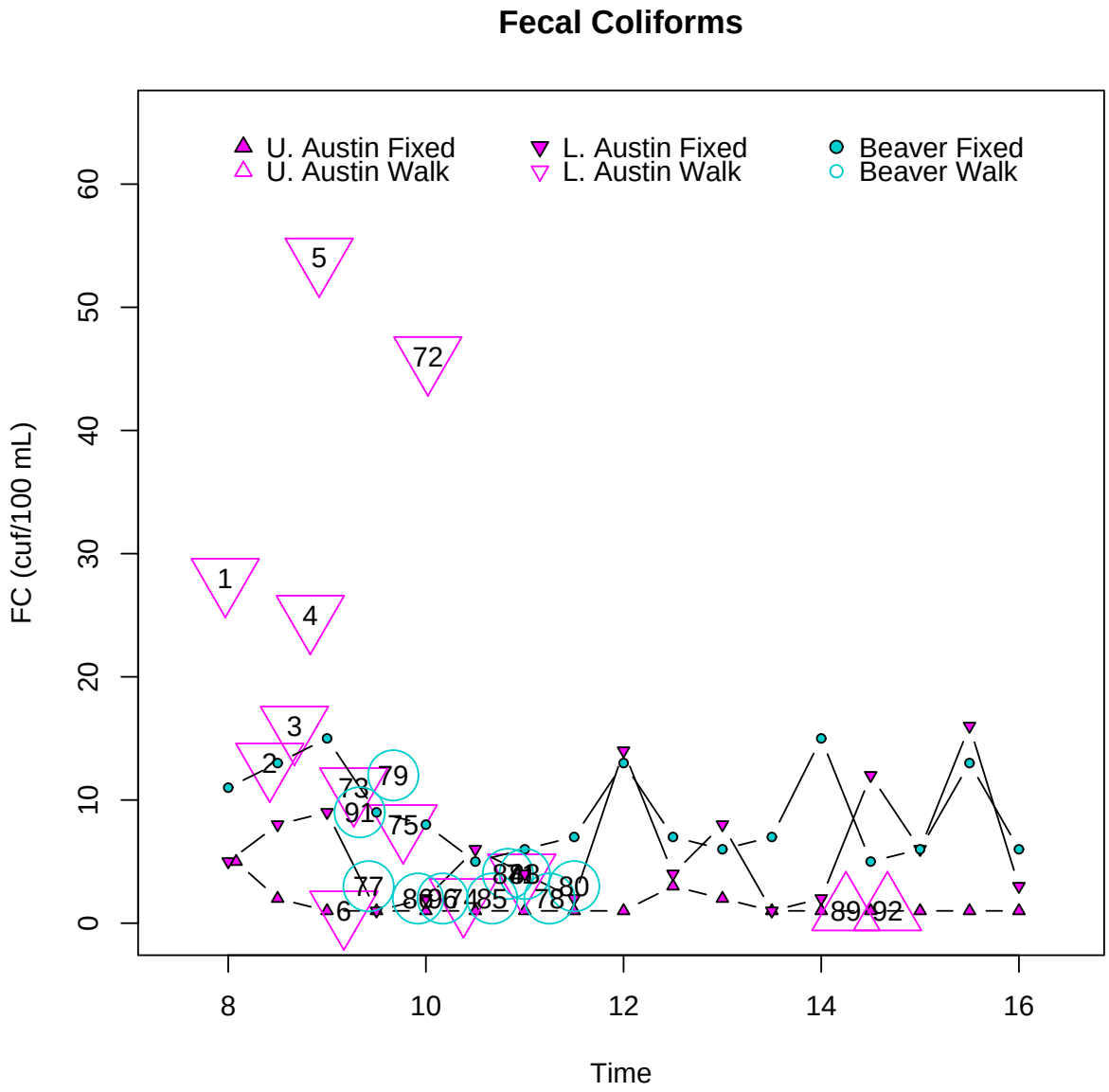


Figure 27: Fecal coliform results from all sites sampled in Austin and Beaver Creeks. Sample identification numbers have been added to show site locations.

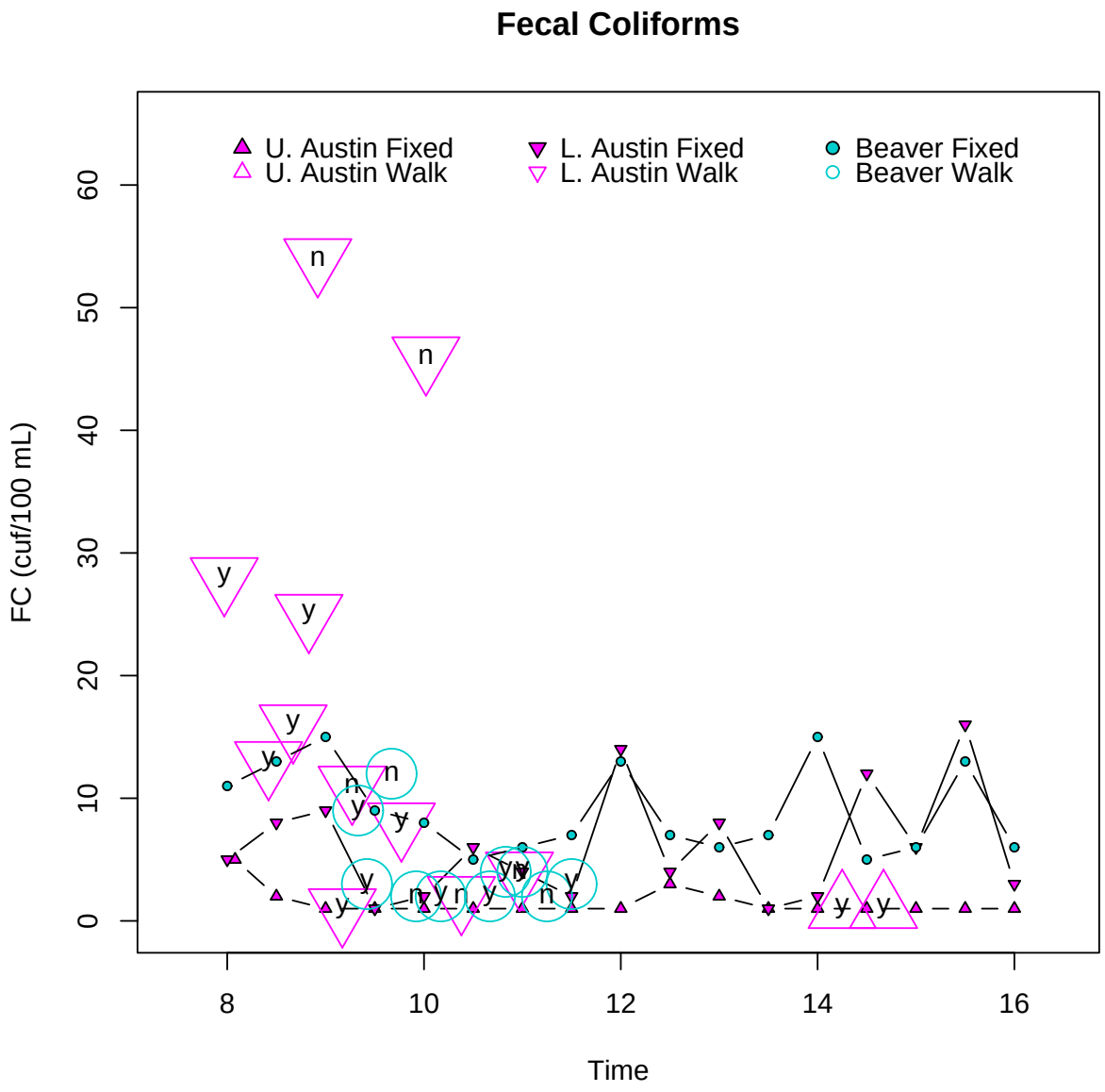


Figure 28: Fecal coliform results from all sites sampled in Austin and Beaver Creeks. Samples indicate whether they were collected in the main channels of Austin or Beaver Creeks (y) or from small inlet pipes or tributaries (n).

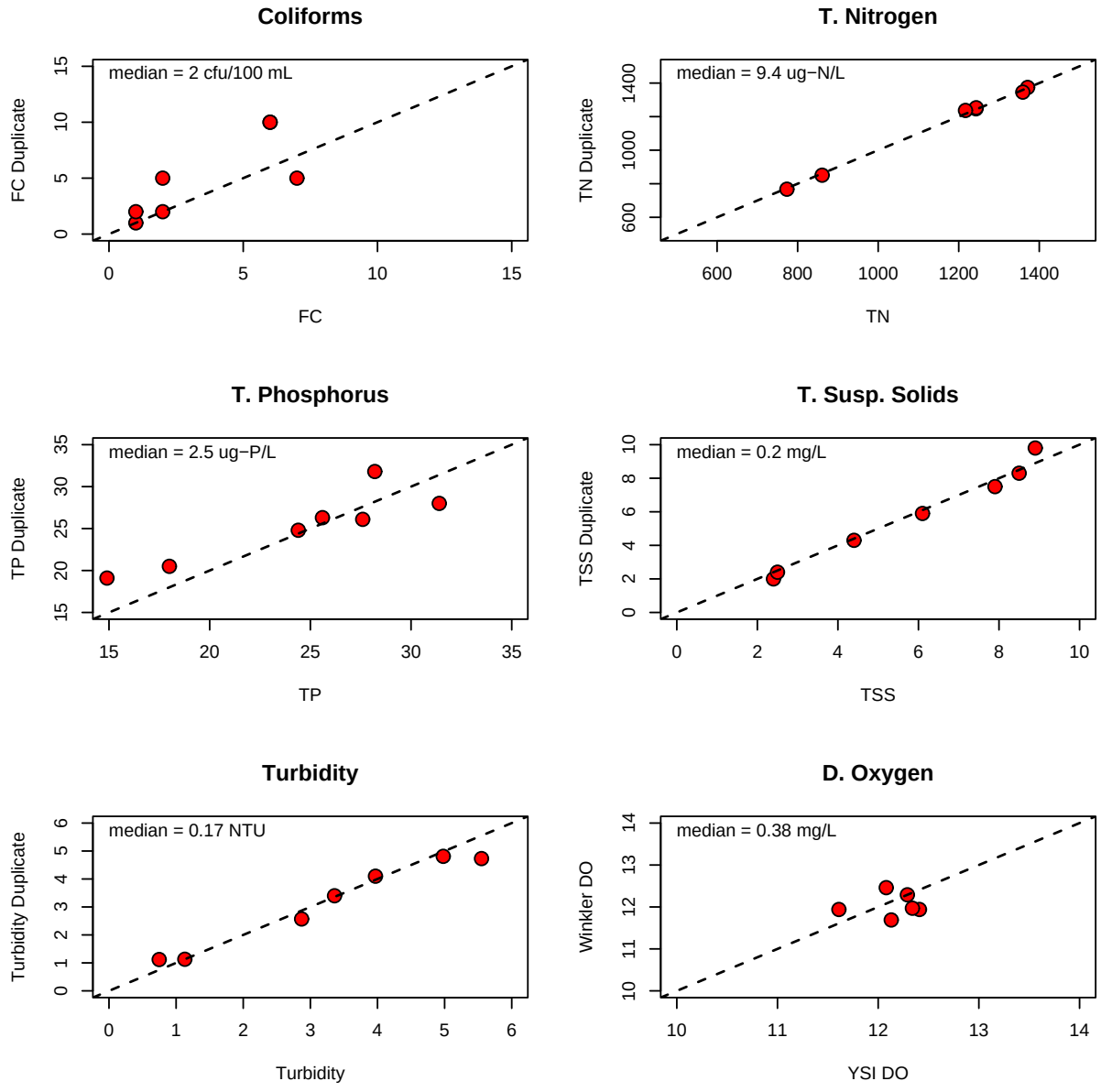


Figure 29: Field duplicate results and YSI/Winkler dissolved oxygen comparisons. Each figure shows the paired QC results, a diagonal 1:1 reference line, and the median of the absolute differences* between paired data.

$$^{*}\text{Absolute difference} = \frac{|\text{Original Sample} - \text{Duplicate Sample}|}{2}$$