ILLINOIS RIVER WATERSHED MONITORING PROGRAM-
NATIONAL MONITORING PROJECT
FY 1996 319(h):
TASK 250

CALIBRATION REPORT

Oklahoma Conservation Commission
Water Quality Division
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Introduction

The Illinois River is designated as a scenic river (outstanding resource water) in Oklahoma and provides a major recreational resource for many state residents and a significant benefit for the local economy. The river is a tributary to Lake Tenkiller, which has long been recognized as one of the outstanding recreational reservoirs in the state and is a popular site for scuba diving.

Nutrient loading in the Illinois River is a severe problem with the most recent documentation indicating over eighty percent of the loading occurs from nonpoint sources (0WRB 1996). This loading has resulted in degradation of water quality of the river perceived by users as decreased water clarity and increased nuisance periphyton growth. A Section 314 Clean Lakes study (0WRB 1996) reported Lake Tenkiller currently shows signs of water quality degradation. Symptoms of this degradation included periodic algal blooms, excessive algal growth, and hypolimnetic anoxia during stratified periods. The source of this degradation was determined to be eutrophication and sedimentation from point and nonpoint sources.

The primary nonpoint sources of nutrients and sediments are associated with improper management of wastes from confined animal operations and stream bank erosion. These problems are compounded by very poor soils composed primarily of coarse chert. Streams are becoming wider, shallower, and loaded with nutrients and soil resulting in loss of fish habitat and increased primary productivity.

The objective of this project is to monitor streams in the watershed selected as a demonstration watershed and a control site or matched pair. These watersheds were selected based upon position in the prioritization ranking, watershed size, land use, number of landowners, and willingness of landowners to participate in cost-share programs. The control watershed was chosen for its similarity to the implementation watershed based on size, geologic structure, soils, slope, population, land use, and position in the Illinois River sub-watershed. The matched sub-watershed will be monitored in an identical fashion as the demonstration watershed. The sites were also chosen for geographic proximity to decrease impacts of scattered weather patterns. This paired design allows closer examination of water quality changes and gives an indication of future water quality in demonstration sub-watersheds in the absence of implementation programs.

Two watersheds were chosen for sampling, one of which has been chosen for an implementation program. Peacheater Creek and upper Tyner Hollow have been chosen with Peacheater Creek being selected for implementation activities. These two watersheds can be compared on the following characteristics:

	Watershed Size (a)	**# Poultry Houses**	**# Dairies**	**# Residences**
Peacheater Creek	16,209	51	9	176
Upper Tyner Creek	16,000	65	7	150

These two streams, typical of others in the Illinois River basin, are characterized by very low turbidity and a substrate composed of flint gravel. In most cases in-stream habitat is rated poor.

The quality of the riparian corridor varies from good to absent in these streams. In most cases vegetation is confined to sycamore and willow trees with very limited understory growth. Understory vegetation is primarily limited by cattle grazing. Significant areas exist on each stream where riparian vegetation, other than streamside grasses, sedges, and rushes, is absent. Additional areas exist where even streamside grasses, sedges, and rushes are absent and replaced by Bermuda or fescue grass or bare soil. The primary aquatic macrophyte in each of these streams is watercress, although the extent of coverage is limited.

Initial data collected during the calibration phase indicated flow conditions were fairly similar between the two streams.

Stream	Average Base Flow
Upper Tyner	4 -13 cfs
Peacheater	2 -13 cfs

Activity in this project follows a phased approach. The first phase is the calibration phase in which data is collected to verify the relationship between the watersheds and establish pre-implementation conditions. The second phase, the treatment phase, involves data collection during and after implementation of BMPs to document effects.

Method

The objective of the paired watershed approach was to establish a significant relationship between water quality data for the two watersheds that will hold before and after implementation of best management practices. This relationship must be sufficiently strong to detect differences between pre- and post-treatment periods. The relationship during the calibration phase was described by the simple linear regression:

$$\textbf{treated} = \textbf{b}_o + \textbf{b}_i\textbf{(control)} + e$$

where **treated** and **control** represent concentrations or values for the respective watersheds, $\mathbf{b_o}$ and $\mathbf{b_1}$ are regression coefficients representing intercept and slope, respectively, and **e** is the residual error.

Three questions must be addressed before shifting from the calibration phase to the treatment phase (USEPA 1993):

1. Is there a significant relationship between the paired watersheds for each parameter of interest?

2. Has the calibration period continued for a sufficient length of time?

3. Are the residual errors about the regression smaller than the expected treatment effect.

For purposes of calibration, we evaluated the relationship between Peacheater and Tyner Creeks on data collected between January 1996 and March 1997 under three different flow regimes; all flows, high flow (> 2 * average flow), and base flow (< 0.5 * average flow). All analyses were conducted on log-transformed data to satisfy assumptions of parametric statistical analysis.

Regression Significance

The significance of the regression between paired observations was tested using analysis of variance (ANOVA). The probability (p) value associated with the resulting F statistic indicated whether the regression explained a significant amount ($P < 0.05$) of the variation in the paired data. The coefficient of determination (r^2) indicated the quality of the regression or its utility to predict y from x. Regression statistics for the watersheds under three different flow regimes are shown in **Table 1**. The column labeled "m.s. resid." refers to mean square of the residuals, an estimate of the variance of the residuals. This is an important statistic for evaluating the precision of the fit of the model. Calibration regression equations are seen in **Figures 1 - 3**.

Significant ($\alpha = 0.05$) relationships between Peacheater and Tyner Creek watersheds were obtained for all water quality parameters using data from combined flow regimes. Significant ($\alpha = 0.05$) relationships between the paired watersheds were obtained for all parameters except turbidity at base flow conditions. Fewer relationships were significant during high flows; TKN, conductivity, chlorides, and hardness were not significant ($\alpha = 0.05$) during high flow events.

TABLE 1. CALIBRATION REGRESSION STATISTICS

Treatment Watershed = P (Peacheater)   Control Watershed = T (Tyner)

CALIBRATION OF ALL DATA

Variable	r^2	Equation	n	m.s. resid.	F	p
TP	0.22	LTPP=0.288(LTPT) - 0.987	39	0.019	10.82	<0.005
oP	0.05	LoPP=0.126(LoPT) - 1.251	39	0.017	127.67	<0.001
nitrate	0.68	LN03P=0.615(LN03T) + 0.245	40	0.005	82.08	<0.001
nitrite	0.53	LN02P=0.967(LN02T) + 0.059	36	0.085	39.06	<0.001
TKN	0.26	LTKNP=0.744(LTKNT) - 0. 1 84	36	0.069	12.30	<0.005
Sulfate	0.45	LS04P=0.763(LS04T) + 0.204	32	0.033	25.02	<0.001
DO	0.45	LDOP=0.870(LDOT) + 0. 123	68	0.004	54.17	<0.001
pH	0.47	LPHP=O. 792(LpHT) + 0. 184	70	0.0001	61.22	<0.001
Cond.	0.15	LcondP=1.584(LcondT) - 1.372	70	0.056	11.93	<0.001
Temp	0.89	LTEMPP=1.701(LTEMPT) - 0.843	70	0.003	564.32	<0.001
Turbidity	0.67	LturbP=0.971 (LTurbT) - 0.050	70	0.028	135.89	<0.001
Alk.	0.44	LalkP=0.684(LalkT) - 0.477	69	0.004	53.03	<0.001
Chloride	0.73	LchIdP=1.098(LchldT) - 0.056	40	0.004	103.71	<0.001
hardness	0.34	LhardP=1.170(LhardT) - 0.364	40	0.010	19.68	<0.001

CALIBRATION OF BASE FLOW DATA (< 0.5* long term mean)

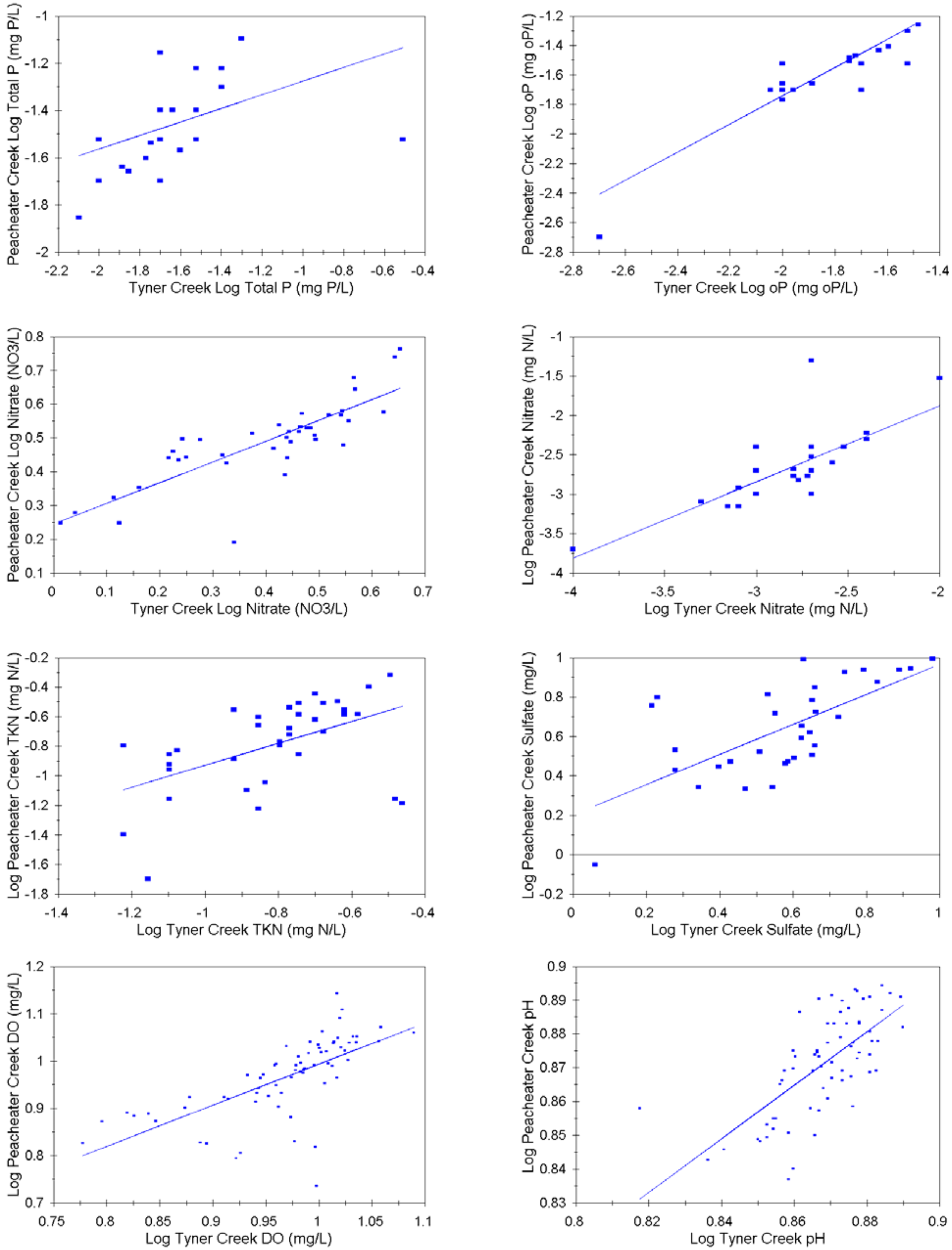
Variable	r^2	Equation	n	m.s. resid.	F	p
TP	0.39	LTPP=0.651 (LTPT) - 0.3 79	15	0.016	8.36	<0.05
oP	0.87	LoPP=1.265(LoPT) + 0.823	15	0.011	89.22	<0.001
nitrate	0.78	LN03P=0.606(LN03T) + 0.270	16	0.002	49.44	<0.001
nitrite	0.50	LN02P=0.941(LN02T) - 0.0002	16	0.132	13.84	<0.005
TKN	0.57	LTKNP=1.458(LTKNT) + 0.450	14	0.049	15.93	<0.005
Sulfate	0.45	LS04P=0.733(LS04T) + 0.200	16	0.0399	11.57	<0.005
DO	0.37	LDOP=0.787(LDOT) + 0.192	28	0.007	15.32	<0.001
pH	0.49	LpHP=0.957(LpHT) + 0.037	28	0.0001	24.67	<0.001

Cond.	0.93	LcondP=1.389(LcondT) - 0.938	28	0.0009	340.38	<0.001
Temp	0.96	LTEMPP=1.829(LTEMPT) - 1.014	28	0.0018	593.49	<0.001
Turbidity	0.11	LturbP = 0.364(LturbT) – 0.079	28	0.0329	3.12	<0.1
Alk.	0.15	LalkP=0.486(LalkT) + 0.847	27	0.004	4.48	<0.005
Chloride	0.78	LchldP= 1. 83 1 (LchldT) - 0.676	15	0.0025	47.2	<0.001
hardness	0.34	LhardP=2.633(LhardT) - 3.198	16	0.022	7.09	<0.05

CALIBRATION OF HIGH FLOW DATA (>2 * LONG_TERM MEAN)

Variable	**r^2**	**Equation**	**n**	**m.s. resid.**	**F**	**p**
TP	0.93	LTPP= 1.316 (LTPT) + 0.599	6	0.001	53.99	<0.005
oP	0.96	LoPP= 0.839(LoPT) - 0.048	6	0.001	89.81	<0.001
nitrate	0.77	LN03P = 1.398(LN03T) - 0.177	6	0.004	13.64	<0.05
nitrite	0.72	LN02P = 1.065(LN02T) + 0.080	6	0.034	10.39	<0.05
TKN	0.59	LTKNP = 1.096(LTKNT) + 0.190	6	0.010	5.79	<0.1
Sulfate	0.89	LSO4P = 1.111(LSO4T) + 0.061	6	0.022	34.34	<0.005
DO	0.25	LDOP = 0.385(LDOT) + 0.607	9	0.0004	2.29	<0.5
pH	0.73	LpHP = 0. 867(LpHT) + 0. 119	10	0.000034	21.43	<0.001
Cond.	0.00	LcondP = 0.380(LcondT) + 1.126	10	0.453	0.002	<1.0
Temp	0.86	LtempP = 1.212(LtempT) 0.248	10	0.0008	47.99	<0.001
Turbidity	0.94	LturbP = 1.013(LturbT) + 0.010	10	0.005	126.44	<0.001
Alk.	0.41	LalkP = 0.493(LalkT) + 0.757	10	0.002	5.52	<0.05
Chloride	0.16	LchldP = 0.643(LchldT) + 0.337	6	0.009	0.751	<0.5
hardness	0.22	LhardP = 0.302(LhardT) + 1.225	6	0.0007	1.123	<0.5

Using data from a combination of flow conditions, coefficient of determination (r^2) values were low to moderate (0.05 - 0.73) for nutrients, chloride, turbidity, and


Peacheater Creek Log Total P (mg P/L)
Tyner Creek Log Total P (mg P/L)
Peacheater Creek Log oP (mg oP/L)
Tyner Creek Log oP (mg oP/L)
Peacheater Creek Log Nitrate (NO3/L)
Tyner Creek Log Nitrate (NO3/L)
Log Peacheater Creek Nitrate (mg N/L)
Log Tyner Creek Nitrate (mg N/L)
Log Peacheater Creek TKN (mg N/L)
Log Tyner Creek TKN (mg N/L)
Log Peacheater Creek Sulfate (mg/L)
Log Tyner Creek Sulfate (mg/L)
Log Peacheater Creek DO (mg/L)
Log Tyner Creek DO (mg/L)
Log Peacheater Creek pH
Log Tyner Creek pH

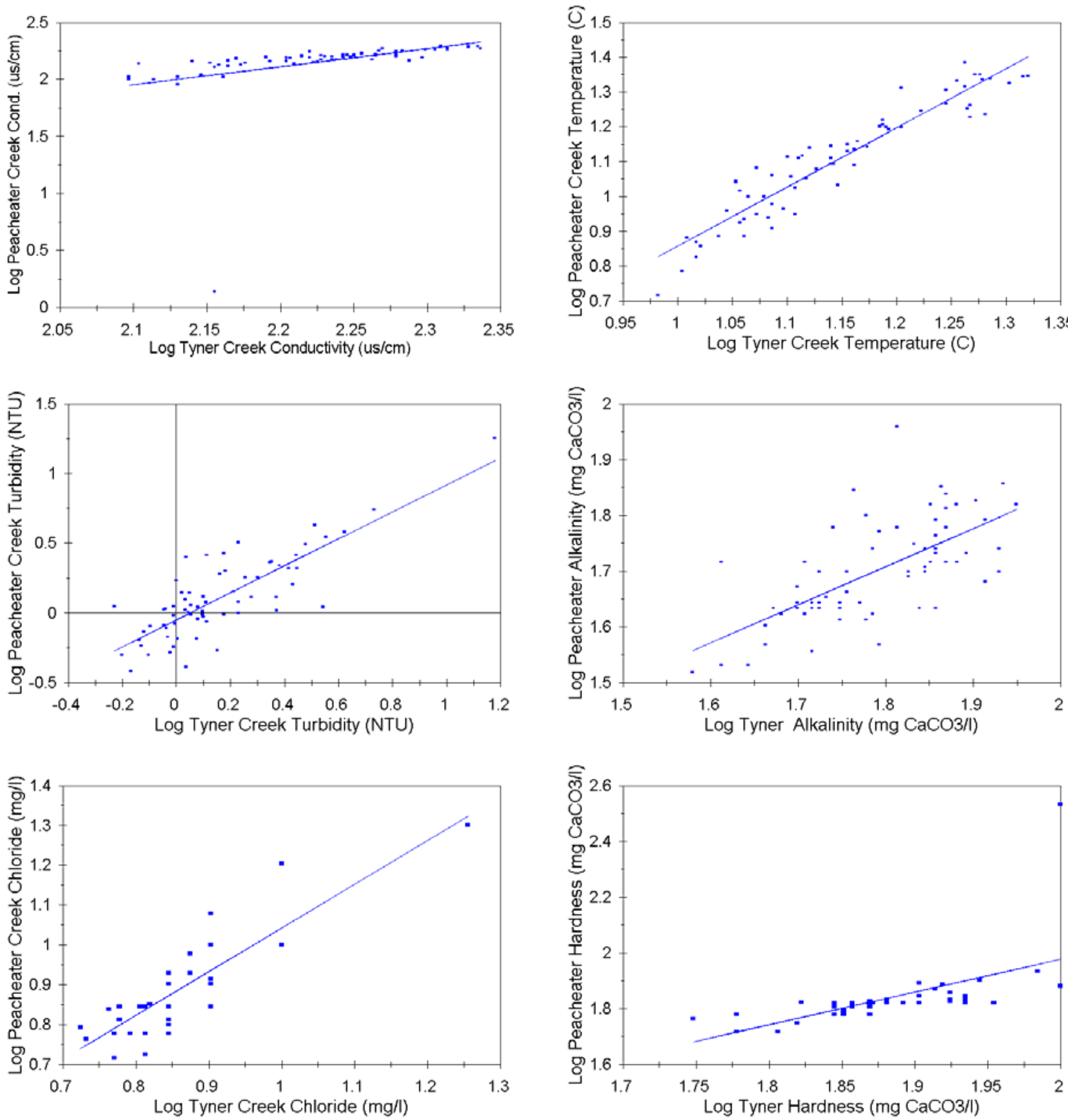


Figure 1. Continued.

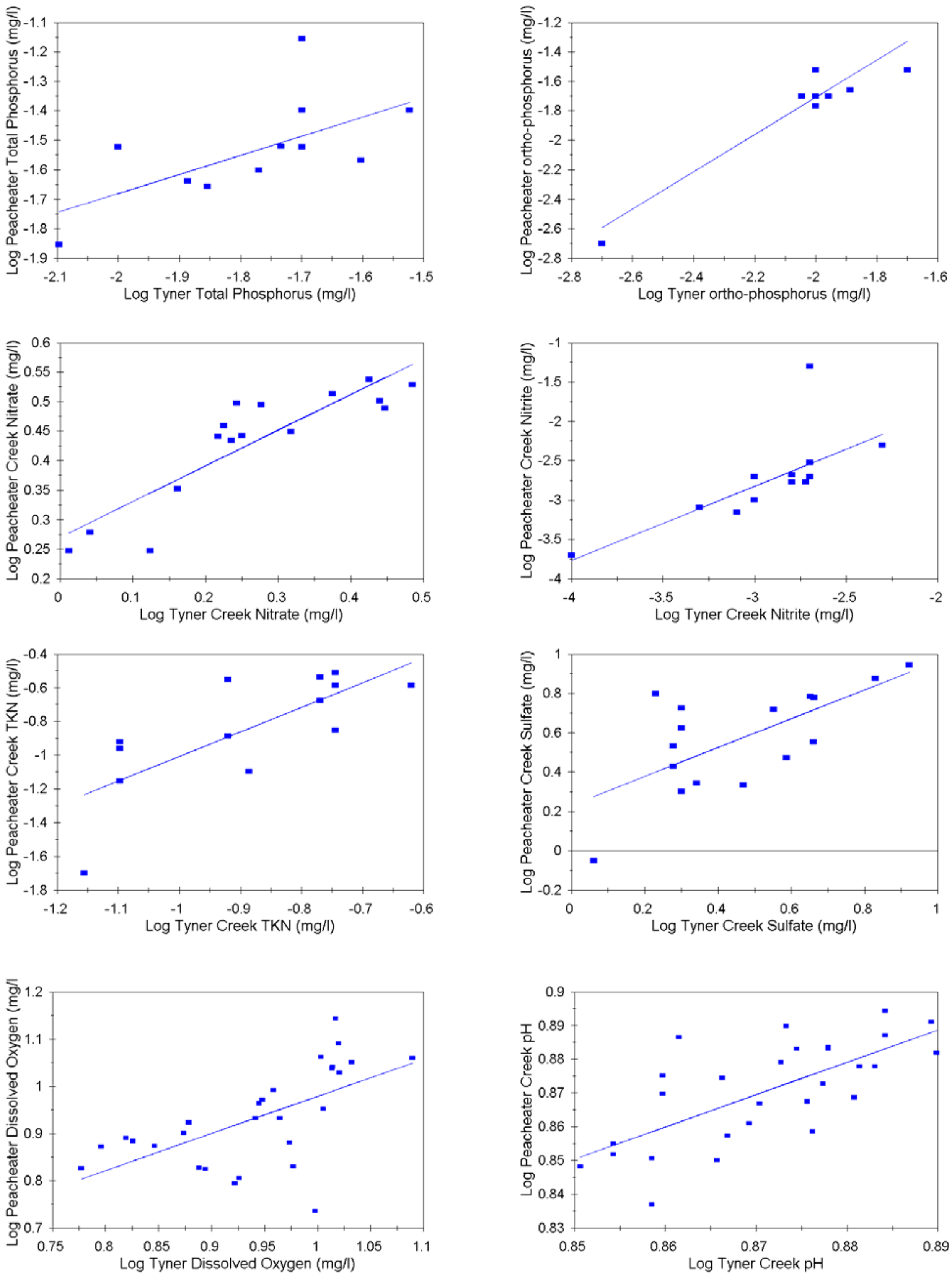


Figure 2. Calibration Regressions for Base Flow Conditions.

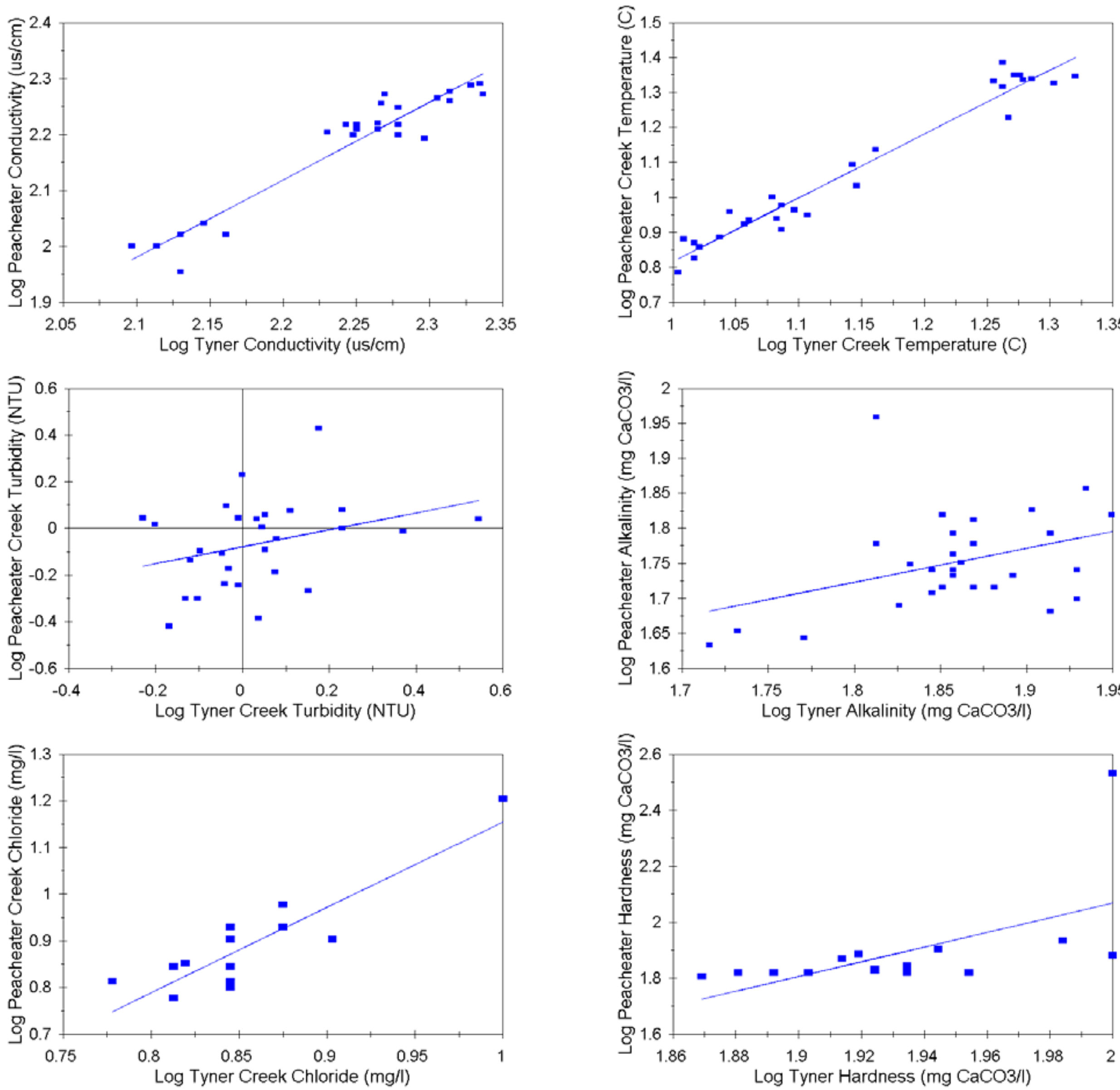


Figure 2. Continued.

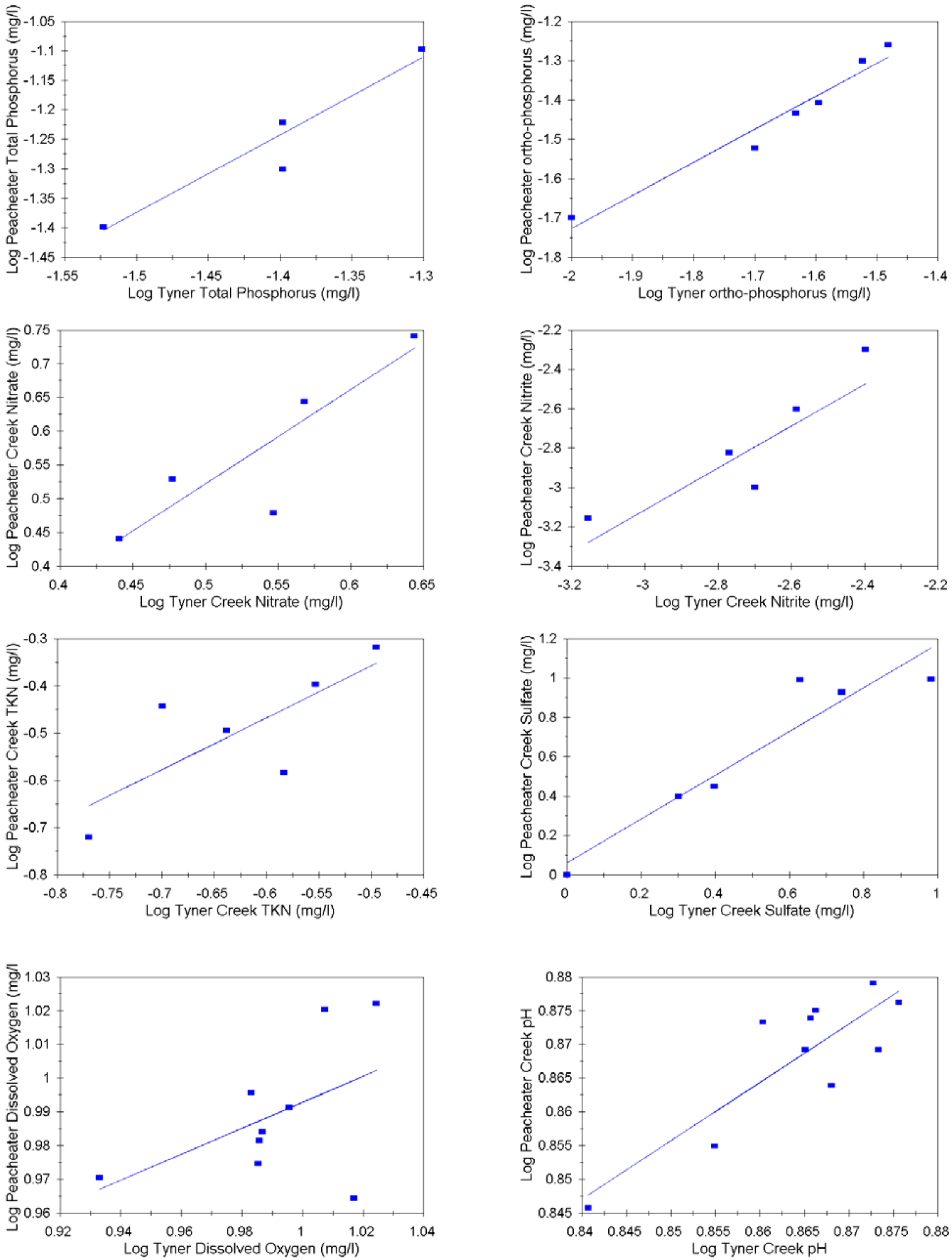


Figure 3. Calibration Regressions at High Flow Conditions.

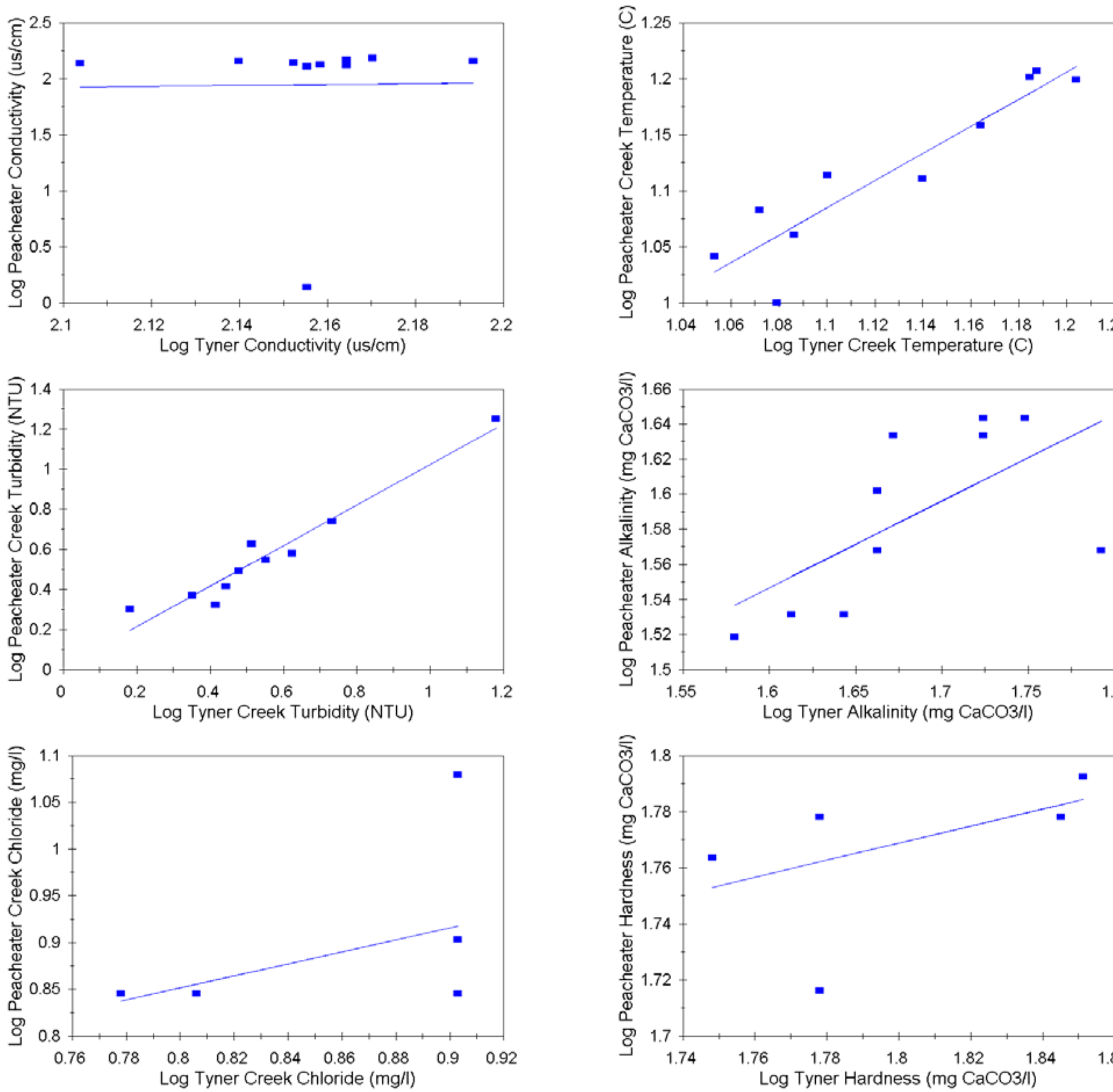


Figure 3. Continued.

sulfate, low for pH, alkalinity, and hardness (0.34 - 0.47), and low for conductivity and dissolved oxygen (0.15 and 0.45, respectively). The r^2 value of temperature was in the high range (0.89), indicating a strong relationship between temperatures of the two watersheds. At base flow conditions, r^2values were low to high for nutrients, dissolved oxygen, chloride, and sulfate (0.11 - 0.87), low to moderate for pH, alkalinity, and hardness (0.15 - 0.49), and high for conductivity and temperature (0.93 and 0.96, respectively). Significant relationships between Tyner and Peacheater watersheds were stronger at high flow values (0.41 - 0.96). Although fewer parameters were significantly related during high flows, relationships were stronger than those of combined or base flow sampling events.

All cases evaluated using combined flow data were significant and deemed acceptable for purposes of calibration. All cases but turbidity were acceptable based on base flow data, and all high flow cases except TKN, dissolved oxygen, conductivity, chloride, and hardness were acceptable.

Calibration Duration

The ratio between the residual variance (S^2_{yx}) for the regression and the smallest worthwhile difference (d) is used to determine whether sufficient data has been collected to detect that difference. The equation used (USEPA 1993) is:

$$(S^2_{yx})/(d^2) = \{(n_1 * n_2)/(n_1 + n_2)\}* \{1/(F/(n_1 + n_2 - 2))))\}$$

where S^2_{YX} is the estimated residual variance about the regression
d is the smallest worthwhile difference in the mean in the treated watershed (e.g. for a difference of 10%, d = 0. 1 * x) n_1 and n_2 are the numbers of observations in the calibration and treatment periods, respectively
F is the table value of F ($p = 0.05$) for the variance ratio at 1 and $n_1 + n_2 - 3$ degrees of freedom

If the left side of the equation is greater than the right side, an insufficient number of samples have been collected to detect the difference, based on the strength and precision of the regression relationship.

Results of the calibration test are shown in **Table 2** for the different flow regimes. Sufficient samples had been collected to detect a 10% difference for all parameters using data from combined flow types. At base flow conditions, sufficient samples had been collected to detect a 10% difference for all parameters except sulfate and turbidity. Sufficient samples had been taken to detect a 12.3% difference in sulfate and a 50% difference in turbidity. This was likely due to the smaller number of samples at base flow as sufficient samples were taken using data from combined flow regimes. Also, the magnitude of

TABLE 2. CALIBRATION TEST

ALL DATA

Variable	Mean	S^2_{yx}	n_1	n_2	F	d	Left side	Right side	Status
TP	-1.516	0.019	39	39	1.69	0.1	0.83	45.15	OK
oP	-1.848	0.017	39	39	1.69	0.1	0.51	45.15	OK
Nitrate	0.428	0.005	40	40	1.69	0.1	2.70	46.33	OK
Nitrite	-2.716	0.085	36	36	1.75	0.1	1.15	40.14	OK
TKN	-0.772	0.069	36	36	1.75	0.1	11.57	40.14	OK
Sulfate	0.619	0.033	32	32	1.81	0.1	8.54	34.36	OK
DO	0.972	0.004	68	68	1.53	0.1	0.40	87.88	OK
pH	0.868	0.0001	70	70	1.53	0.1	0.02	90.50	OK
Cond	0.221	0.056	70	70	1.53	0.1	1.14	90.50	OK
Temp	1.155	0.003	70	70	1.53	0.1	0.21	90.50	OK
Turbidity	0.248	0.028	70	70	1.53	0.1	45.42	90.50	OK
Alk	1.796	0.004	69	69	1.53	0.1	0.14	89.19	OK
Chloride	0.863	0.004	40	40	1.69	0.1	0.50	46.33	OK
hardness	1.886	0.010	40	40	1.69	0.1	0.27	47.52	OK

BASE FLOW DATA

Variable	Mean	S^2_{yx}	n_1	n_2	F	d	Left side	Right side	Status
TP	-1.734	0.016	15	15	2.46	0.1	0.52	11.21	OK
oP	-1.986	0.011	15	15	2.46	0.1	0.27	11.21	OK
Nitrate	0.289	0.002	16	16	2.40	0.1	2.69	12.34	OK
Nitrite	-2.798	0.132	16	16	2.40	0.1	1.69	12.34	OK
TKN	-0.863	0.049	14	14	2.60	0.1	6.57	9.79	OK
Sulfate	0.528	0.0399	16	16	2.40	0.1	14.31	12.35	NO GOOD
DO	0.949	0.007	28	28	1.88	0.1	0.78	28.79	OK
pH	0.871	0.0001	28	28	1.88	0.1	0.02	28.79	OK

Cond	2.239	0.0009	28	28	1.88	0.1	0.02	28.79	OK
Temp	1.158	0.0018	28	28	1.88	0.1	0.14	28.79	OK
Turbidity	0.071	0.0329	28	28	1.88	0.1	645.74	28.79	NO GOOD
Alk	1.862	0.004	27	27	1.90	0.1	0.13	27.42	OK
Chloride	0.856	0.0025	15	15	2.46	0.1	0.34	11.21	OK
hardness	1.934	0.022	16	16	2.40	0.1	0.58	12.35	OK

HIGH FLOW DATA

Variable	Mean	S^2_{yx}	n_1	n_2	F	d	Left side	Right side	Status
TP	-1.416	0.001	6	6	5.05	0.1	0.059	1.579	OK
oP	-1.627	0.001	6	6	5.05	0.1	0.051	1.579	OK
Nitrate	0.546	0.004	6	6	5.05	0.1	1.256	1.579	OK
Nitrite	-2.664	0.034	6	6	5.05	0.1	0.483	1.579	OK
TKN	-0.614	0.010	6	6	5.05	0.1	2.78	1.579	NO GOOD
Sulfate	0.617	0.022	9	9	5.05	0.1	5.73	1.579	NO GOOD
DO	0.992	0.0004	9	9	3.44	0.1	0.037	4.88	OK*
pH	0.864	0.000034	10	10	3.18	0.1	0.005	5.35	OK
Cond	2.156	0.453	10	10	3.18	0.1	9.74	5.35	NO GOOD
Temp	1.130	0.0008	10	10	3.18	0.1	0.066	5.35	OK
Turbidity	0.640	0.005	10	10	3.18	0.1	1.276	5.35	OK
Alk	1.687	0.002	10	10	3.18	0.1	0.058	5.35	OK
Chloride	0.869	0.009	6	6	5.05	0.1	1.22	1.579	OK*
hardness	1.798	0.0007	6	6	5.05	0.1	0.022	1.579	OK*

* - although a sufficient number of samples collected, regression was not significant at α = 0.05.

turbidity at base flow is much smaller than at other flow conditions, thus a 10% change would be a very small number, requiring more samples to detect a difference. Sufficient samples were collected at high flow to detect a 10% difference for fewer parameters; insufficient samples were collected to detect a difference for TKN, sulfate, and conductivity. Sufficient samples were collected to detect a 12.5% difference in sulfate, a 20% difference in TKN, and a 13.6%

difference in conductivity. Again, this was likely due to the smaller number of samples collected at high flow conditions as sufficient samples were taken using data from all flow regimes. Although sufficient samples were taken to detect a 10% difference in dissolved oxygen, chloride, and hardness, the regressions of these parameters were not significant, therefore the models for these parameters at high flows are not valid.

Residual Errors

The confidence bands for the regression allow more precise determination of the level of change needed to show a significant treatment effect. Confidence bands for the regression are determined from:

$$\mathbf{CI = \pm (t)(S_{yx})\ (1/n)^{0.5}}$$

where CI is the confidence interval
t is the table value of Student's t at n – 1 degrees of freedom
S_{yx} is the square root of S^2_{yx} from the first equation

Calculations of 95% confidence intervals at the means for all variables for the different flow regimes are seen in **Table 3**. The columns labeled "+/- CI" indicate the range within which the treatment value (y) is expected to fall ($\alpha = 0.05$) at the mean of control value (x) during the calibration period. During the treatment period, a y value at the mean of the x value would have to fall outside this range for the treatment data to be significantly different. This range suggests the level of change necessary to show a significant treatment effect.

The data in **Table 3** suggested the level of change necessary to show a significant response to treatment was 24% or less using data from combined flow regimes. With the exception of nitrite, a 30% or less change was necessary to show a significant response using base flow data. Nitrite required a 47% change to show a significant response using base flow data. Of the valid regression models calculated using high flow data (excludes TKN, sulfate, dissolved oxygen, conductivity, chloride, and hardness), parameters required a 15% or less change (except nitrite which required a 50% change) to show a significant response to treatment.

Conclusions

The three conditions for acceptable calibration outlined in USEPA (1993) have been met using data from the combined flow regimes. Significant relationships exist between Peacheater and Tyner Creek watersheds for all parameters of

TABLE 3. CHANGE DETECTABLE BY CALIBRATION TEST
ALL DATA

Variable	Mean	Log Mean	t	S_{yx}	n	CI (mean)	+CI	-CI	-%	+%	Mean %d
TP	0.03	-1.516	2.023	0.1385	39	0.0449	0.0275	0.0316	10	4	7
oP	0.01	-1.848	2.023	0.1322	39	0.0428	0.0129	0.0157	9	11	10
Nitrate	2.68	0.428	2.021	0.0704	40	0.0225	2.5439	2.8216	2	5	3.5
Nitrite	0.002	-2.716	2.030	0.2910	36	0.0984	0.0015	0.0024	21	26	23.5
TKN	0.17	-0.772	2.030	0.2626	36	0.0888	0.1378	0.2074	19	23	21
Sulfate	4.16	0.619	2.034	0.1810	32	0.0651	3.5801	4.8317	14	16	15
DO	9.38	0.972	2.000	0.0619	68	0.0160	9.0365	9.7275	4	4	4
pH	7.39	0.868	2.000	0.0107	70	0.0026	7.3350	7.4234	1	0.5	0.75
Cond	167.72	0.221	2.000	0.2375	70	0.0568	145.95	189.58	13	13	13
Temp	14.30	1.155	2.000	0.0524	70	0.0125	13.884	14.706	3	3	3
Turbidity	1.77	0.248	2.000	0.1674	70	0.0400	1.6144	1.9409	9	10	9.5
Alk	65.59	1.796	2.000	0.0672	69	0.0162	63.212	68.108	4	4	4
Chloride	7.30	0.863	2.021	0.0609	40	0.0192	6.9791	7.6243	4	4	4
hardness	76.86	1.886	2.021	0.0989	40	0.0312	71.581	82.642	7	7	7

BASE FLOW DATA (<O.5 * long term mean)

Variable	Mean	Log Mean	t	S_{yx}	n	CI (mean)	+CI	-CI	-%	+%	Mean %d
TP	0.02	-1.734	2.145	0.1246	15	0.0690	0.0157	0.0216	15	17	16
oP	0.01	-1.986	2.145	0.1029	15	0.0570	0.0091	0.0118	12	15	13.5
Nitrate	1.94	0.289	2.131	0.0473	16	0.0252	1.8357	2.0616	6	6	6
Nitrite	0.002	-2.798	2.131	0.3635	16	0.1936	0.0010	0.0025	38	56	47
TKN	0.14	-0.863	2.160	0.2212	14	0.1277	0.1022	0.1836	25	34	30
Sulfate*	3.37	0.528	2.030	0.1998	16	0.1065	2.6394	4.3102	22	28	25
DO	8.89	0.949	2.052	0.0836	28	0.0324	8.2528	9.5808	7	8	7.5

pH	7.44	0.871	2.052	0.0111	28	0.0042	7.3587	7.5024	1	1	1
Cond	173.57	2.239	2.052	0.0304	28	0.0118	168.73	178.16	3	3	3
Temp	14.38	1.158	2.052	0.0427	28	0.0166	13.848	14.949	6	4	5
Turbidity*	1.18	0.071	2.052	0.1813	28	0.0703	1.0016	1.3845	15	17	16
Alk	72.78	1.862	2.056	0.0667	27	0.0264	68.486	77.339	6	6	6
Chloride	7.17	0.856	2.145	0.0502	15	0.0278	6.7329	7.6524	6	7	6.5
hardness	85.84	1.934	2.131	0.1475	12	0.0786	71.680	102.94	16	20	18

HIGH FLOW DATA (> 2 * long term mean)

Variable	Mean	Log Mean	t	S_{yx}	n	CI (mean)	+CI	-CI	-%	+%	Mean %d
TP	0.04	-1.416	2.571	0.034	6	0.0353	0.0353	0.0417	7	10	8.5
oP	0.02	-1.627	2.571	0.037	6	0.0216	0.216	0.0258	11	8	9.5
Nitrate	3.51	0.546	2.571	0.061	6	3.0325	3.0325	4.0757	14	16	15
Nitrite	0.002	-2.664	2.571	0.185	6	0.0014	0.0014	0.0034	30	70	50
TKN*	0.24	-0.614	2.571	0.1022	6	0.1900	0.1900	0.3114	22	28	25
Sulfate*	4.14	0.617	2.571	0.1476	6	2.8973	2.8973	5.9156	30	43	36.5
DO*	9.81	0.992	2.306	0.0191	9	9.4907	9.4907	10.156	3	4	3.5
pH	7.32	0.864	2.262	0.006	10	7.241	7.241	7.382	1	1	1
Cond*	143.3	2.156	2.262	0.6731	10	47.26	47.26	434.01	67	203	135
Temp	13.5	1.130	2.262	0.029	10	12.859	12.859	14.151	5	5	5
Turbidity	4.37	0.640	2.262	0.072	10	3.875	3.875	4.917	11	13	12
Alk	48.6	1.687	2.262	0.041	10	45.478	45.478	52.054	6	7	6.5
Chloride*	7.4	0.869	2.571	0.0962	6	5.8627	5.8627	9.3304	21	26	23.5
Hardness*	62.83	1.798	2.571	0.0266	6	58.898	58.898	66.973	6	7	6.5

*: not a valid model – either due to non-significant regression lines or insufficient sample size

interest. The calibration was adequate to detect changes following treatment, and the residual errors of the regressions were small enough to determine changes of 24% or less following implementation of BMPS. The models did not calibrate as well when only using data from base flow or high flow conditions. This is to be expected with smaller sample sizes, the wide range of values which may result from high flow events, and values close to detection limits collected at base flow conditions. However, the models of important parameters (nutrients at base flows and nutrients and turbidity at high flows) were calibrated. Overall, data collected during calibration appear to be adequate to proceed with the implementation or treatment phase.

NUTRIENT LOADINGS

Nutrients (predominantly nitrogen and phosphorus) are one of the primary water quality problems in the Illinois River Basin. Thus, it is essential to understand the differences in nutrient concentrations and loadings between the paired watersheds prior to implementation of best management practices in the treatment watershed. Nutrient concentrations and instantaneous flows were collected at least monthly between December 1995 and April 1997. Loading estimates can be made from these values and compared to summarize the initial relationship between watersheds.

Figure 4 explains subsequent graphs depicting comparisons of nutrient loadings in Tyner and Peacheater Creeks. The upper and lower bars of the box represent the upper and lower quartiles of the distribution. The middle bar in the box represents the median. The upper and lower whiskers represent maximum and minimum values, respectively. The notch represents the statistical domain such that overlapping notches designate no statistically significant difference between distributions.

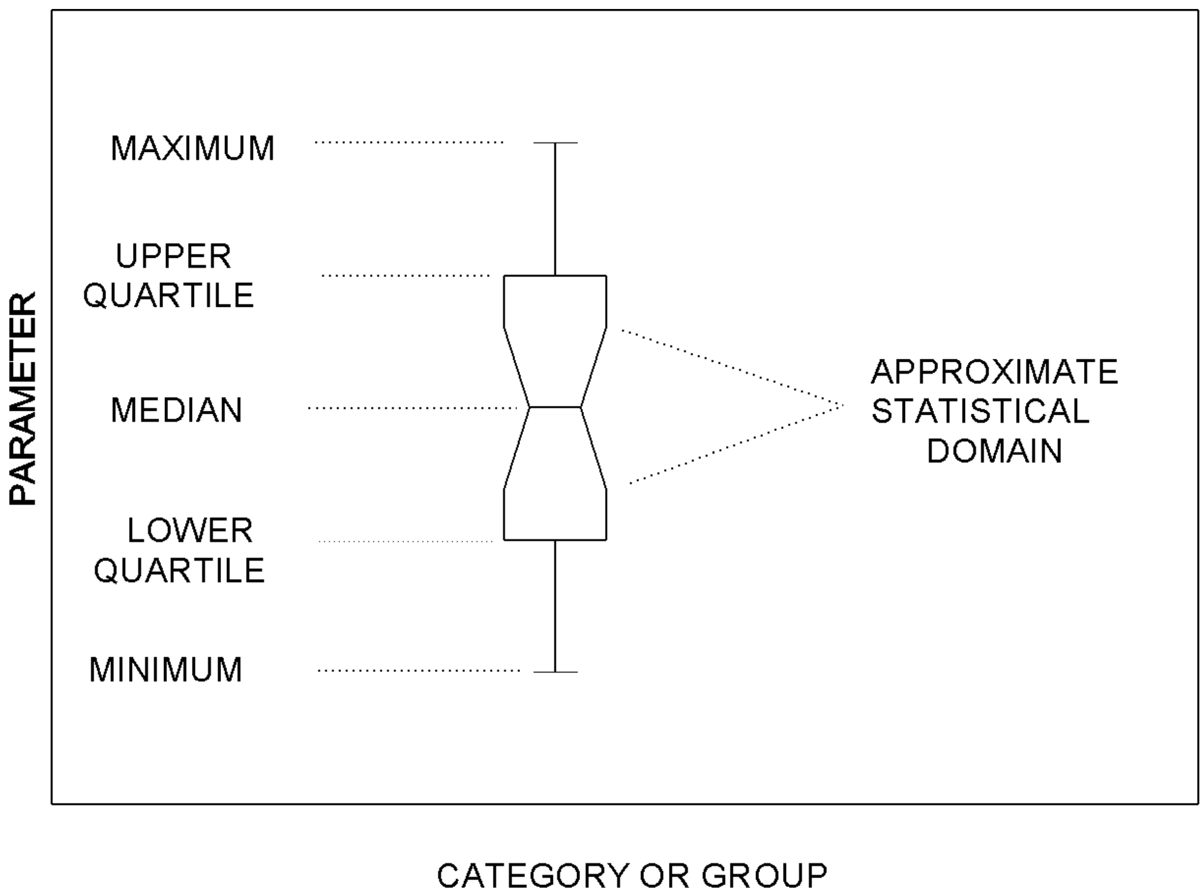


Figure 4. Explanation of Box and Whisker Plots.

Average concentrations and loadings for the period of record are seen in **Table 4** and **Figures 5-6**. Median total phosphorus concentrations of 0.02 mg P/l and 0.04 mg P/l in Tyner and Peacheater Creeks, respectively, were above 0.005 mg P/l, a critical level for phosphorus above which problems can occur (Sawyer and McCarty 1978). Median total nitrogen concentrations were above 300 μg/l, Sawyer's (1947) limit indicating a high probability of nuisance algae growth during the growing season. Average concentrations and loadings are higher than medians, indicating outliers much higher than normal skewed the distributions. This suggests several samples were collected during or soon after runoff events when loadings were high. Although concentrations were higher in Peacheater Creek than in Tyner Creek for all nutrient constituents measured, the differences were not statistically significant (**Table 5**).

Nutrients are of concern due to their impact on primary productivity; high concentrations increase algal growth in the river and Lake Tenkiller, decreasing water clarity and affecting a host of other parameters such as oxygen and pH dynamics. Not only are the concentrations of individual nutrients important, but also ratios of nutrients relative to one another. Algae require approximately fifteen parts nitrogen to one part phosphorus, and ratios of nitrogen to phosphorus above or below this number can affect dominance patterns of algae. Certain species of bluegreen algae can fix atmospheric nitrogen and thus don't require as much water-borne nitrogen as other algal species. Thus, bluegreen algae are more likely to be dominant at TN:TP ratios < 15. Bluegreen algae are undesirable due to their propensity to form nuisance blooms and cause taste and odor problems. TN:TP ratios in Tyner and Peacheater Creek were both well above 15, promoting dominance by other forms of algae such as green algae and diatoms. The TN:TP ratio is slightly less in Peacheater than Tyner Creek.

No point source discharges exist in either watershed and thus nutrients in the paired watersheds stem entirely from nonpoint sources. These sources can be broken into natural or background loading and anthropogenic nonpoint sources. The extent to which loading is due to anthropogenic activities relates to the feasibility of limiting nutrient loading. One method of estimating background or natural loading of phosphorus is to use a morphoedaphic index (MEI). Vighi and Chiaudani (1985) developed the MEI by relating phosphorus concentrations in relatively unimpacted waters to easily measured chemical parameters such as alkalinity and conductivity. **Figure 7** displays suggested background loadings to Peacheater and Tyner Creeks based upon MEI calculations. Application of a MEI to Peacheater and Tyner Creek data indicated 30% of the median phosphorus loading in Tyner Creek and 20% of the median phosphorus loading was natural or background loading. This suggested implementation of best management practices could have a significant impact on phosphorus loads in Tyner and Peacheater Creeks and thus to the Illinois River and Lake Tenkiller.

Table 4. Nutrient Concentrations and Loadings for Peacheater and Tyner Creeks.

		Tyner Creek @ Autosampler	Peacheater Creek @ Hwy. 62
oP Concentration (mg/l)	Average	0.01	0.03
	Median	0.01	0.02
oP Daily Load (kg/day)	Average	1.22	2.98
	Median	0.41	0.69
oP Yearly Load (kg/yr.)	Average	446.41	1088.01
	Median	148.17	252.72
TP Concentration (mg/l)	Average	0.02	0.04
	Median	0.02	0.03
TP Daily Load (kg/day)	Average	1.95	6.33
	Median	0.86	1.17
TP Yearly Load (kg/yr.)	Average	709.95	2311.55
	Median	313.06	427.02
% oP	Average	64.79	71.79
	Median	58.82	66.67
NO_3 Concentration (mg/l)	Average	2.67	3.27
	Median	2.77	3.17
NO_3 Daily Load (kg/day)	Average	199.03	294.81
	Median	102.70	87.51
NO_3 Yearly Load (kg/yr.)	Average	72646.23	107606.38
	Median	37485.2	31940.8
NO_2 Concentration (mg/l)	Average	0.002	0.005
	Median	0.002	0.002
NO_2 Daily Load (kg/day)	Average	0.14	1.00
	Median	0.06	0.07
NO_2 Yearly Load (kg/yr.)	Average	50.15	365.20
	Median	23.04	27.31
TKN Concentration (mg/l)	Average	0.17	0.22
	Median	0.17	0.18
TKN Daily Load (kg/day)	Average	13.63	39.20
	Median	4.77	6.13
TKN Yearly Load (kg/yr.)	Average	4973.96	14306.85
	Median	1739.94	2239.03
TN* Concentration (mg/l)	Average	2.87	3.53
	Median	2.98	3.45
TN* Daily Load (kg/day)	Average	217.32	348.15
	Median	111.60	120.98
TN* Yearly Load (kg/yr.)	Average	79321.57	127075.8
	Median	40732.7	44157.5
TN:TP	Average	134.86	104.90
	Median	127.55	87.6

*TN = TKN + NO_3 + NO_2

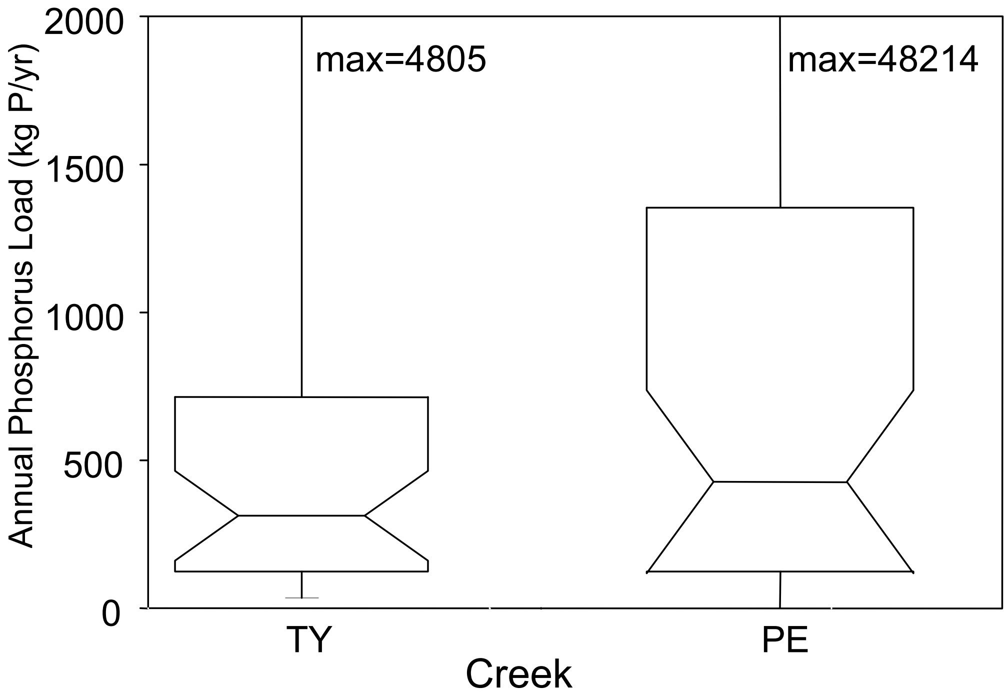


Figure 5. Annual Total Phosphorus Loads to Peacheater and Tyner Creeks.

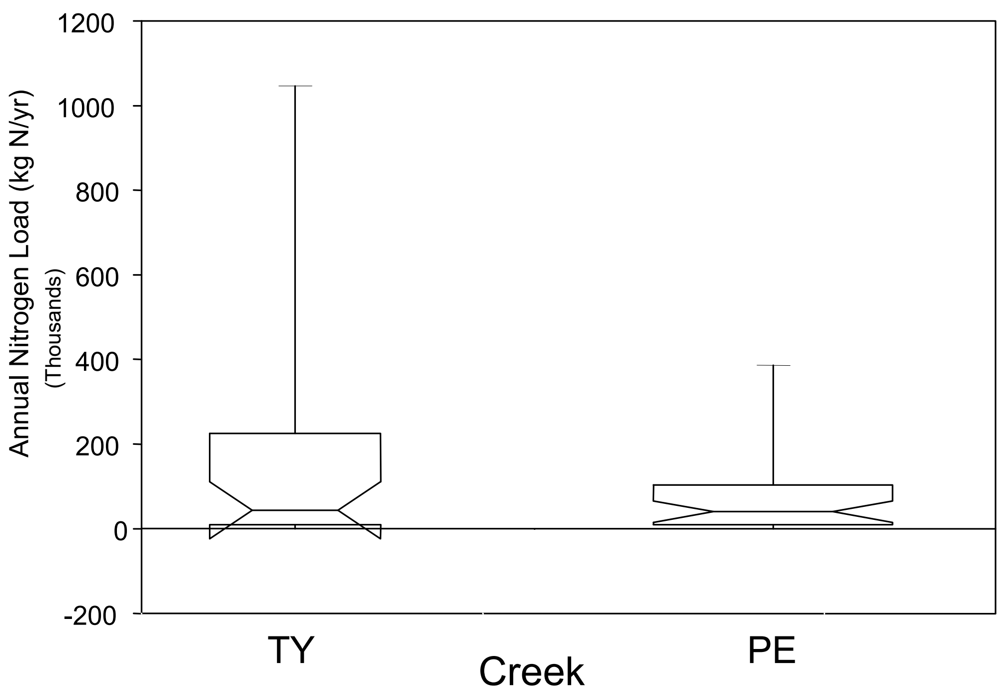


Figure 6. Annual Total Nitrogen Loads to Peacheater and Tyner Creeks.

Table 5. Statistics for Comparability of Nitrogen and Phosphorus in Peacheater and Tyner Creeks.

Parameter	P value	df	Conclusion
Total Phosphorus Concentrations	0.34	119	No Significant Difference
Orthophosphorus Concentrations	0.31	119	No Significant Difference
Nitrate Concentrations	0.11	123	No Significant Difference
Nitrite Concentrations	0.95	123	No Significant Difference
Total Kjeldahl Nitrogen Concentrations	0.84	112	No Significant Difference
Total Phosphorus Loads	0.80	74	No Significant Difference
Total Nitrogen Loads	0.71	58	No Significant Difference

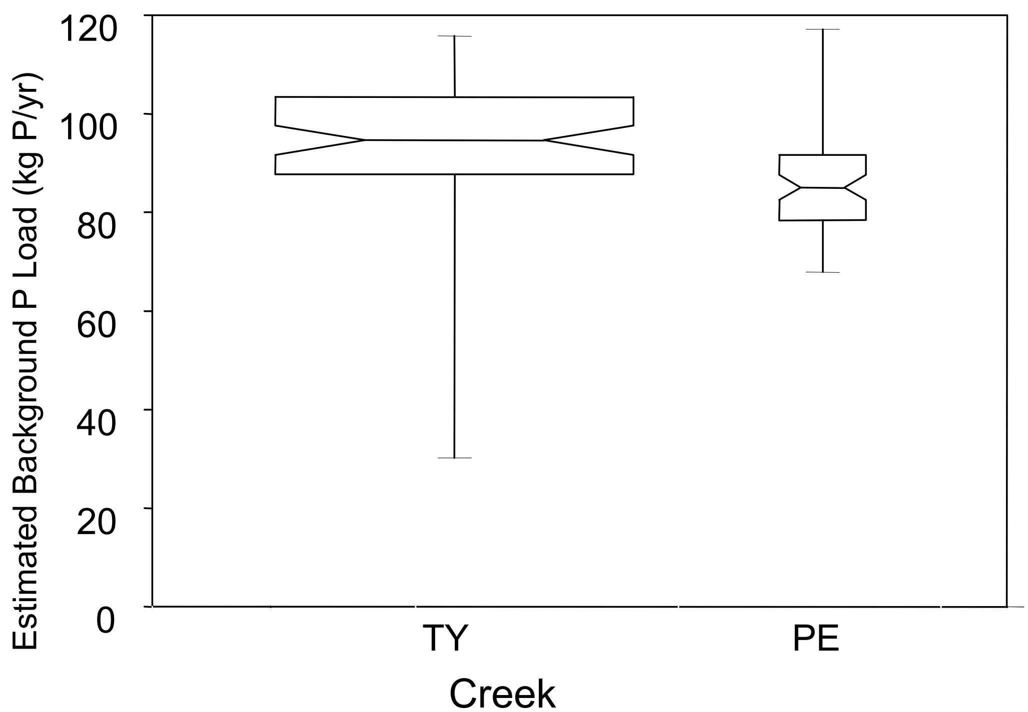


Figure 7. Background Total Phosphorus Loads to Peacheater and Tyner Creeks.

Evaluation of nutrient concentrations and loadings in Peacheater and Tyner Creeks led to several conclusions. First, nutrient concentrations in Peacheater and Tyner Creeks are sufficient to indicate potentially negative impacts to both creeks, as well as the Illinois River and Lake Tenkiller. Secondly, calculations indicate approximately 20-30% of the phosphorus load is due to natural loading, suggesting installation of best management practices could have a beneficial impact on the systems. Finally, nutrient concentrations and loadings in Tyner and Peacheater Creeks were not significantly different, suggesting a good basis for implementation to proceed.

STREAMBANK EROSION

Bank erosion and the subsequent deposition of eroded material is a primary problem in the Illinois River Basin. The water quality related problems stem not only from the addition of nutrients and turbidity from the sediment, but also the loss of habitat due to sediment deposition. Eroded material fills in critical habitat for many aquatic species in the Illinois River and its tributaries. Deleterious effects of streambank erosion are notable throughout the Illinois River Watershed and in Lake Tenkiller.

These problems are notable in Peacheater and Tyner Creeks where loss and mismanagement of riparian areas have resulted in substantial streambank erosion. Although the problem was believed to be substantial, streambank erosion had not been quantified either in terms of amount of material eroded or nutrient contribution from eroded material. Thus, the OCC monitored streambank erosion in Peacheater and Tyner Creeks to better understand the extent of the problem. Results were compared between the two creeks to establish a relationship in streambank erosion and sediment nutrient concentrations prior to implementation of best management practices.

METHODS

Bank Erosion Measurement

Streambank erosion was measured at seven sites on Tyner Creek and four sites on Peacheater Creek. Erosion measurements were taken at permanent benchmarks set on each bank of the stream cross section. A tape was connected to each benchmark. A drop (cord and plumb bob) was placed at a known interval from the reference benchmark. A ruled riser was held plumb along the drop from the stream bottom to above the top edge of the bank. Vertical and horizontal measurements were recorded wherever the soil type or bank slope changed. These measurements were taken with a ruled level. **Figure 8** illustrates the procedure.

The measurements were completed quarterly at each benchmark using identical procedures. Erosion rates/volumes were calculated using the average soil layer thickness and the horizontal erosion distance over the one-year period, multiplied by the eroded bank length.

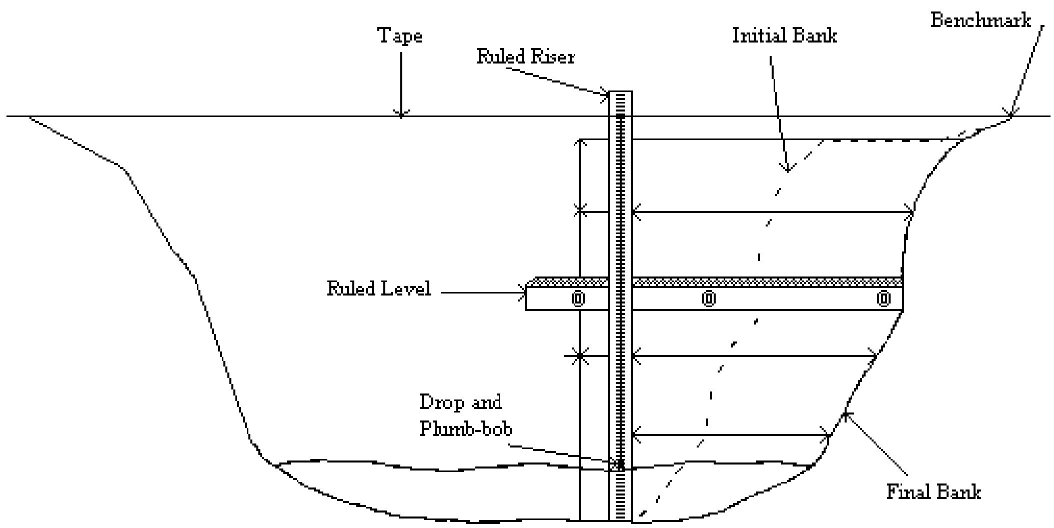


Figure 8. Bank Erosion Measurement.

Bank Soil Nutrient Sampling

Soil samples were taken from each soil layer based on the given layer's proportion of the total cross-sectional erosion area. The layer that lost the largest area of soil was arbitrarily set at 64 ounces of soil sample volume. This volume was chosen to ensure enough fine material sample volume for laboratory analysis. Each soil layer with less eroded surface area composed the equal proportion to which the layer eroded. For example, if the subsoil 1 (SS1) layer lost 4 ft^2 and the topsoil (TS) lost 2 ft^2 of soil, then 64 ounces of soil were taken from the SS1 and 21 ounces were taken from the TS. The samples were processed through a 2 mm mesh and the volume of fines was recorded. The fine material was then packed, placed on ice, and shipped to the Oklahoma City-County Health Department Laboratory for nutrient analysis. The volume of coarse material was measured through volume displacement and recorded.

Quantifying Nutrient Loading

Nutrient loading was calculated using an actual measured soil density constant, bank erosion volume, and bank soil nutrient concentration.

$$NL\left(\frac{\frac{kg}{yr}}{bank}\right) = \frac{\left(SD\left(\frac{kg}{ft^3}\right) \times EV\left(\frac{ft^3}{yr}\right) \times N\left(\frac{mg}{kg}\right)\right)}{1{,}000{,}000kg}$$

where: NL: nutrient load from bank
SD: soil density constant

EV: erosion volume
N: nutrient concentration

Soil Density Constant

The soil density constant (SD) was calculated from actual soil measurements. One quart of topsoil and one quart of subsoil was collected from one bank at Tyner Creek and one bank at Peacheater Creek and processed (sieved) identically to those sent to the laboratory for analysis. The processed soil was then weighed on a triple beam balance at the NSU Biology Department. The average weight was used to calculate the soil density constant.

Subsoil: Tyner Creek (TB5) 1 quart = 1007 grams
Peacheater Creek (PE5) 1 quart = 1006.5 grams

Topsoil: Tyner Creek (TB5) 1 quart = 965 grams
Peacheater Creek (PE5) 1 quart = 894 grams

Average = 968 g/qt

$$SD = 0.968\left(\frac{kg}{0.25gal}\right)\times 1\left(\frac{gal}{231in^3}\right)\times 1728\left(\frac{in^3}{ft^3}\right) = 28.96\left(\frac{kg}{ft^3}\right)$$

Average Nutrient Loading (kg/ft^2/yr)

Average nutrient loading was calculated by dividing the total loading of the bank by the surface area of the bank (length * average height).

The average nutrient loading for lower Tyner Creek, upper Tyner Creek, and Peacheater Creek was calculated by dividing the total loading by all banks monitored in each stream by the total bank surface of the monitored banks.

Bank Material Composition

The proportion of fine and coarse material was measured at each monitored bank during nutrient sampling. The percent fines (<2mm) and percent coarse (>2mm) was calculated for each stream section by dividing the estimated volume of each by the total estimated volume of both material types from all banks monitored.

$$\%EF = \left(\frac{EF}{TEM}\right)\times 100$$

where: %EF: percent eroded fines
EF: estimated volume eroded fines
TEM: total estimated volume eroded material

RESULTS

Nutrient Loading

Nutrient loadings and average amount of eroded sediment are seen in **Figures 9-14**. Average nutrient loadings and average sediment eroded suggested significant nutrient loading results from bank erosion. Average nutrient and sediment loadings from the 3 reaches are summarized in **Table 6**. Nutrient loadings were log-transformed and tested for differences between the two creeks using a student's t-test. Results of the t-test are seen in **Table 7**. Peacheater and Tyner Creek nutrient loadings were not significantly different except for nitrate- and nitrite- nitrogen loadings. Nitrate loadings were significantly greater in Tyner than in Peacheater Creek and nitrite loadings were significantly greater in Peacheater than in Tyner Creek.

The percentage of the total nutrient load contributed by bank erosion cannot be calculated from these data as these values could not measure all eroding bank material. In addition, measurements were made on solid-phase material while instream loading calculations were made from waterbourne concentrations, excluding bedload material. Exclusion of bedload concentrations from the calculation underestimates the total load and overestimates the percentage bank erosion contributes to the total loading. However, the data suggest a significant contribution of sediment and nutrients to both systems due to bank erosion (15 – 110 % of the annual TP load based on instream concentrations). The lack of significant differences (except nitrate and nitrite) between the two systems suggests Peacheater and Tyner Creek are a good pair of streams to implement a treatment/control- type study.

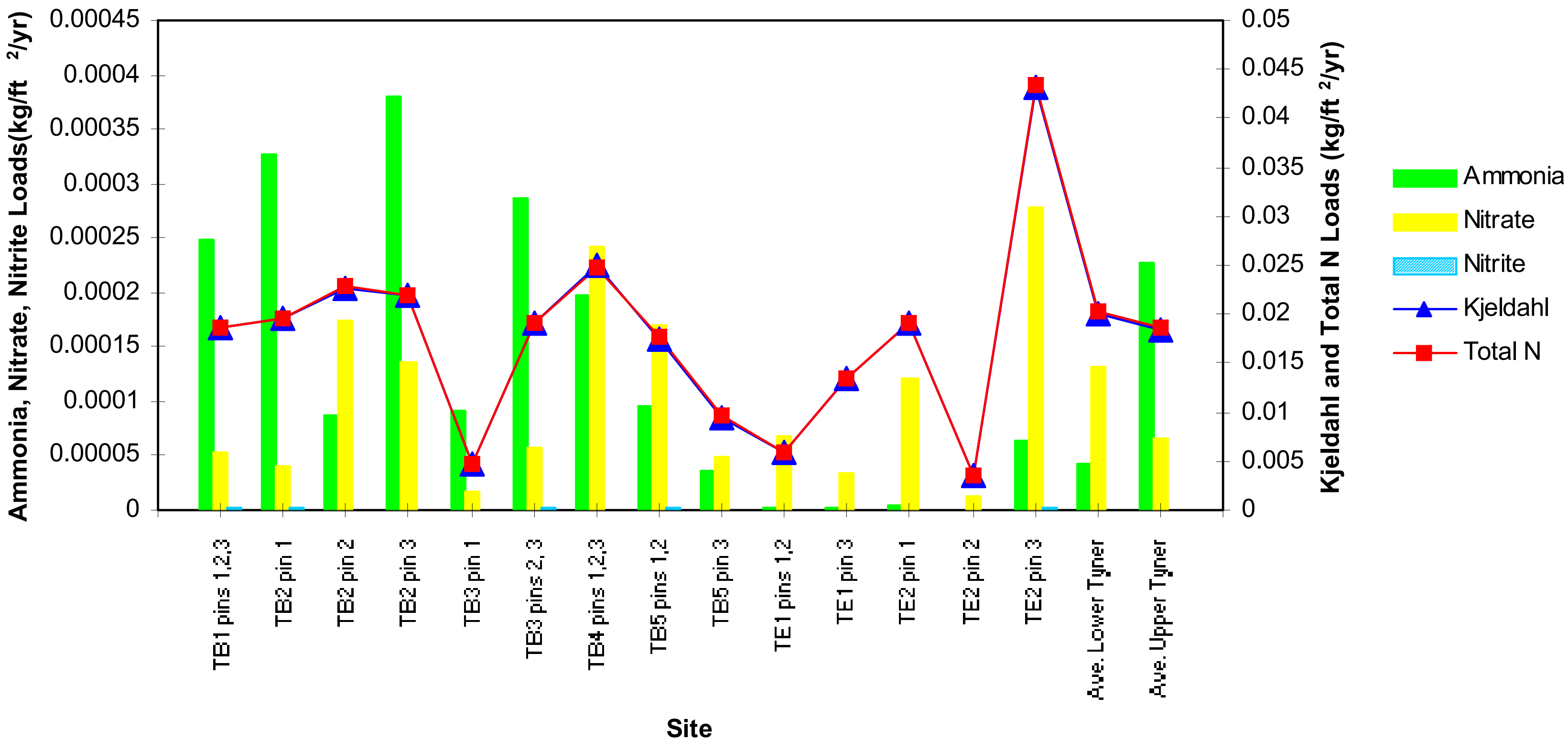


Figure 9. Nitrogen Loadings in Tyner Creek Streambank Sediments.

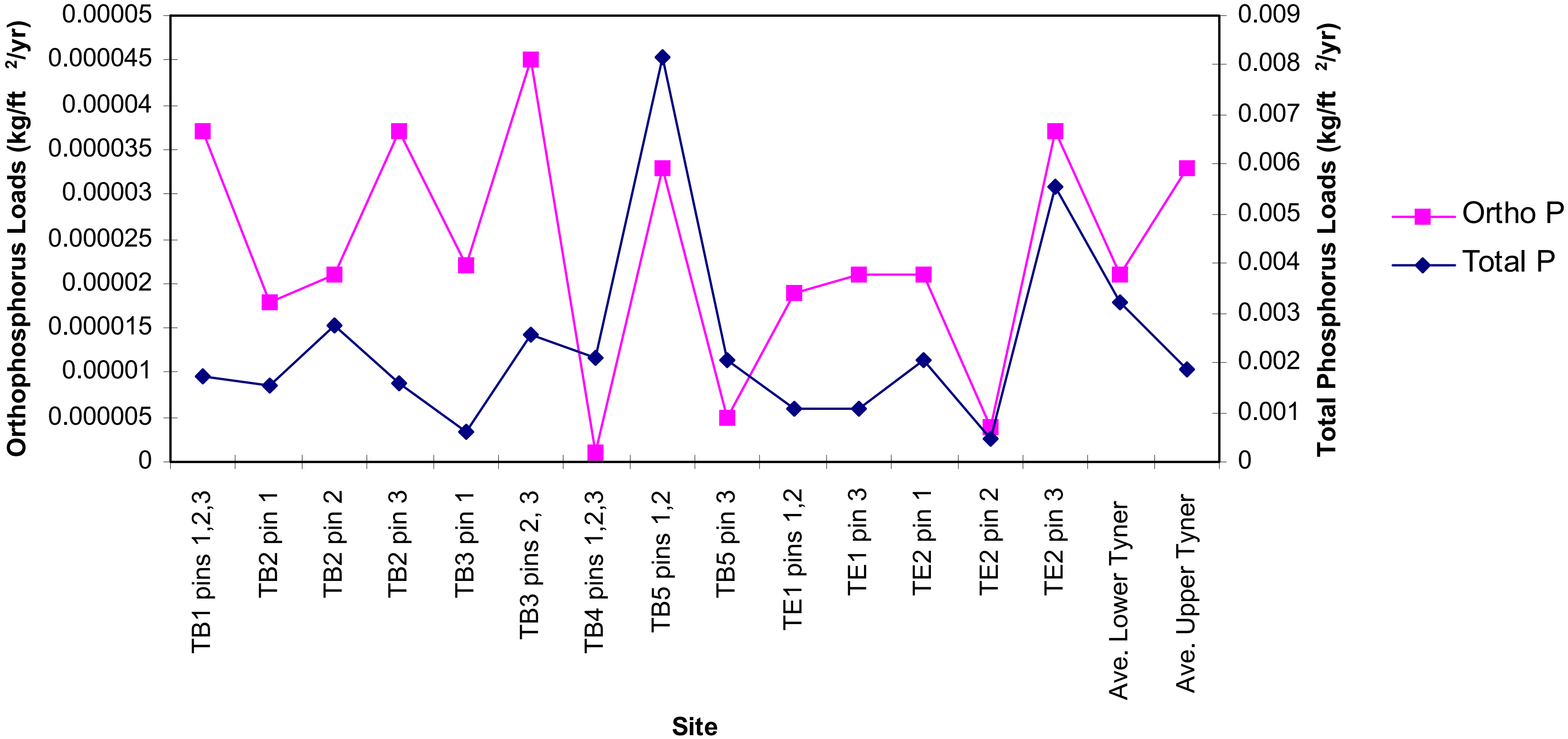


Figure 10. Phosphorus Loadings in Tyner Creek Streambank Sediments.

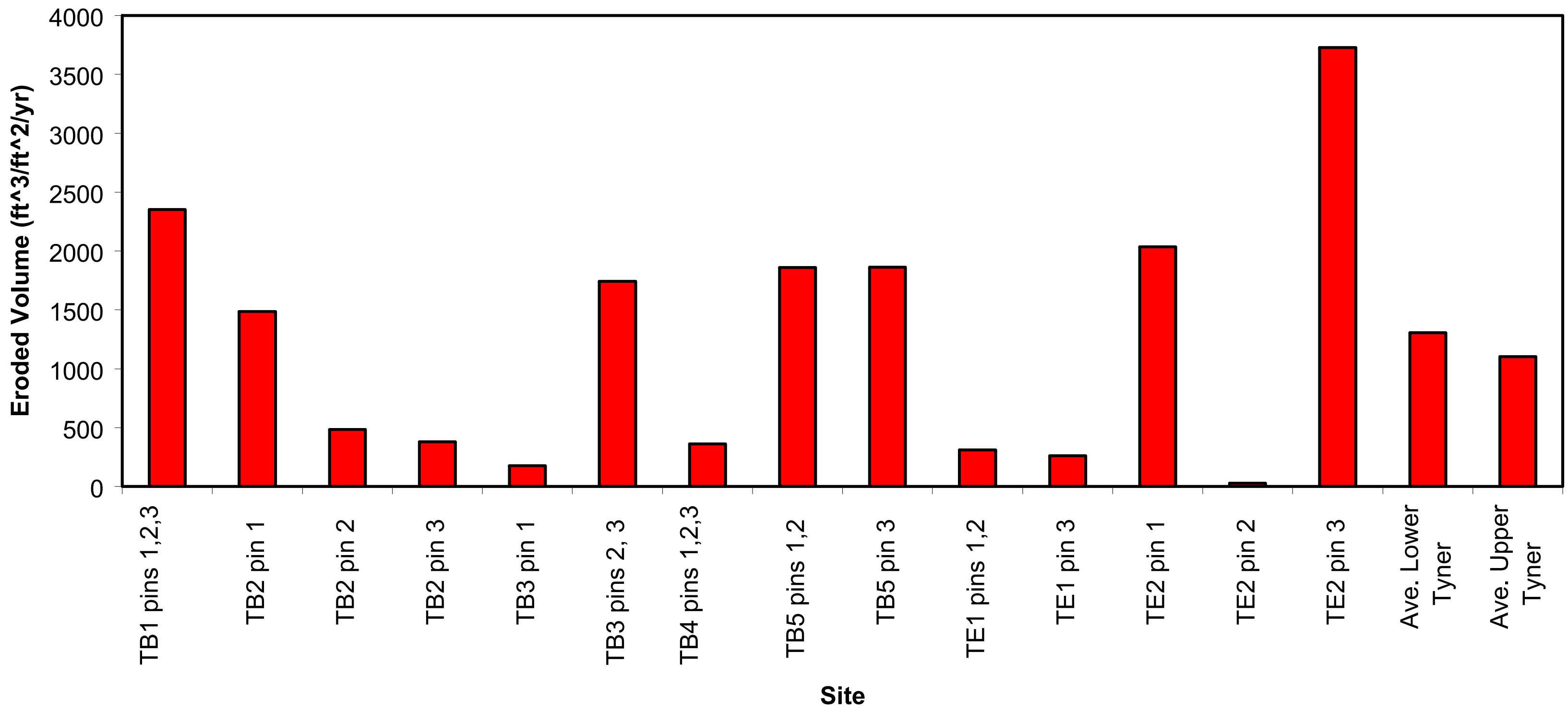


Figure 11. Amount of Eroded Sediment from Streambanks in Tyner Creek.

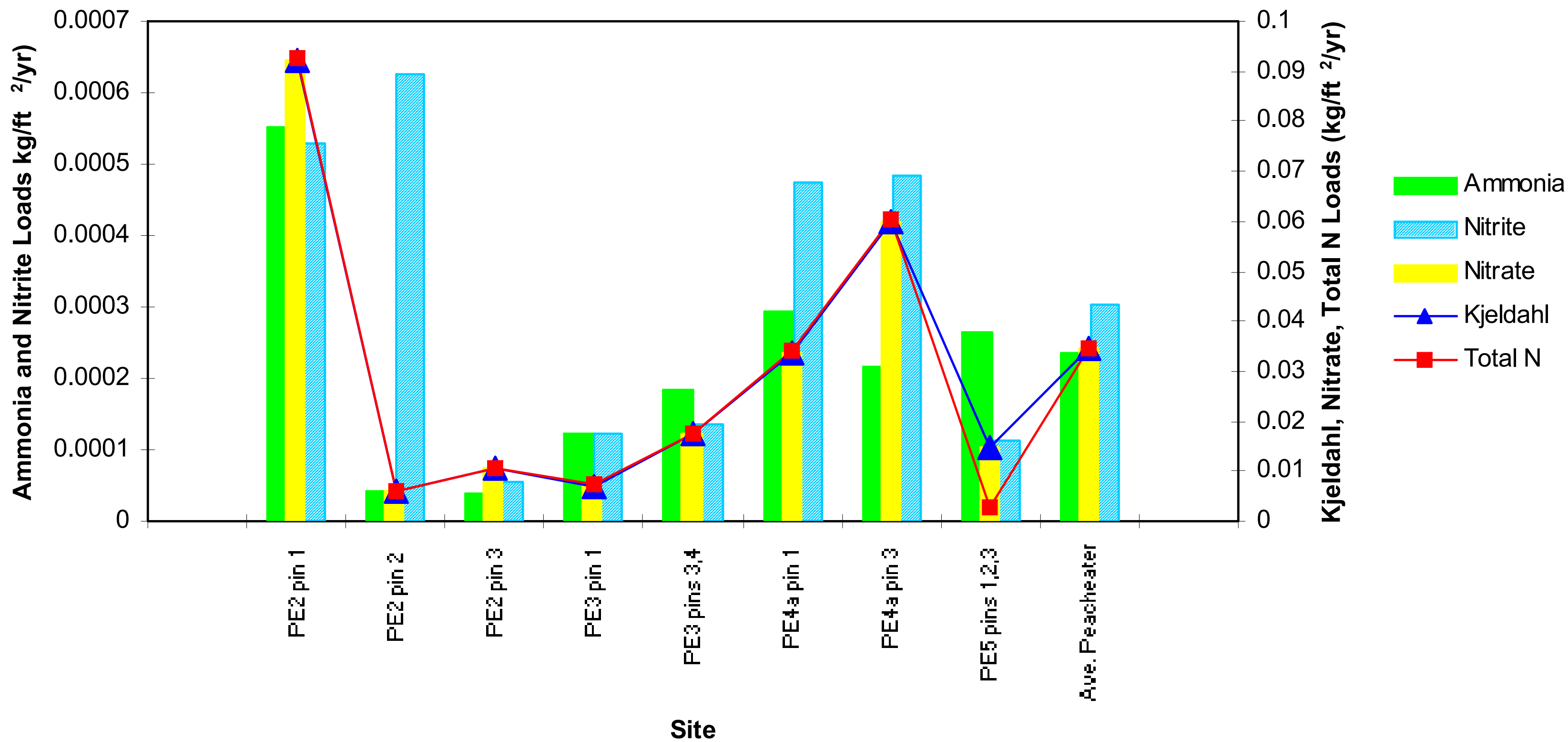


Figure 12. Nitrogen Loadings in Peacheater Creek Streambank Sediments.

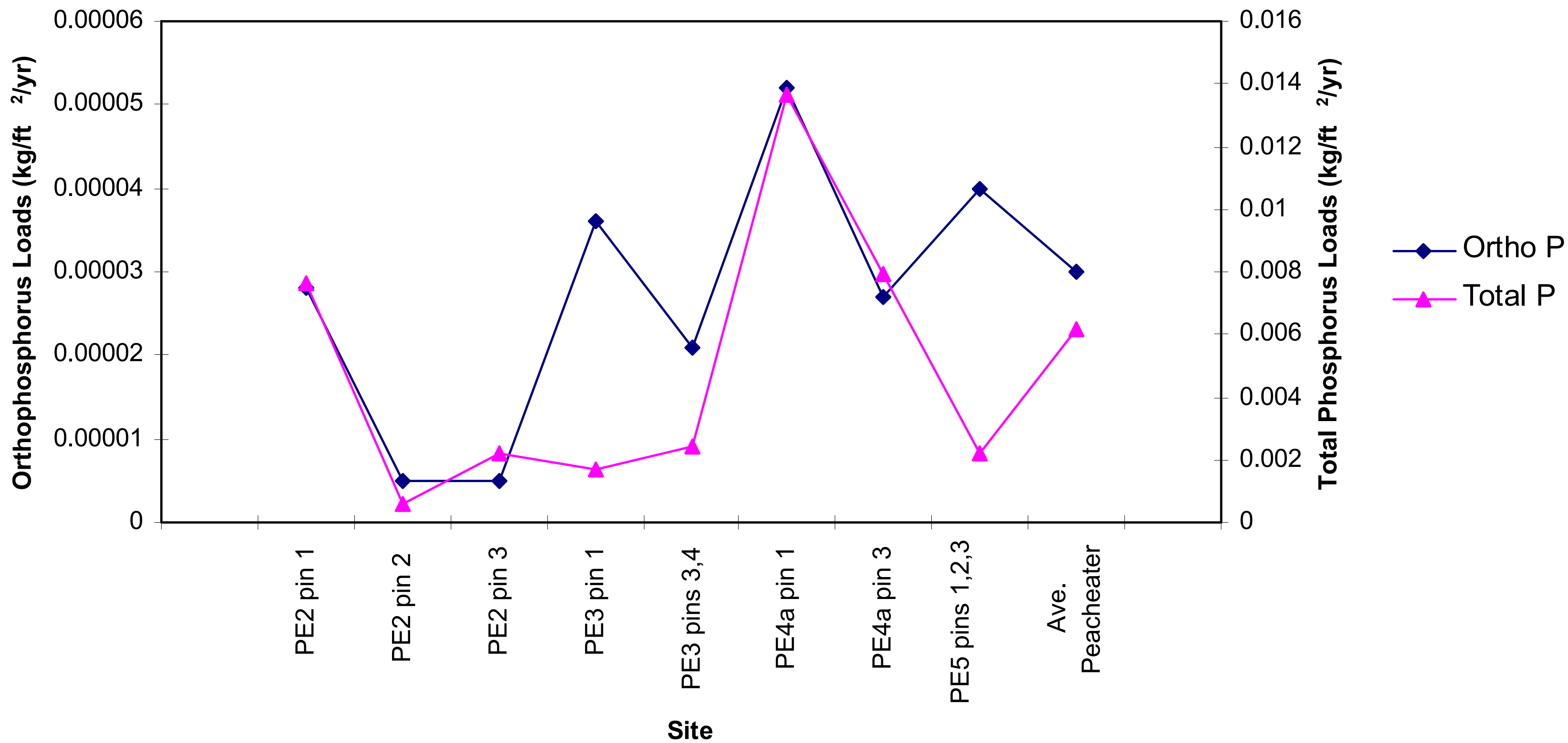


Figure 13. Phosphorus Loadings in Peacheater Creek Streambank Sediments.

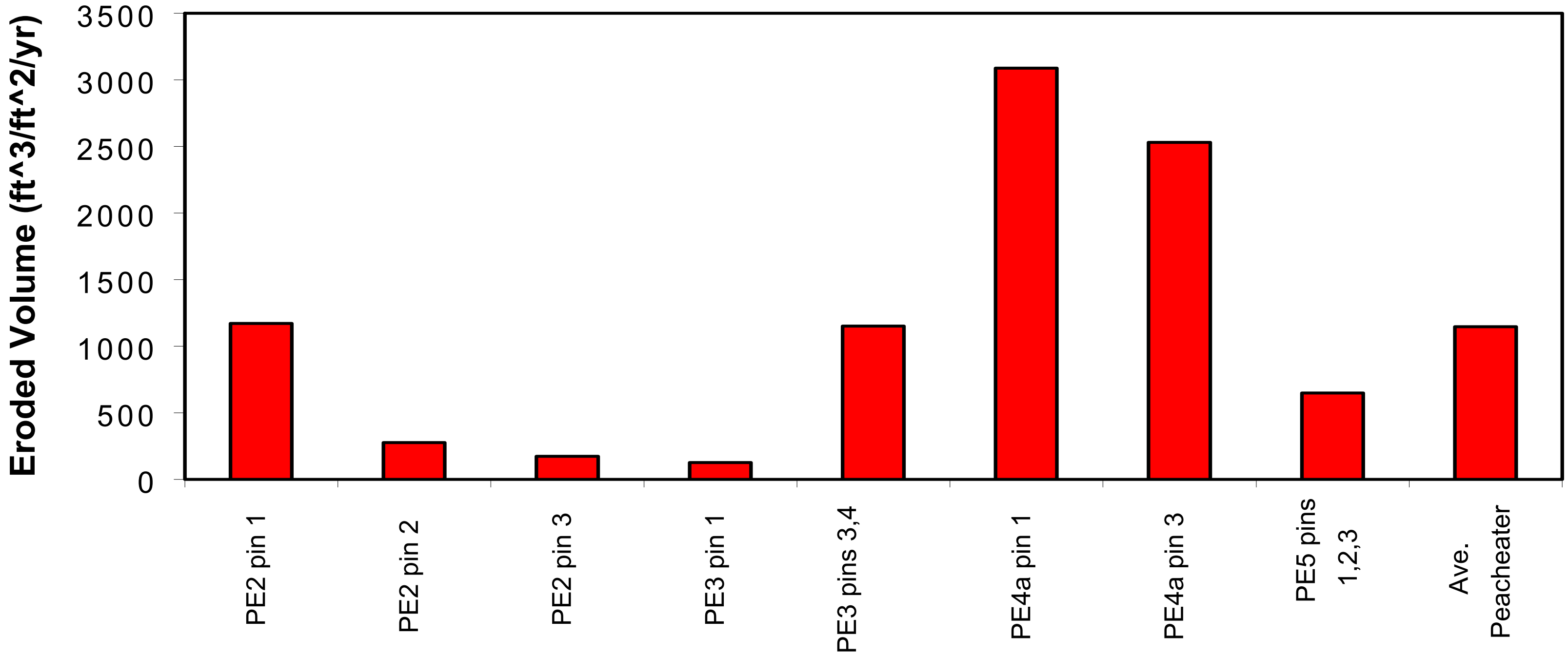


Figure 14. Amount of Eroded Sediment from Streambanks in Peacheater Creek.

Table 6. Average Nutrient and Sediment Loadings for Three Stream Reaches.

Parameter	Lower Tyner Creek	Upper Tyner Creek	Peacheater Creek
Ammonia (kg/ft^2/yr)	0.000043	0.000228	0.000235
Nitrate (kg/ft^2/yr)	0.000132	0.000065	0.00000408
Nitrite (kg/ft^2/yr)	0.000001	0.000001	0.000302
Total Kjeldahl Nitrogen (kg/ft^2/yr)	0.020158	0.018455	0.034479
Total Nitrogen (kg/ft^2/yr)	0.020269	0.01859	0.034785
Orthophosphorus (kg/ft^2/yr)	0.000021	0.000033	0.00003
Total Phosphorus (kg/ft^2/yr)	0.003227	0.001877	0.006173
Sediment (ft^3/ft^2/yr)	1304.6	1102.23	1145.51

Table 7. Results of Student's t-test Comparisons.

Parameter	df	p value	Significance	Direction of Significance
Ammonia	20	0.13	No significant difference	NA
Nitrate	20	1.0×10^{-7}	Significant difference	Peacheater < Tyner Creek
Nitrite	20	1.7×10^{-9}	Significant difference	Peacheater > Tyner Creek
Total Kjeldahl Nitrogen	20	0.40	No significant difference	NA
Total Nitrogen	20	0.78	No significant difference	NA
Orthophosphorus	20	0.64	No significant difference	NA
Total Phosphorus	20	0.15	No significant difference	NA
Volume Eroded Sediment	20	0.99	No significant difference	NA

COMPARISON OF IN-STREAM HABITAT

The presence of suitable habitat is critical to the survival of biological communities in streams. Comparison of habitat available and biota present may provide insight to whether water quality, habitat availability, or some other factor limits the biological community. As part of the pre-implementation phase to the Peacheater Creek Paired Watershed Project, it is important to establish a relationship between habitat in Peacheater and Tyner Creeks.

Comparison of the habitat metrics (**Table 8 - 9**) suggests little difference between overall habitat measurements in Peacheater and Tyner Creeks. For purposes of general comparison, scores reported in **Table 8** represent the average of scores collected from multiple sites on each creek. Peacheater and Tyner Creeks received identical ratings throughout the sampling period for the amount and type of in-stream cover and type of pool bottom substrate. Scores differed on a single date for Percent Canopy Cover Shading and Percent Rocky Runs and Riffles and on two dates for Pool Variability, Channel Alteration, and Streamside Cover. The greatest amount of variability between Peacheater and Tyner Creeks concerned Bank Stability and Bank Vegetation Stability, where ratings differed on three dates or 38% of the dates sampled. This variability is clearer when the actual metrics for percent-eroded bank, height eroded, and bank slope are compared between the two creeks (**Table 10**). Although the total percent eroded is generally similar between creeks, larger differences exist on a few dates. This overall similarity suggests a good relationship between Peacheater and Tyner Creeks prior to implementation of Best Management Practices that in turn, will help suggest changes in habitat in the treatment watershed result from implementation, rather than some other factor.

The similarity in habitat between Peacheater and Tyner Creeks is also evident in **Figure 15 - 26**. **Figure 15** compares the quartile distribution of thalweg depths in Peacheater and Tyner Creeks. The thalweg depth is important because depth influences physico-chemical properties of water such as temperature and dissolved oxygen concentrations, which, in turn, influence biota (**Hynes 1972**). No significant difference in thalweg depth is evident between Peacheater and Tyner Creeks.

Stream width is a function of frequency and magnitude of flow, size and type of transported sediment, and the bed and bank materials of the channel (**Rosgen 1996**). Channel width may alter in response to one of several factors; direct channel disturbance such as channelization, changes in riparian vegetation that may alter susceptibility to streambank erosion, changes in stream flow regime due to watershed changes, and changes in the sediment regime (**Rosgen 1996**).

Table 8. Summary of Habitat Metrics of Peacheater and Tyner Creeks.

Stream	Date	In-stream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Rocky Runs and Riffles	Channel Alteration	Bank Stability	Bank Vegetation Stability	Streamside Cover
Peacheater	11/30/93	15.4	19.5	14.8	13.9	16.5	7.1	7.1	4.2	4.9
Tyner	12/22/93	14.5	18.4	14.9	12.6	16.5	8.2	7.0	4.0	4.9
Peacheater	8/22/96	18.4	19.5	10.3	8.1	15.0	10.6	7.6	6.8	4.0
Tyner	8/30/96	17.1	18.2	8.8	12.4	11.0	10.5	6.4	4.8	5.7
Tyner	9/24/96	17.0	19.0	5.9	11.8	9.5	10.9	4.7	4.2	4.6
Peacheater	10/24/96	18.8	19.5	18.2	14.0	15.6	0.8	5.8	2.5	6.0
Tyner	10/24/96	18.1	18.2	14.5	11.3	14.1	3.5	6.1	3.3	6.9
Peacheater	12/27/96	19.2	19.3	14.6	13.9	18.5	1.2	5.8	2.2	4.9
Tyner	12/30/96	18.9	17.8	14.8	11.5	17.9	4.2	6.3	2.8	4.6
Peacheater	1/23/97	19.2	19.2	18.2	13.9	16.8	1.2	5.5	2.2	4.9
Tyner	1/24/97	18.3	18.0	14.4	11.4	14.6	2.9	5.4	2.7	4.6
Peacheater	3/19/97	19.2	20.0	14.7	13.8	20.0	1.2	8.5	4.4	4.9
Tyner	3/18/97	18.8	18.6	13.1	11.4	19.8	3.2	6.6	2.3	4.5
Peacheater	4/29/97	19.0	19.6	13.4	14.3	17.7	0.3	6.8	2.5	6.4
Tyner	4/30/97	18.9	19.0	13.6	11.3	19.3	1.1	6.7	2.3	4.5
Peacheater	5/28/97	18.9	19.5	13.2	14.5	17.4	0.0	6.8	2.5	6.4
Tyner	5/23/97	18.3	19.4	13.5	11.3	16.1	1.0	5.7	2.4	4.5

Table 9. Qualitative Summary of Habitat Metrics for Peacheater and Tyner Creeks.

Stream	Date	In-stream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Rocky Runs and Riffles	Channel Alteration	Bank Stability	Bank Vegetation Stability	Streamside Cover
Peacheater	11/30/93	adequate	optimal	adequate	adequate	optimal	fair	adequate	fair	fair
Tyner	12/22/93	adequate	optimal	adequate	adequate	optimal	adequate	adequate	fair	fair
Peacheater	8/22/96	optimal	optimal	fair	fair	adequate	adequate	adequate	adequate	fair
Tyner	8/30/96	optimal	optimal	fair	adequate	adequate	adequate	adequate	fair	fair
Tyner	9/24/96	optimal	optimal	fair	adequate	fair	adequate	fair	fair	fair
Peacheater	10/24/96	optimal	optimal	optimal	adequate	adequate	poor	fair	poor	adequate
Tyner	10/24/96	optimal	optimal	adequate	adequate	adequate	poor	adequate	fair	adequate
Peacheater	12/27/96	optimal	optimal	adequate	adequate	optimal	poor	fair	poor	fair
Tyner	12/30/96	optimal	optimal	adequate	adequate	optimal	fair	adequate poor	fair	
Peacheater	1/23/97	optimal	optimal	optimal	adequate	optimal	poor	fair	poor	fair
Tyner	1/24/97	optimal	optimal	adequate	adequate	adequate	poor	fair	poor	fair
Peacheater	3/19/97	optimal	optimal	adequate	adequate	optimal	poor	adequate	fair	fair
Tyner	3/18/97	optimal	optimal	adequate	adequate	optimal	poor	adequate	poor	fair
Peacheater	4/29/97	optimal	optimal	adequate	adequate	optimal	poor	adequate	poor	adequate
Tyner	4/30/97	optimal	optimal	adequate	adequate	optimal	poor	adequate	poor	fair
Peacheater	5/28/97	optimal	optimal	adequate	adequate	optimal	poor	adequate	poor	adequate
Tyner	5/23/97	optimal	optimal	adequate	adequate	optimal	poor	fair	poor	fair

Table 10. Habitat Metrics for Peacheater and Tyner Creeks.

Stream	Date	ave cover brl	ave cover sav	ave cover eav	ave cover tv	ave cover cb	% canopy	ave width wat	% erode left	% erode right	Total % eroded	erode ht left	erode ht right	left slope	right slope
Peacheater	11/30/93	0.03	0.10	0.85	0.01	12.43	23.66	6.38	16.72	19.92	36.64	0.41	0.48	43.94	42.89
Tyner	12/22/93	0.05	0.00	0.89	0.05	5.71	22.89	7.66	24.92	13.96	38.88	0.65	0.39	51.97	42.95
Peacheater	08/22/96	0.02	0.00	1.99	0.21	71.37	12.05	5.11	7.75	9.35	17.10	0.24	0.33	51.20	49.30
Tyner	08/30/96	0.05	0.00	0.96	0.25	51.76	22.63	5.34	19.72	13.00	32.72	0.46	0.28	53.91	50.41
Peacheater	10/24/96	0.01	0.00	0.00	0.01	83.45	25.35	5.86	28.15	24.78	52.93	1.06	0.45	52.55	52.55
Tyner	11/04/96	0.05	0.00	0.01	0.06	71.44	19.89	6.89	26.75	19.71	46.46	0.60	0.40	55.96	50.82
Peacheater	12/27/96	0.04	0.00	0.00	0.00	86.92	25.15	5.90	31.00	25.80	56.80	0.48	0.48	53.00	52.60
Tyner	12/31/96	0.06	0.00	0.00	0.02	85.23	20.11	6.52	29.00	22.25	51.25	0.59	0.38	56.29	50.54
Peacheater	01/31/97	0.02	0.00	0.00	0.00	87.83	24.95	4.29	31.10	25.90	57.00	0.47	0.47	52.85	52.85
Tyner	01/29/97	0.12	0.00	0.00	0.01	72.34	19.89	4.89	28.68	23.54	52.21	0.58	0.39	56.18	50.96
Peacheater	03/20/97	0.00	0.00	0.00	0.00	86.30	24.38	8.70	19.13	17.63	36.75	0.21	0.22	25.44	35.25
Tyner	03/25/97	0.00	0.00	0.00	0.00	81.93	19.54	8.65	33.25	21.93	55.18	0.62	0.37	53.54	48.61
Peacheater	04/29/97	0.01	0.00	0.00	0.01	84.82	25.15	6.72	26.45	24.00	50.45	0.37	0.40	44.05	49.45
Tyner	04/30/97	0.00	0.00	0.00	0.01	82.42	19.46	8.45	31.96	21.79	53.75	0.59	0.38	53.64	49.66
Peacheater	05/28/97	0.00	0.00	0.00	0.00	82.56	25.65	5.94	26.25	23.20	49.45	0.38	0.37	43.65	48.50
Tyner	05/23/97	0.00	0.00	0.00	0.01	69.92	19.54	6.79	32.07	21.71	53.79	0.60	0.37	53.57	48.79

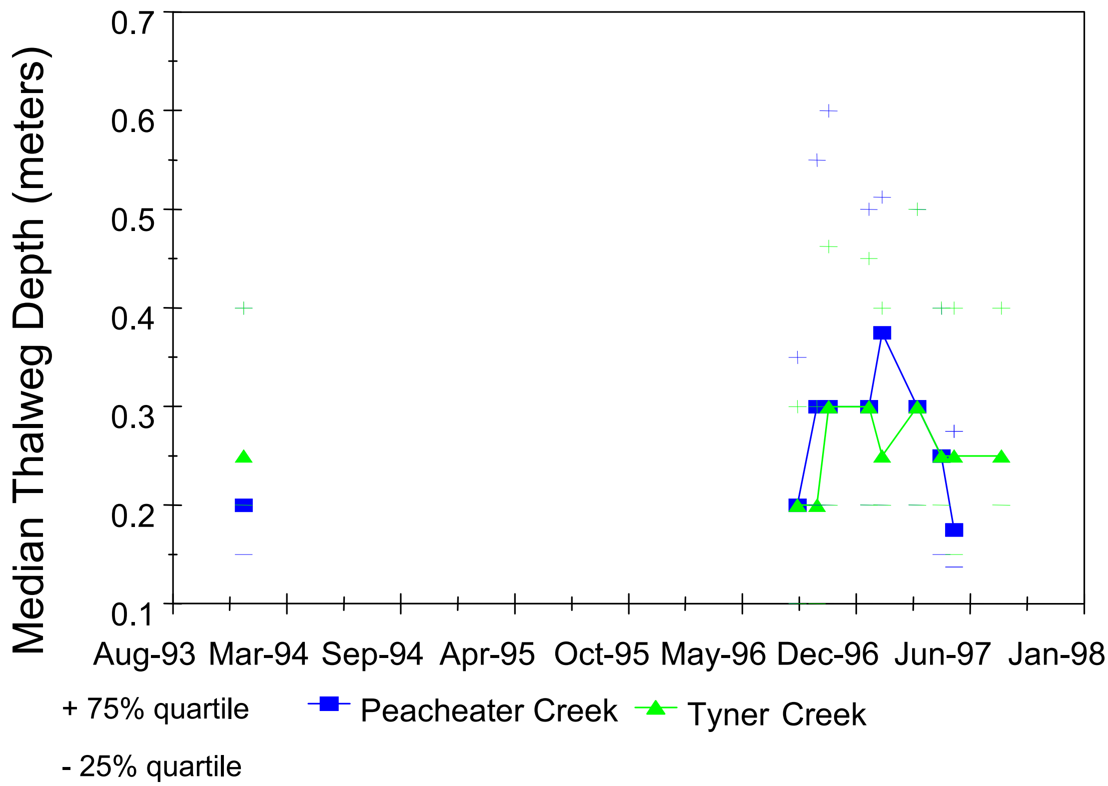


Figure 15. Thalweg Depths in Peacheater and Tyner Creeks.

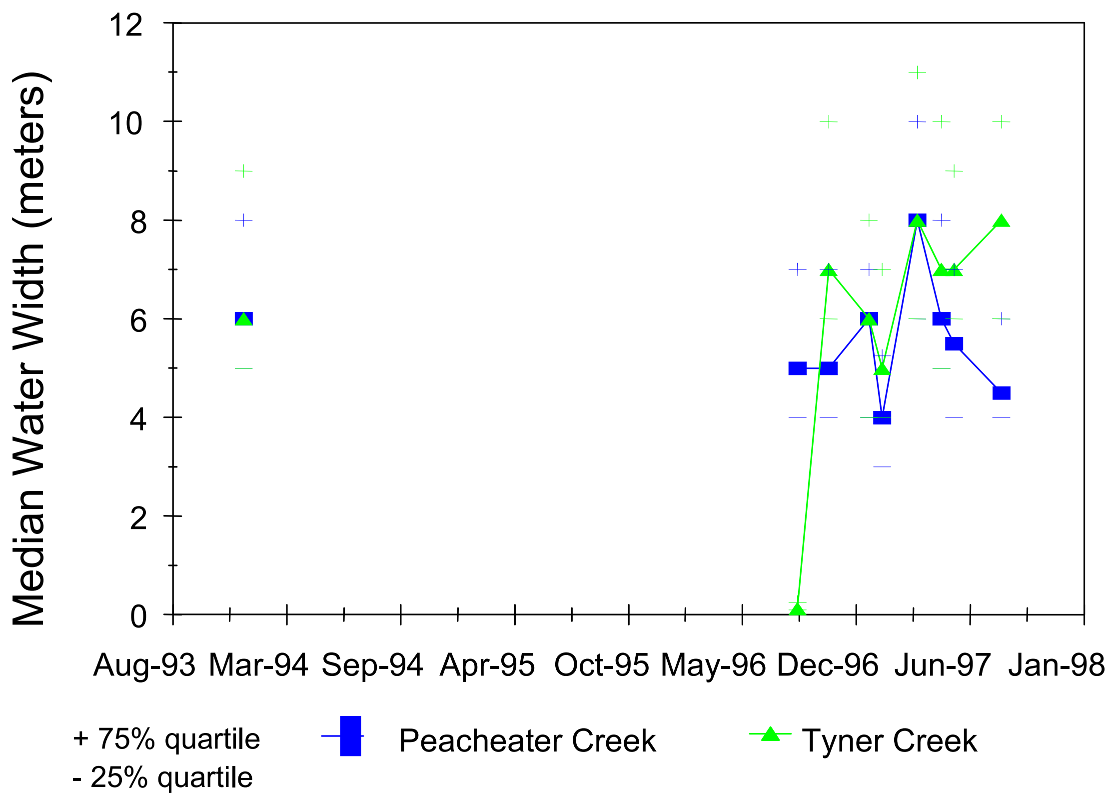


Figure 16. Comparison of Water Widths in Peacheater and Tyner Creeks.

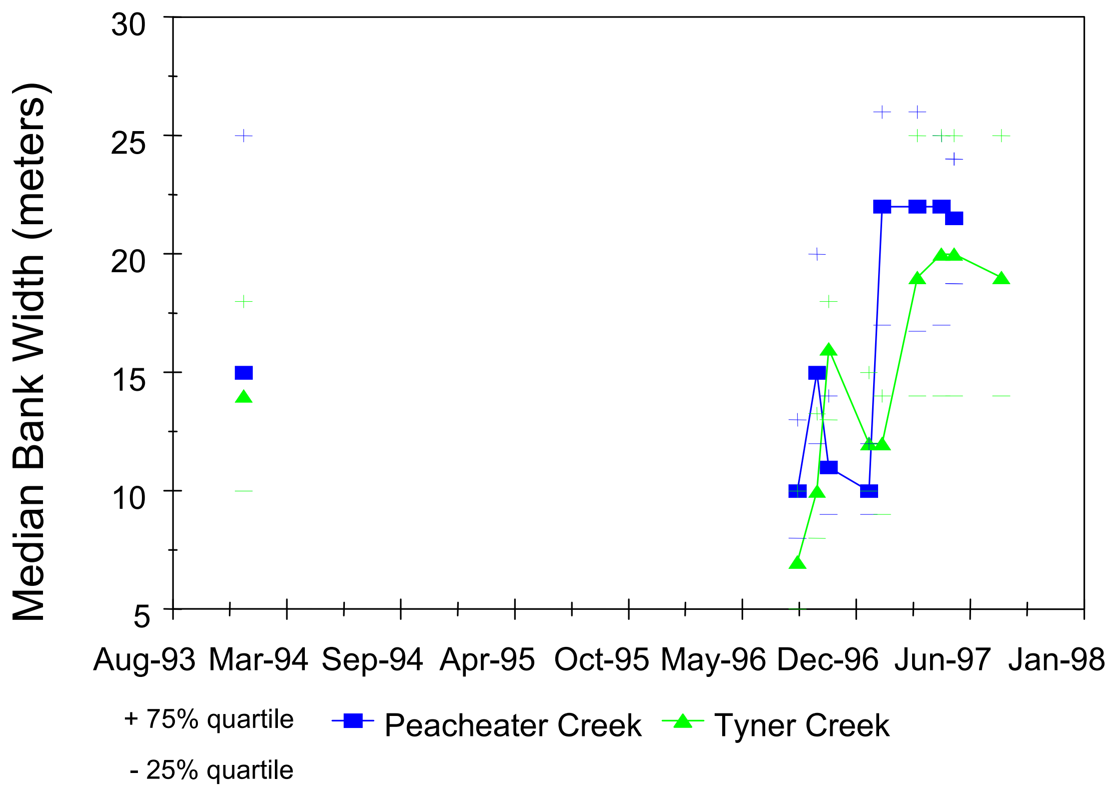


Figure 17. Comparison of Streambank Width in Peacheater and Tyner Creeks.

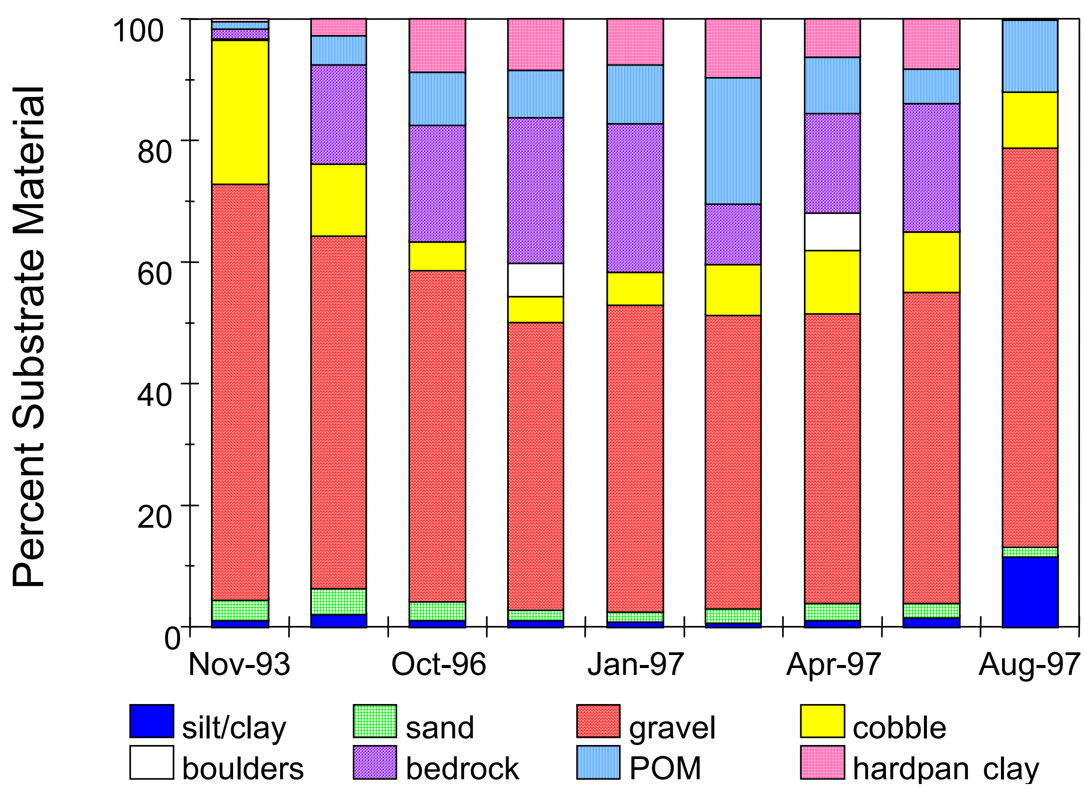


Figure 18. Peacheater Creek Bottom Substrate Composition.

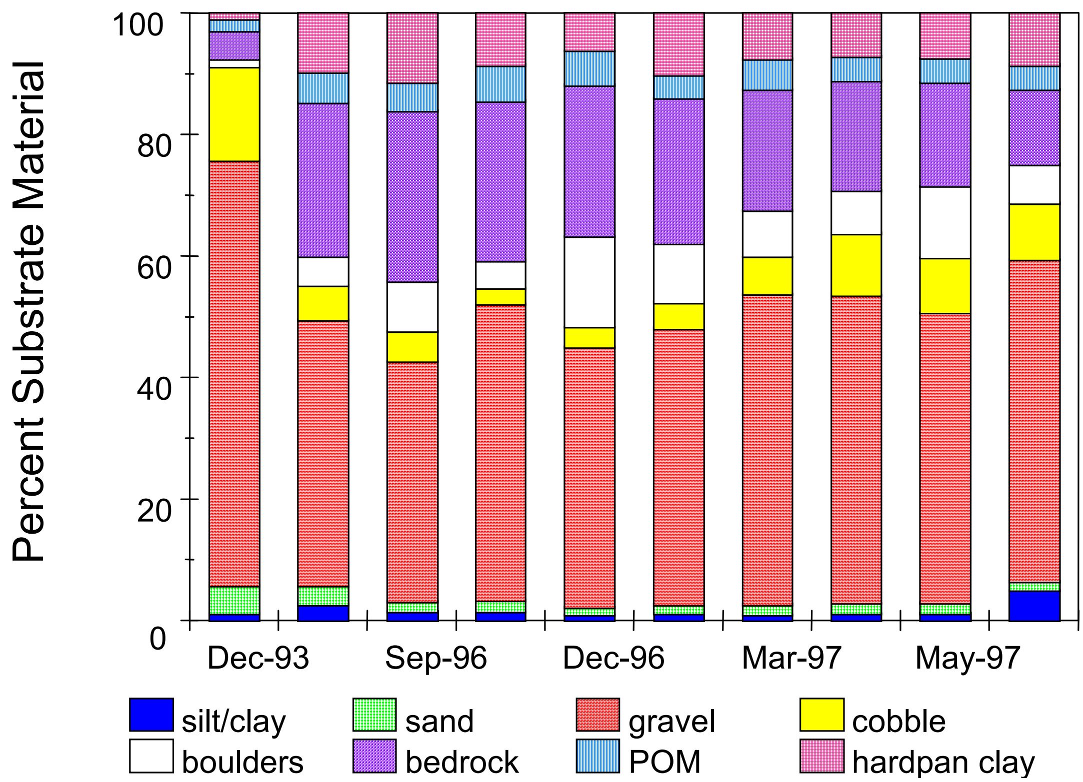


Figure 19. Tyner Creek Bottom Substrate Composition.

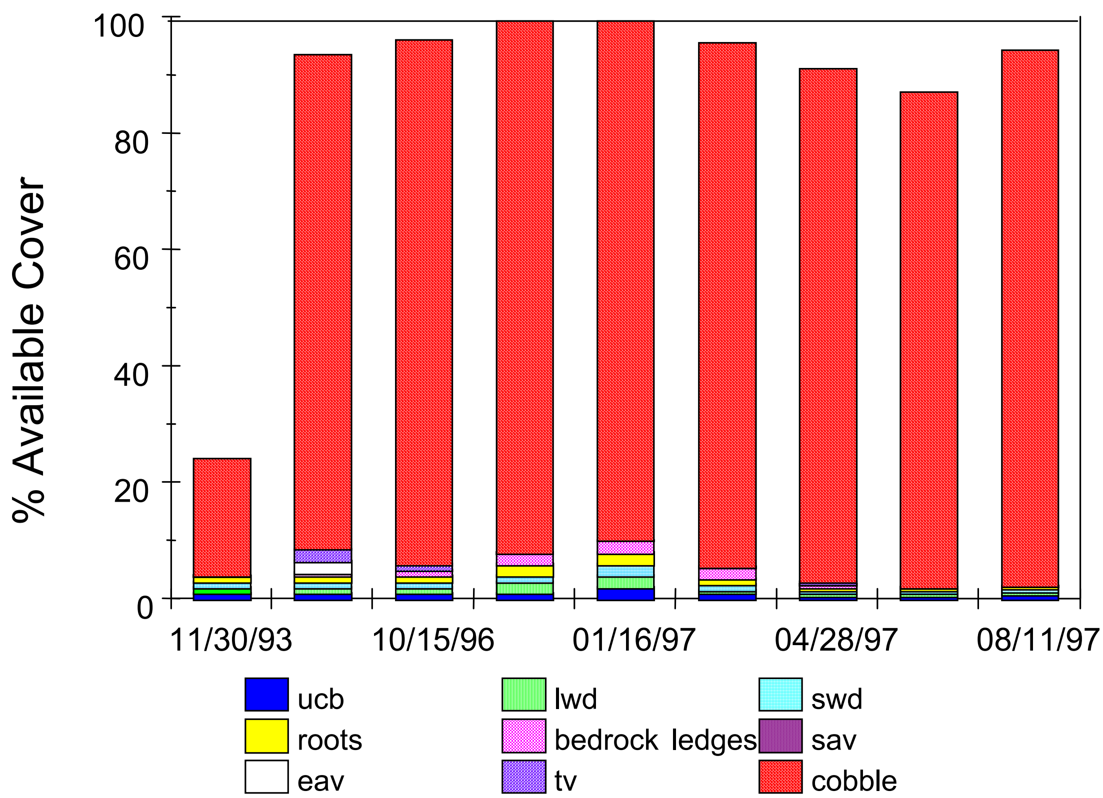


Figure 20. Cover Composition in Peacheater Creek.

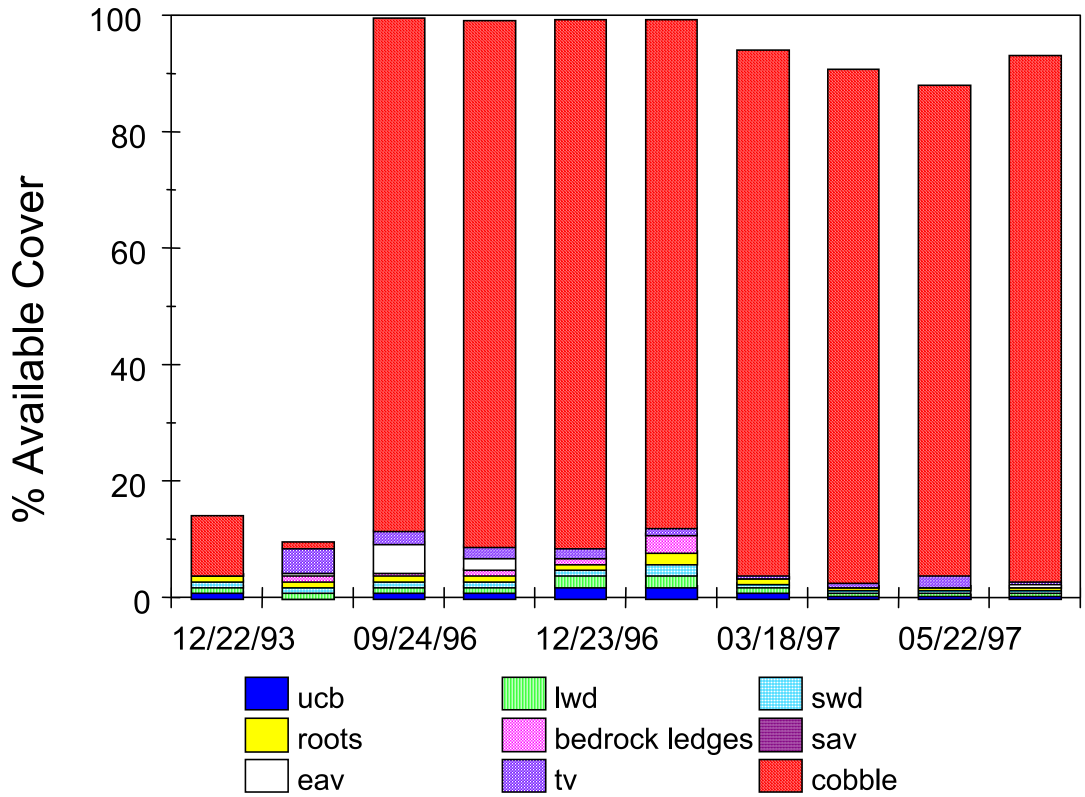


Figure 21. Cover Composition in Tyner Creek.

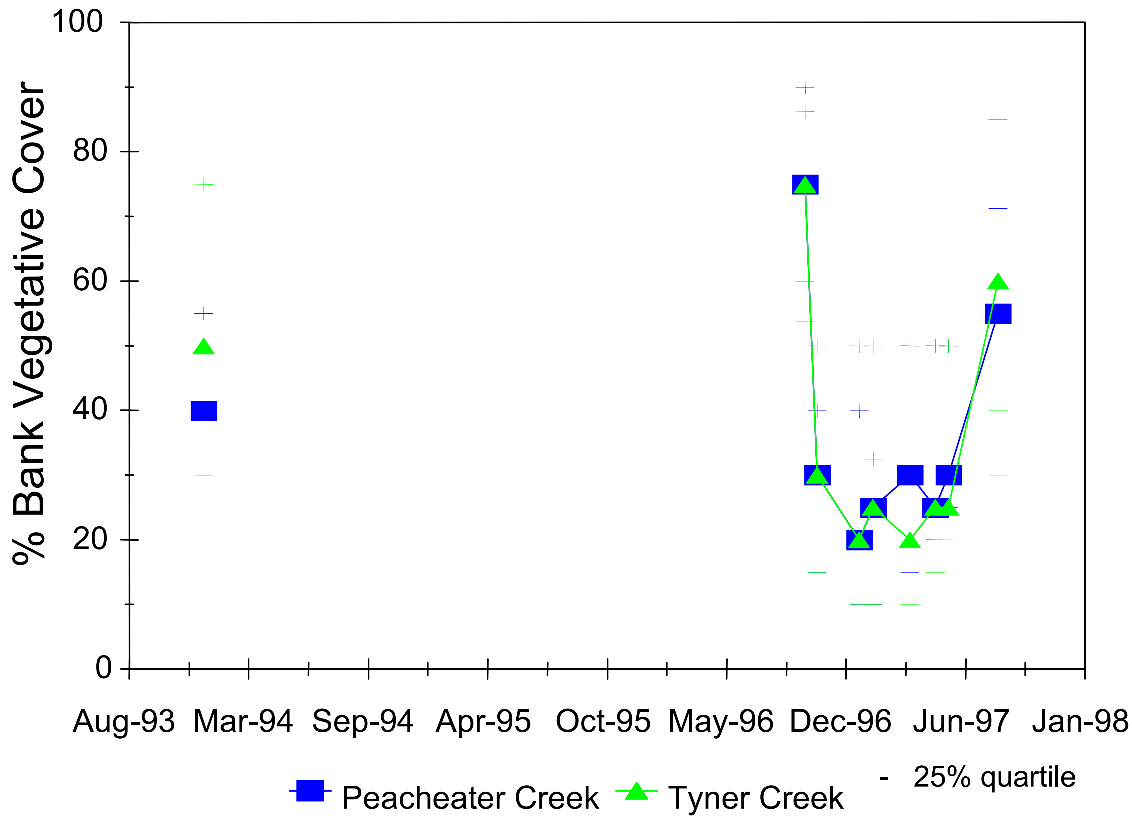


Figure 22. Comparison of Bank Vegetative Cover.

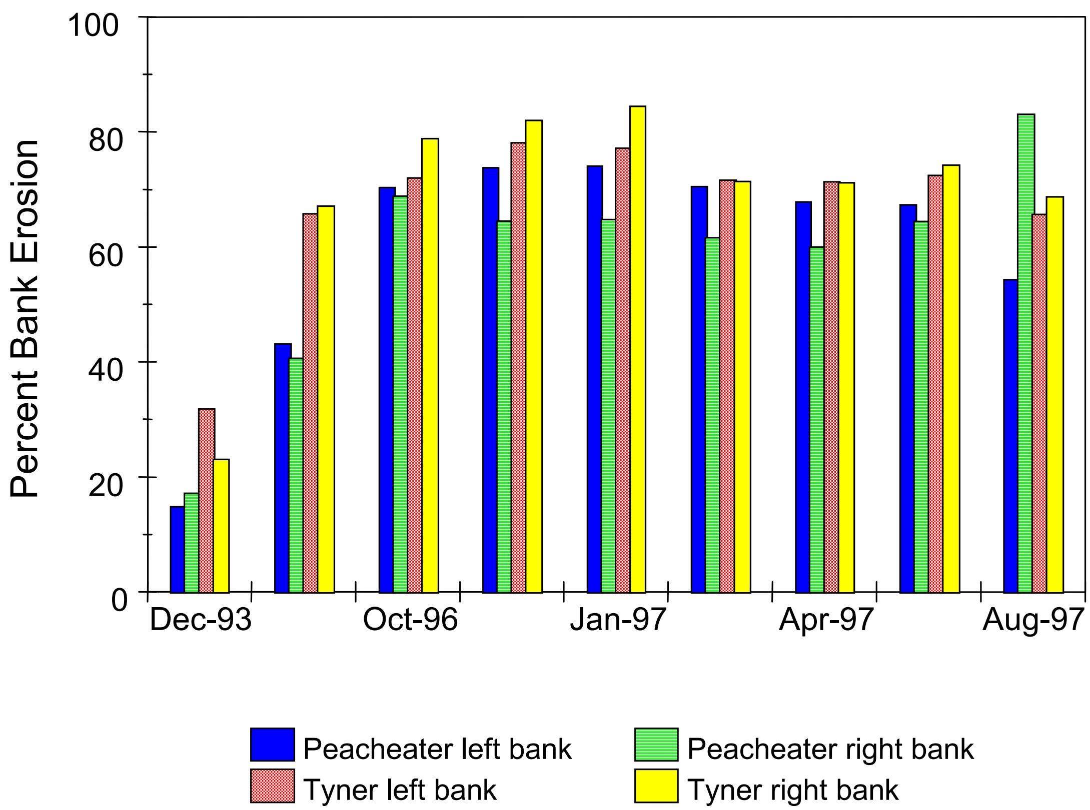


Figure 23. Bank Erosion in Peacheater and Tyner Creeks.

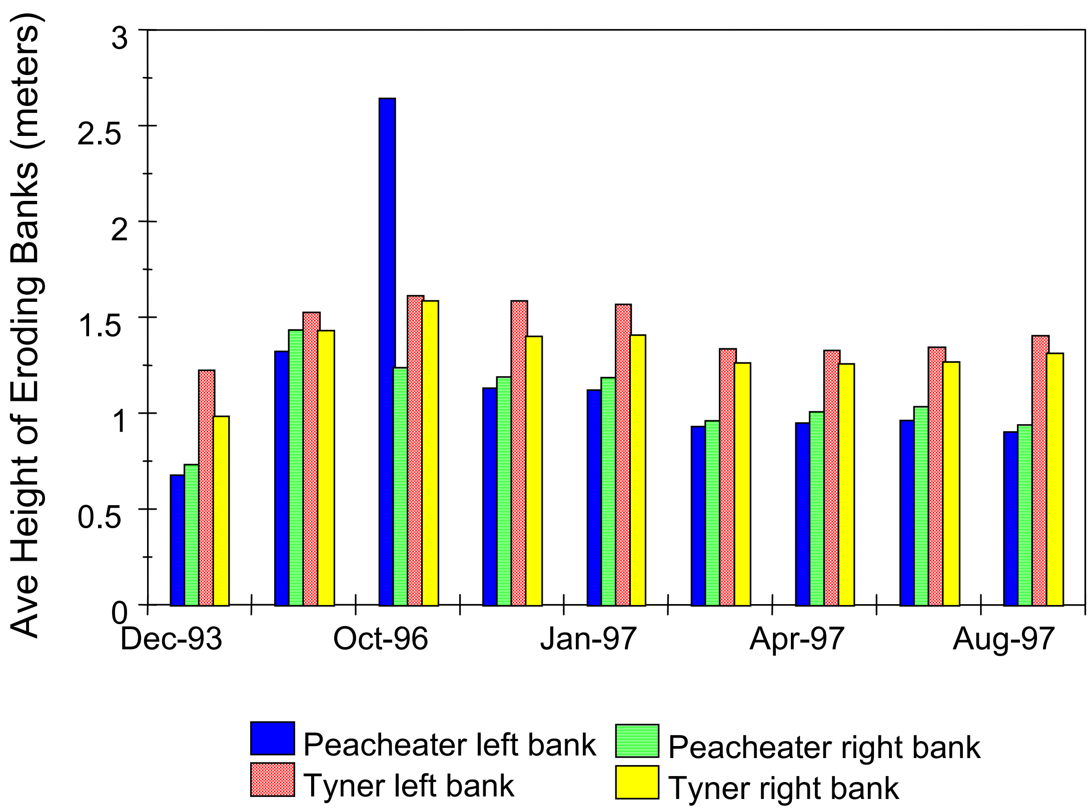


Figure 24. Comparison of Average Height of Eroding Banks.

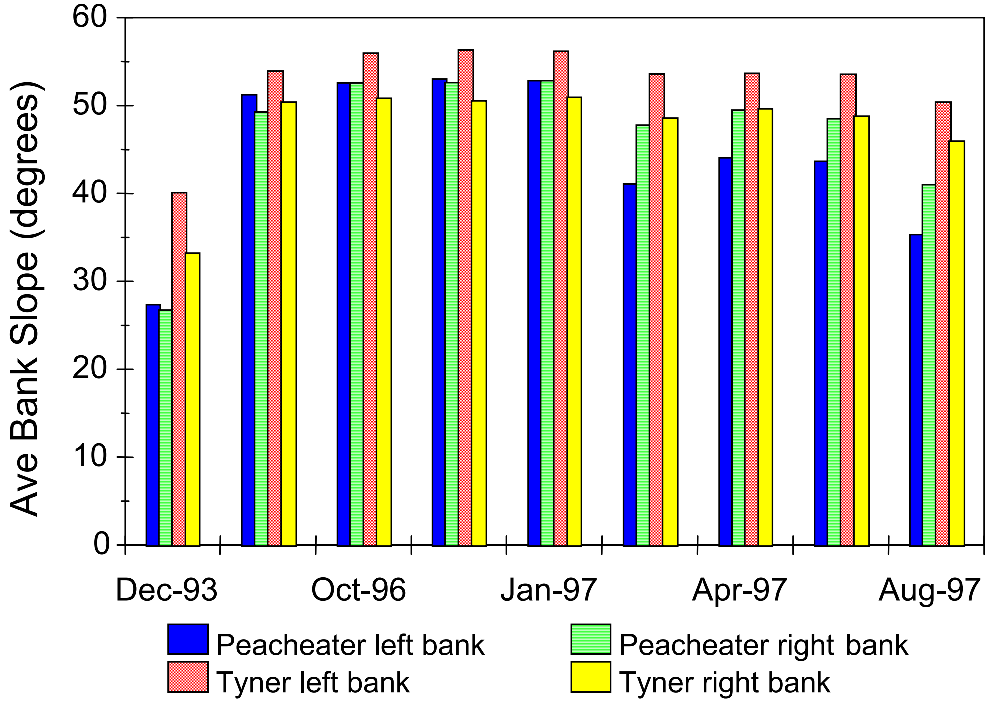


Figure 25. Comparison of Average Slope of Streambanks.

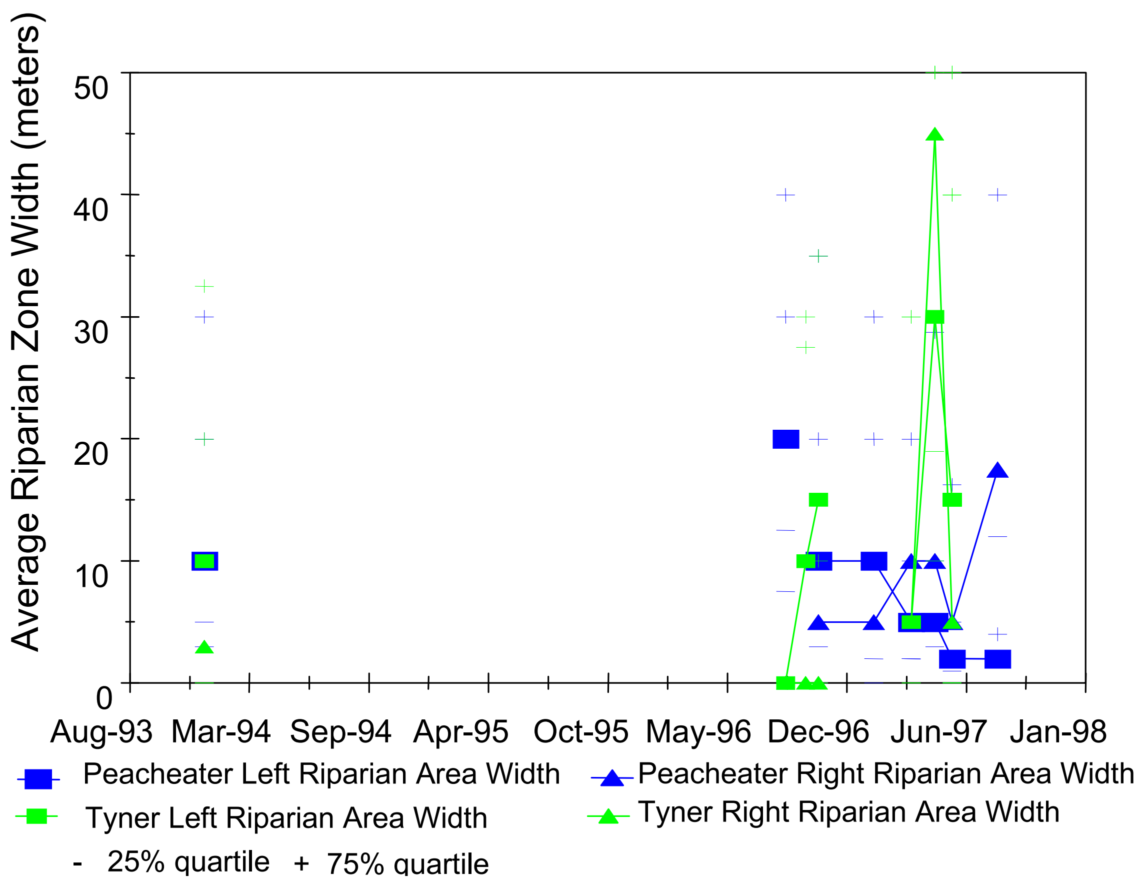


Figure 26. Comparison of Riparian Zone Widths of Peacheater and Tyner Creeks.

Figure 16 compares water widths in Peacheater and Tyner Creeks. No significant difference was evident in water width between Peacheater and Tyner creeks except in August 1996 when water width in Tyner Creek was significantly less than that in Peacheater Creek.

Bank width, compared to water width, is often, although not always, a measure of channel stability. It may also be indicative of flow magnitude and frequency and substrate material. Bank width also provides information about the volume and path of high flows. **Figure 17** compares bank widths between Tyner and Peacheater Creeks. Median bank width did not differ significantly between Peacheater and Tyner Creeks.

The bottom substrate is an important parameter as it affects stability of the streambed. It may also affect turbidity and water chemistry. **Figure 18** and **Figure 19** illustrate the bottom substrate composition of Peacheater and Tyner Creeks. Bottom substrate in both creeks is primarily gravel, with some bedrock, particulate organic matter (POM), and hardpan clay. Tyner Creek had somewhat more diverse substrate typically more boulders and bedrock than Peacheater Creek.

Available cover types affect availability and stability of refugia for macroinvertebrates and fish. **Figure 20** and **Figure 21** present available cover composition in Peacheater and Tyner Creeks. Cover classes are divided into undercut banks (UCB), large woody debris (LWD), small woody debris (SWD), roots, bedrock ledges (BRL), submerged aquatic vegetation (SAV), emergent aquatic vegetation (EAV), terrestrial vegetation (TV), and cobble, boulders, and gravel (COBBLE). Available cover is consistent between the two creeks, with the majority provided by cobble, boulders, and gravel.

Bank vegetative cover is one of the most important factors influencing the stability of stream banks (**Rosgen 1996**). **Figure 22** compares quartile distributions of bank vegetative cover in Peacheater and Tyner Creeks. No significant differences are apparent. Vegetative cover may follow seasonal changes, impacted both by seasonality of rainfall and winter dormancy of vegetation.

Bank erosion, both percent of total bank eroded and average height of eroding banks, was compared between Peacheater and Tyner Creeks. On most sampling dates (with the exception of August 1996), percent bank erosion was similar between Peacheater and Tyner Creeks (**Figure 23**). Approximately 60-80% of the total bank was eroded in both creeks. Average height of eroded banks was similar between Peacheater and Tyner creeks, although Tyner Creek often had somewhat higher eroded banks (**Figure 24**). Average bank slope is also similar between creeks (**Figure 25**). Typical bank slope is approximately 50 degrees which is somewhat steeper than optimal to prevent bank erosion (**Rosgen 1996**).

The width of the riparian area plays a crucial role in streambank stability and transport of runoff to the stream. Average width of the riparian area surrounding Peacheater Creek did not differ significantly from the average area surrounding Tyner Creek except during August and October 1996 (**Figure 26**). During August and October, 1996, the average width of the riparian area on Tyner Creek was significantly less than the riparian area in Peacheater Creek.

Another important similarity between Peacheater and Tyner Creeks is the response in habitat metrics to high flow events. On September 26, 1996, the gauge at Peacheater Creek recorded an average daily flow of 741 cfs (baseflow 3-8 cfs). Although only a few habitat assessments were collected prior to that event, a cursory comparison can be made between pre- and post-storm data. **Figure 15** indicates a similar response in thalweg depth in both creeks. Depth increased slightly though not significantly, suggesting scouring and/or higher water levels, and then decreased with time. **Figure 16** suggests no significant difference in water width in response to a high flow event in both Peacheater and Tyner Creeks. **Figure 17** displays similar responses in bank width between creeks following a storm event.

Figure 18 and **Figure 19** depict the response of bottom substrates to high flow events, suggesting little change in bottom substrate composition resulting from storm events. Notable changes in Peacheater Creek were less sand, cobble, and gravel and more hardpan clay. The percentage of gravel increased in Tyner Creek, while boulders, cobble, and hardpan clay decreased. **Figure 20** and **Figure 21** indicate negligible response in cover composition to storm events in both creeks. **Figure 22** indicates identical responses in bank vegetative cover to a highflow event in Peacheater and Tyner Creeks. Percent bank vegetative cover decreased, although not significantly, as would be expected following a storm event.

Correlation of pre- and post-storm event average percent bank erosions suggested increased bank erosion in Peacheater Creek (approx. 30% increase) while Tyner Creek remained relatively stable (approx. 5-10% increase) (**Figure 23**). Average height of eroded banks did not change dramatically in Tyner Creek, however, in Peacheater Creek, the average height or eroding left banks increased over one meter following the September storm event (**Figure 24**). This value later fell to pre-storm heights. Average bank slope did not change significantly following the storm event (**Figure 25**).

Comparison of habitat metrics, scores, and ratings between Peacheater and Tyner Creeks suggested few overall differences between the two systems. Nor did the systems respond differently to high flow events. This close relationship in habitat supports the use of these two systems for a paired watershed implementation study.

COMPARISON OF FISHERIES

The primary objective of the Peacheater Creek Implementation Project is to monitor water quality in Peacheater and Tyner Creeks to provide baseline data to support implementation of best management practices and verify results of that implementation. The ultimate goal of the Peacheater project and other projects in the Illinois River Basin is to improve water quality and habitat for biota in the river, its tributaries, and Lake Tenkiller. The design of the paired watershed project necessitates verification of preimplementation similarities in aquatic communities in the two creeks to ensure postimplementation differences result from implementation rather than some other factor. Thus, fish populations were surveyed in Peacheater and Tyner Creeks using seining and electrofishing techniques for purposed of comparison between the two systems. Types and numbers of fish collected were analyzed for an index of biological integrity (IBI) to give the overall populations a rating.

To minimize deleterious impacts of collection on indigenous populations, fish were collected from riffles, runs, and pools, every other year and pools were surveyed at least quarterly. Thus, IBI ratings are more appropriately used to compare populations of Peacheater and Tyner Creeks to each other, rather than give an overall rating of the systems.

Results of the collections are shown in **Tables 11-19**. Comparison of the results suggests that Peacheater and Tyner Creek collections resulted in identical ratings for both creeks (**Tables 11-13** and **Table 15**) on these dates. Ratings differed slightly between creeks on the remaining dates. On 1 Aug 96, one Peacheater Creek site (PE3) received a poor rating while the remaining sites received fair ratings (**Table 14**). The score at the PE3 was similar to the scores at the other sites, but fell slightly below the fair-poor ratings cutoff. The main differences between PE3 and the other sites were in metric 5 (number and identity of intolerant species) and metric 9 (portion of individuals as top carnivores). PE3 had fewer intolerant species and a lower percentage of top carnivores than other sites.

In January 1997, one Tyner Creek site (TB5) received a different rating than the other sites (**Table 16**). The score at TB5 was substantially lower than other sites. The main differences were seen in metric 5 and metric 7 (portion of individuals as omnivores). Low ratings in metric 1 (total number of species), metric 8 (portion of individuals as insectivorous carnivores), and metric 9 also contributed to the low score.

One Tyner Creek site (TB3) differed from the other sites on 14 Feb 97 (**Table 17**). The collections at the different sites were highly variable on this date. A single species was collected from Pools in Peacheater Creek (PE5), *Semotilus atromaculatus*- the creek chub. The creek chub is a moderately intolerant insectivore. Two species were collected from Tyner Creek site TB3, *Ambloplites*

Table 11. Comparison of Fish Metrics between Tyner and Peacheater Creeks (15 OCT 91).

	15 OCT 91			
Site ID	**Tyner Low-1**		**Peacheater Creek (PE1)**	
Site #	**OK121700-05-0090G**		**OK121700-05-0120B**	
Metric 1		**13**		**13**
Metric 2	*Campostoma anomalum*	45	*Campostoma anomalum*	24
	Etheostoma blennoides	1	*Etheostoma flabellare*	13
	Etheostoma flabellare	10	*Etheostoma spectabile*	4
	Etheostoma spectabile	2		
	Etheostoma zonale	1		
# Species		**5**		**3**
n		**59**		**41**
Metric 3	*Micropterus dolomieui*	2	*Micropterus dolomieui*	2
			Lepomis cyanellus	1
# Species		**1**		**2**
n		**2**		**3**
Metric 4	*Campostoma anomalum*	45	*Campostoma anomalum*	24
	Luxilus cardinalis	34	*Luxilus cardinalis*	14
	Nocomis asper	1	*Nocomis asper*	9
	Notropis nubilis	7	*Notropis nubilis*	5
	Semotilus atromaculatus	11	*Semotilus atromaculatus*	20
	Hypentelium nigricans	2	*Hypentelium nigricans*	2
	Noturus exilis	2	*Noturus exilis*	5
			Phoxinus erythrogaster	13
# Species		**7**		**8**
n		**102**		**92**
Metric 5	*Luxilus cardinalis*	34	*Luxilus cardinalis*	14
	Nocomis asper	1	*Nocomis asper*	9
	Hypentelium nigricans	2	*Hypentelium nigricans*	2
	Noturus exilis	2	*Noturus exilis*	5
	Cottus carolinae	3	*Cottus carolinae*	24
	Micropterus dolomieui	2	*Micropterus dolomieui*	2
	Etheostoma blennoides	1	*Phoxinus erythrogaster*	13
	Etheostoma flabellare	10	*Etheostoma flabellare*	13
	Etheostoma zonale	2		
# Species		**9**		**8**
n		**56**		**82**
Metric 6			*Lepomis cyanellus*	1
# Species		**0**		**1**
n		**0**		**1**
Metric 7		**9.09**		**15.44**
Metric 8		**34.71**		**20.59**
Metric 9		**1.65**		**1.47**
Metric 10		**121**		**136**
IBI Score		**47**		**44**
IBI Rating		**FAIR**		**FAIR**

Table 12. Comparison of Fish Metrics Between Tyner and Peacheater Creeks (July 1993).

	19 JUL 93		15 JUL 93	
Site ID	**Tyner Up-1**		**Peach Slab-1**	
Site #	**OK121700-05-0090P**		**OK121700-05-0120F**	
Metric 1		**16**		**15**
Metric 2	*Campostoma anomalum*	62	*Campostoma anomalum*	53
	Etheostoma flabellare	53	*Etheostoma flabellare*	26
	Etheostoma punctulatum	1	*Etheostoma spectabile*	3
	Etheostoma spectabile	2		
# Species		**4**		**3**
n		**118**		**82**
Metric 3	*Ambloplites ariommus*	1	*Ambloplites ariommus*	9
	Lepomis cyanellus	11	*Lepomis cyanellus*	1
			Micropterus dolomieui	1
# Species		**2**		**3**
n		**12**		**11**
Metric 4	*Campostoma anomalum*	62	*Campostoma anomalum*	53
	Luxilus cardinalis	146	*Luxilus cardinalis*	128
	Nocomis asper	7	*Nocomis asper*	13
	Phoxinus erythrogaster	336	*Phoxinus erythrogaster*	26
	Semotilus atromaculatus	40	*Semotilus atromaculatus*	39
	Hypentelium nigricans	6	*Noturus exilis*	9
	Noturus exilis	2	*Notropis nubilis*	10
	Ictalurus melas	1	*Notropis rubellus*	2
	Moxostoma duquesnei	2		
	Catostomus commersoni	2		
# Specie		**10**		**8**
n		**604**		**280**
Metric 5	*Luxilus cardinalis*	146	*Luxilus cardinalis*	128
	Nocomis asper	7	*Nocomis asper*	13
	Noturus exilis	2	*Notropis rubellus*	2
	Phoxinus erythrogaster	336	*Phoxinus erythrogaster*	26
	Catostomus commersoni	2	*Noturus exilis*	9
	Hypentelium nigricans	6	*Cottus carolinae*	165
	Moxostoma duquesnei	2	*Ambloplites ariommus*	9
	Cottus carolinae	241	*Micropterus dolomieui*	1
	Ambloplites ariommus	1	*Etheostoma flabellare*	26
	Etheostoma flabellare	53		
	Etheostoma punctulatum	1		
# Species		**11**		**9**
n		**797**		**379**
Metric 6	*Ictalurus melas*	1	*Gambusia affinis*	1
	Lepomis cyanellus	11		
# Species		**2**		**1**
n		**12**		**1**
Metric 7		**5.81**		**8.02**
Metric 8		**16.78**		**31.48**
Metric 9		**0.11**		**2.06**
Metric 10		**913**		**486**
IBI Score		**42**		**44**
IBI Rating		**FAIR**		**FAIR**

Table 13. Comparison of Fish Metrics Between Tyner and Peacheater Creeks (July 1996).

	22 JUL 96				29 JUL 96	
Site ID	**Tyner Creek (TB4)**		**Tyner Creek (TB5)**		**Peacheater Creek (PE1)**	
Site #	**OK121700-05-0090M**		**OK121700-05-0090P**		**OK121700-05-0120B**	
Metric 1		**5**		**3**		**11**
Metric 2						
# Species		**0**		**0**		**0**
n		**0**		**0**		**0**
Metric 3	*Lepomis cyanellus*	4	***Lepomis cyanellus***	12	*Lepomis cyanellus*	10
	Lepomis macrochirus	1			*Lepomis megalotis*	11
					Lepomis microlophus	3
					Lepomis macrochirus	5
					Micropterus dolomieui	5
					Micropterus salmoides	1
# Species		**2**		**1**		**6**
n		**5**		**12**		**35**
Metric 4	*Nocomis asper*	9	*Hypentelium nigricans*	13	*Hypentelium nigricans*	10
	Hypentelium nigricans	7	*Semotilus atromaculatus*	33	*Semotilus atromaculatus*	16
	Semotilus atromaculatus	20			*Ictalurus melas*	2
					Ictalurus natalis	2
					Moxostoma erythrurum	1
# Species		**3**		**2**		**5**
n		**36**		**46**		**31**
Metric 5	*Nocomis asper*	9	*Hypentelium nigricans*	13	*Micropterus dolomieui*	5
	Hypentelium nigricans	7			*Hypentelium nigricans*	10
# Species		**2**		**1**		**2**
n		**16**		**13**		**15**
Metric 6	*Lepomis cyanellus*	4	*Lepomis cyanellus*	12	*Ictalurus melas*	2
					Lepomis cyanellus	10
# Species		**1**		**1**		**2**
n		**4**		**12**		**12**
Metric 7		**58.54**		**77.59**		**39.39**
Metric 8		**21.95**		**0**		**0**
Metric 9		**0**		**0**		**9.09**
Metric 10		**41**		**58**		**66**
IBI Score		**36**		**35**		**36**
IBI Rating		**POOR**		**POOR**		**POOR**

Table 14. Comparison of Fish Metrics Between Tyner and Peacheater Creeks (1 AUG 96).

1 AUG 96								
Site ID	**Tyner Creek (TB1)**		**Tyner Creek (TB5)**		**Peacheater Creek (PE-2)**		**Peacheater Creek (PE3)**	
Site #	**OK121700-05-0090G**		**OK121700-05-0090I**		**OK121700-05-0120F**		**OK121700-05-0120I**	
Metric 1		**6**		**9**		**8**		**10**
Metric 2								
# Species		**0**		**0**		**0**		**0**
n		**0**		**0**		**0**		**0**
Metric 3	*Ambloplites rupestris*	3	*Ambloplites rupestris*	1	*Ambloplites rupestris*	2	*Ambloplites rupestris*	1
	Lepomis cyanellus	5	*Lepomis cyanellus*	27	*Lepomis cyanellus*	10	*Lepomis cyanellus*	7
	Micropterus dolomieui	7	*Lepomis macrochirus*	1	*Lepomis macrochirus*	2	*Lepomis macrochirus*	2
			Micropterus dolomieui	7	*Micropterus dolomieui*	5	*Micropterus salmoides*	1
			Micropterus salmoides	3				
# Species		**3**		**5**		**4**		**4**
n		**15**		**39**		**19**		**11**
Metric 4	*Nocomis asper*	40	*Nocomis asper*	12	*Nocomis asper*	25	*Nocomis asper*	18
	Hypentelium nigricans	12	*Hypentelium nigricans*	16	*Hypentelium nigricans*	19	*Hypentelium nigricans*	3
	Semotilus atromaculatus	12	*Semotilus atromaculatus*	16	*Semotilus atromaculatus*	28	*Semotilus atromaculatus*	41
			Ictalurus melas	2			*Ictalurus melas*	1
							Ictalurus natalis	6
							Moxostoma erythrurum	1
# Species		**3**		**4**		**3**		**6**
n		**64**		**46**		**73**		**70**
Metric 5	*Nocomis asper*	40	*Nocomis asper*	12	*Nocomis asper*	25	*Nocomis asper*	18
	Ambloplites rupestris	3	*Ambloplites rupestris*	1	*Ambloplites rupestris*	2	*Ambloplites rupestris*	1
	Micropterus dolomieui	7	*Micropterus dolomieui*	7	*Micropterus dolomieui*	5	*Micropterus dolomieui*	3
	Hypentelium nigricans	12	*Hypentelium nigricans*	16	*Hypentelium nigricans*	19		
# Species		**4**		**4**		**4**		**3**
n		**62**		**36**		**51**		**22**
Metric 6	*Lepomis cyanellus*	5	*Lepomis cyanellus*	27	*Lepomis cyanellus*	10	*Lepomis cyanellus*	7
			Ictalurus melas	2			*Ictalurus melas*	1
# Species		**1**		**2**		**1**		**2**
n		**5**		**29**		**10**		**8**
Metric 7		**21.52**		**50.59**		**41.3**		**59.26**
Metric 8		**50.63**		**14.11**		**27.17**		**22.22**
Metric 9		**12.66**		**12.94**		**7.61**		**2.47**
Metric 10		**79**		**85**		**92**		**81**
IBI Score		**42**		**38**		**40**		**36**
IBI Rating		**FAIR**		**FAIR**		**FAIR**		**POOR**

Table 15. Comparison of Fish Metrics Between Tyner and Peacheater Creeks (August 96).

	15 AUG 96		16 AUG 96		22 AUG 96			
Site ID	**Tyner Creek (T31)**		**Tyner Creek**		**Peacheater Creek (PE4a)**		**Peacheater Creek (PE5)**	
Site #	**OK121700-05-0090K**		**OK121700-05-0090N**		**OK121700-05-0120L**		**OK121700-05-0120Q**	
Metric 1		**6**		**4**		**6**		**5**
Metric 2								
# Species		**0**		**0**		**0**		**0**
N		**0**		**0**		**0**		**0**
Metric 3	*Lepomis cyanellus*	6			*Lepomis cyanellus*	1	*Lepomis cyanellus*	2
	Lepomis macrochirus	2					*Micropterus salmoides*	3
# Species		**2**		**0**		**1**		**2**
N		**8**		**0**		**1**		**5**
Metric 4	*Nocomis asper*	9	*Nocomis asper*	9	*Nocomis asper*	11	*Nocomis asper*	6
	Hypentelium nigricans	20	*Hypentelium nigricans*	16	*Hypentelium nigricans*	1	*Semotilus atromaculatus*	26
	Semotilus atromaculatus	48	*Semotilus atromaculatus*	29	*Semotilus atromaculatus*	57	*Ictalurus melas*	2
	Moxostoma erythrurum	4	*Moxostoma erythrurum*	7	*Ictalurus melas*	1		
					Moxostoma erythrurum	7		
# Species		**4**		**4**		**5**		**3**
n		**81**		**61**		**77**		**34**
Metric 5	*Nocomis asper*	9	*Nocomis asper*	9	*Nocomis asper*	11	*Nocomis asper*	6
	Hypentelium nigricans	20	*Hypentelium nigricans*	16	*Hypentelium nigricans*	1		
# Species		**2**		**2**		**2**		**1**
n		**29**		**25**		**12**		**6**
Metric 6	*Lepomis cyanellus*	6			*Lepomis cyanellus*	1	*Lepomis cyanellus*	2
					Ictalurus melas	1	*Ictalurus melas*	2
# Species		**1**		**0**		**2**		**2**
n		**6**		**0**				**4**
Metric 7		**60.67**		**47.51**		**74.36**		**71.79**
Metric 8		**10.11**		**14.75**		**14.1**		**15.38**
Metric 9		**0**		**0**		**0**		**7.69**
Metric 10		**89**		**61**		**78**		**39**
IBI Score		**32**		**34**		**36**		**36**
IBI Rating		**POOR**		**POOR**		**POOR**		**POOR**

Table 16. Comparison of Fish Metrics Between Tyner and Peacheater Creeks (January 1997).

	24 JAN 97						31 JAN 97					
Site ID	**Tyner Creek (TB1)**		**Tyner Creek (TB4)**		**Tyner Creek (TB5)**		**Peacheater Creek (PE1)**		**Peacheater Creek (PE2)**		**Peacheater Creek (PE4a)**	
Site #	**OK121700-05-0090G**		**OK121700-05-0090M**		**OK121700-05-0090P**		**OK121700-05-0120B**		**OK121700-05-120F**		**OK121700-05-0120L**	
Metric 1		**7**		**2**		**3**		**9**		**7**		**6**
Metric 2												
#		**0**		**0**		**0**		**0**		**0**		**0**
n		**0**		**0**		**0**		**0**		**0**		**0**
Metric 3	*Ambloplites rupestris*	1			*Lepomis cyanellus*	7	*Ambloplites rupestris*	8	*Ambloplites rupestris*	2	*Ambloplites rupestris*	2
	Lepomis cyanellus	3					*Lepomis cyanellus*	2	*Lepomis cyanellus*	3	*Lepomis cyanellus*	1
	Lepomis megalotis	1					*Lepomis megalotis*	6	*Lepomis megalotis*	2		
	Micropterus dolomieui	2					*Micropterus dolomieui*	2				
# Species		**4**		**0**		**1**		**4**		**3**		**2**
n		**7**		**0**		**7**		**18**		**7**		**3**
Metric 4	*Nocomis asper*	5	*Hypentelium nigricans*	14	*Hypentelium nigricans*		*Nocomis asper*	8	*Nocomis asper*	11	*Nocomis asper*	26
	Hypentelium nigricans	16	*Semotilus atromaculatus*	4	*Semotilus atromaculatus*		*Hypentelium nigricans*	9	*Hypentelium nigricans*	21	*Semotilus atromaculatus*	38
	Semotilus atromaculatus	7					*Semotilus atromaculatus*	8	*Semotilus atromaculatus*	8	*Ictalurus melas*	1
							Ictalurus melas	1	*Moxostoma erythrurum*	2	*Moxostoma erythrurum*	2
							Noturus exilis	5				
# Species		**3**		**2**		**2**		**5**		**4**		**4**
n		**7**		**18**		**8**		**31**		**43**		**67**
Metric 5	*Nocomis asper*	5	*Hypentelium nigricans*	14	*Hypentelium nigricans*	9	*Nocomis asper*	8	*Nocomis asper*	11	*Nocomis asper*	26
	Hypentelium nigricans	16					*Hypentelium nigricans*	9	*Hypentelium nigricans*	21	*Ambloplites rupestris*	2
	Ambloplites rupestris	1					*Noturus exilis*	5	*Ambloplites rupestris*	2		
	Micropterus dolomieui	2					*Ambloplites rupestris*	8				
							Micropterus dolomieui	2				
# Species		**4**		**1**		**1**		**5**		**3**		**2**
n		**24**		**14**		**9**		**132**		**34**		**28**
Metric 6	*Lepomis cyanellus*	3			*Lepomis cyanellus*	7	*Lepomis cyanellus*	2	*Lepomis cyanellus*	3	*Lepomis cyanellus*	1
							Ictalurus melas	1			*Ictalurus melas*	1
# Species		**1**		**0**		**1**		**2**		**1**		**2**
N		**3**		**0**		**7**		**3**		**3**		**2**
Metric 7		**28.57**		**22.22**		**65.38**		**20.41**		**22**		**55.71**
Metric 8		**14.29**		**0**		**0**		**16.33**		**22**		**37.14**
Metric 9		**8.57**		**0**		**0**		**20.41**		**4**		**2.86**
Metric 10		**35**		**18**		**26**		**49**		**50**		**70**
IBI Score		**42**		**38**		**30**		**44**		**42**		**38**
IBI Rating		**FAIR**		**FAIR**		**POOR**		**FAIR**		**FAIR**		**FAIR**

Table 17. Comparison of Fish Metrics Between Tyner and Peacheater Creeks (14 FEB 97).

	14 FEB 97					
Site ID	**Tyner Creek (TB2)**		**Tyner Creek (TB3)**		**Peacheater Creek (PE5)**	
Site #	**OK121700-05-0090I**		**OK121700-05-0090K**		**OK121700-05-0120Q**	
Metric 1		**7**		**2**		**1**
Metric 2						
# Species		**0**		**0**		**0**
n		**0**		**0**		**0**
Metric 3	*Ambloplites rupestris*	1	*Ambloplites rupestris*	1		
	Lepomis cyanellus	19				
	Lepomis macrochirus	2				
	Micropterus dolomieui	1				
# Species		**4**		**1**		**0**
n		**23**		**1**		**0**
Metric 4	*Nocomis asper*	18	*Hypentelium nigricans*	4	*Semotilus atromaculatus*	14
	Hypentelium nigricans	11				
	Semotilus atromaculatus	7				
# Species		**3**		**1**		**1**
n		**36**		**4**		**14**
Metric 5	*Nocomis asper*	18	*Ambloplites rupestris*	1		
	Ambloplites rupestris	1	*Hypentelium nigricans*	4		
	Micropterus dolomieui	1				
	Hypentelium nigricans	11				
# Species		**4**		**1**		**0**
n		**31**		**5**		**0**
Metric 6	*Lepomis cyanellus*	19				
# Species		**1**		**0**		**0**
n		**19**		**0**		**0**
Metric 7		**44.07**		**0**		**100**
Metric 8		**30.51**		**0**		**0**
Metric 9		**3.39**		**20**		**0**
Metric 10		**59**		**5**		**14**
IBI Score		**36**		**44**		**32**
IBI Rating		**POOR**		**FAIR**		**POOR**

rupestris - the rock bass, and *Hypentelium nigricans* - the northern hog sucker. The rock bass is a moderately intolerant piscivore and the northern hog sucker is an intolerant insectivore. Seven species were collected from Tyner Creek site (TB2). These species included *Semotilus atromaculatus, Hypentelium nigricans, Ambloplites rupestris, Lepomis cyanellus-* the green sunfish (tolerant omnivore), *Lepomis macrochirus* - the bluegill (tolerant insectivore), *Micropterus dolomieui* - smallmouth bass (moderately intolerant piscivore), and *Nocomis asper* - redspot chub (intolerant insectivore). Although TB2 had more species, a large percentage of the fish collected were intolerant (19 green sunfish). Only five fish were collected at TB3, but they were all from less tolerant species, thus the fishery was rated higher than the fishery at TB2 or PE5.

Fish collections in Tyner and Peacheater Creeks in May and June 1997 received either a poor (TB5, TB2, TB4, PE1, PE5, PE2) or fair (TB1, TB3, PE3, PE4a) rating **(Tables 18-19**). The four sites rated fair had a higher percentage of intolerant species combined with a lower percentage of tolerant species than the other sites.

Comparison of fish lengths suggest little difference between the two creeks (**Figure 27-30).** Catostomidae species *Hypentelium nigricans* and *Moxostoma erythrurum* (golden redhorse) median fish length did not differ significantly between creeks (**Figure 27**). However, a wider range of sizes of *Hypentelium nigricans* was collected in Peacheater Creek than in Tyner Creek.

Comparison of Cyprinidae species lengths between creeks suggested median length of *Nocomis asper* (redspot chub) was longer in Tyner Creek than in Peacheater Creek (**Figure 28**). Median length of *Semotilus atromaculatus* did not differ between creeks although longer fish were collected in Peacheater than Tyner Creek.

Two Centrarchidae species differed in median length between Peacheater and Tyner Creeks (**Figure 29**). Median length of *Lepomis cyanellus* was significantly longer in Peacheater than in Tyner Creek. Median length of *Micropterus salmoides* (largemouth bass) was longer in Tyner Creek than Peacheater Creek. Median lengths of *Ambloplites ariommus, Ambloplites rupestris, Lepomis macrochirus, Lepomis megalotis (longear sunfish), and Micropterus dolomieui* did not differ between creeks.

Median lengths of Ictaluridae species did not differ significantly between creeks (**Figure 30**). Although longer *Ictalurus melas* (black bullhead) were collected in Peacheater than Tyner Creek, median lengths were not significantly different. *Ictalurus natalis* (yellow bullhead) were not measured and collected in Tyner Creek, however, median lengths are not different from those of black bullheads.

Table 18. Comparison of Fish Metrics for Tyner Creek (June 1997).

	3 JUN 97						5 JUN 97			
Site ID	**Tyner Creek (TB1)**		**Tyner Creek (TB5)**		**Tyner Creek (TB3)**		**Tyner Creek (TB2)**		**Tyner Creek (TB4)**	
Site #	**OK121700-05-0090G**		**OK121700-05-009P**		**OK121700-05-0090K**		**OK121700-05-0090I**		**OK121700-05-0090M**	
Metric 1		**6**		**4**		**5**		**11**		**5**
Metric 2										
# Species		**0**		**0**		**0**		**0**		**0**
N		**0**		**0**		**0**		**0**		**0**
Metric 3	Ambloplites rupestris	5	Lepomis cyanellus	10	Lepomis cyanellus	1	Ambloplites ariommus	1	*Lepomis* cyanellus	2
	Lepomis cyanellus	13					Lepomis cyanellus	11		
	Micropterus dolomieui	1					Lepomis microlophus	1		
							Micropterus dolomieui	6		
							Micropterus salmoides	1		
# Species		**3**		**1**		**1**		**5**		**1**
N		**19**		**10**		**1**		**20**		**2**
Metric 4	Nocomis asper	24	Hypentelium nigricans	1	Nocomis asper	4	Nocomis asper	4	*Nocomis asper*	3
	Hypentelium nigricans	1	Semotilus atromaculatus	12	Hypentelium nigricans	2	Hypentelium nigricans	11	***Hypentelium nigricans***	2
	Semotilus atromaculatus	18	Moxostoma erythrurum	1	Semotilus atromaculatus	12	Semotilus atromaculatus	28	*Semotilus*	22
					Moxostoma erythrurum	1	Moxostoma duquesnei	2	Moxostoma erythrurum	1
							Ictalurus melas	1		
							Moxostoma erythrurum	5		
# Species		**3**		**3**		**4**		**6**		**4**
n		**43**		**14**		**19**		**51**		**28**
Metric 5	Nocomis asper	24	Hypentelium nigricans	1	Nocomis asper	4	Nocomis asper	4	Nocomis asper	3
	Hypentelium nigricans	1			Hypentelium nigricans	2	Hypentelium nigricans	11	Hypentelium nigricans	2
	Ambloplites rupestris	5					Moxostoma duquesnei	2		
	Micropterus dolomieui	1					Ambloplites ariommus	1		
							Micropterus dolomieui	6		
# Species		**4**		**1**		**2**		**5**		**2**
n		**31**		**1**		**6**		**24**		**5**
Metric 6	*Lepomis cyanellus*	13	*Lepomis cyanellus*	10	*Lepomis cyanellus*	1	*Lepomis cyanellus*	11	*Lepomis cyanellus*	2
							Ictalurus melas	1		
# Species		**1**		**1**		**1**		**2**		**1**
n		**13**		**10**		**1**		**12**		**2**
Metric 7		**50**		**91.67**		**65**		**54.93**		**80**
Metric 8		**38.71**		**0**		**20**		**5.63**		**10**
Metric 9		**9.68**		**0**		**0**		**11.27**		**0**
Metric 10		**62**		**24**		**20**		**71**		**30**
IBI Score		**38**		**28**		**38**		**36**		**32**
IBI Rating		**FAIR**		**POOR**		**FAIR**		**POOR**		**POOR**

Table 19. Comparison of Fish Metrics for Peacheater Creek (May, June 1997).

	28 MAY 97				4 JUN 97				5 JUN 97	
Site ID	**Peacheater Creek (PE3)**		**Peacheater Creek (PE4a)**		**Peacheater Creek (PE1)**		**Peacheater Creek (PE5)**		**Peacheater Creek (PE2)**	
Site #	**OK121700-05-0120I**		**OK121700-050120L**		**OK121700-05-0120B**		**OK121700-05-0120Q**		**OK121700-05-0120F**	
Metric 1		**9**		**6**		**7**		**6**		**10**
Metric 2										
# Species		**0**		**0**		**0**		**0**		**0**
N		**0**		**0**		**0**		**0**		**0**
Metric 3	*Ambloplites ariommus*	1	*Lepomis cyanellus*	8	*Ambloplites ariommus*	2	*Lepomis cyanellus*	2	*Ambloplites ariommus*	2
	Lepomis megalotis	1	*Lepomis macrochirus*	3	*Lepomis cyanellus*	10	*Lepomis macrochirus*	1	*Lepomis cyanellus*	16
	Lepomis cyanellus	3			*Lepomis megalotis*	6			*Lepomis macrochirus*	2
	Lepomis macrochirus	2							*Lepomis megalotis*	2
	Micropterus punctulatus	1							*Micropterus dolomieui*	2
									Micropterus salmoides	1
# Species		**5**		**2**		**3**		**2**		**6**
N		**8**		**11**		**18**		**3**		**25**
Metric 4	*Nocomis asper*	20	*Nocomis asper*	47	*Nocomis asper*	3	*Nocomis asper*	4	*Nocomis asper*	11
	Hypentelium nigricans	86	*Semotilus*	63	*Hypentelium nigricans*	1	*Semotilus atromaculatus*	34	*Hypentelium nigricans*	6
	Semotilus atromaculatus	18	*Ictalurus melas*	1	*Semotilus atromaculatus*	13	*Moxostoma erythrurum*	3	*Semotilus atromaculatus*	22
	Ictalurus melas	2	*Moxostoma erythrurum*	63	*Ictalurus melas*	1	*Ictalurus melas*	4	*Ictalurus melas*	2
# Species		**4**		**4**		**4**		**4**		**4**
N		**126**		**174**		**18**		**45**		**41**
Metric 5	*Nocomis asper*	20	*Nocomis asper*	47	*Nocomis asper*	3	*Nocomis asper*	4	*Nocomis asper*	11
	Hypentelium nigricans	86			*Hypentelium nigricans*	1			*Hypentelium nigricans*	6
	Ambloplites ariommus	1			*Ambloplites ariommus*	2			*Ambloplites ariommus*	2
									Micropterus dolomieui	2
# Species		**3**		**1**		**3**		**1**		**4**
n		**107**		**47**		**6**		**4**		**21**
Metric 6	*Lepomis cyanellus*	3	*Ictalurus melas*	1	*Lepomis cyanellus*	10	*Ictalurus melas*	4	*Ictalurus melas*	2
			Lepomis cyanellus	8	*Ictalurus melas*	1	*Lepomis cyanellus*	2	*Lepomis cyanellus*	16
# Species		**1**		**2**		**2**		**2**		**2**
n		**3**		**9**		**11**		**6**		**18**
Metric 7		**15.67**		**38.38**		**63.89**		**75**		**57.58**
Metric 8		**14.92**		**25.41**		**8.33**		**8.33**		**16.67**
Metric 9		**1.49**		**0**		**5.56**		**0**		**7.58**
Metric 10		**134**		**185**		**36**		**48**		**66**
IBI Score		**42**		**38**		**32**		**30**		**32**
IBI Rating		**FAIR**		**FAIR**		**POOR**		**POOR**		**POOR**

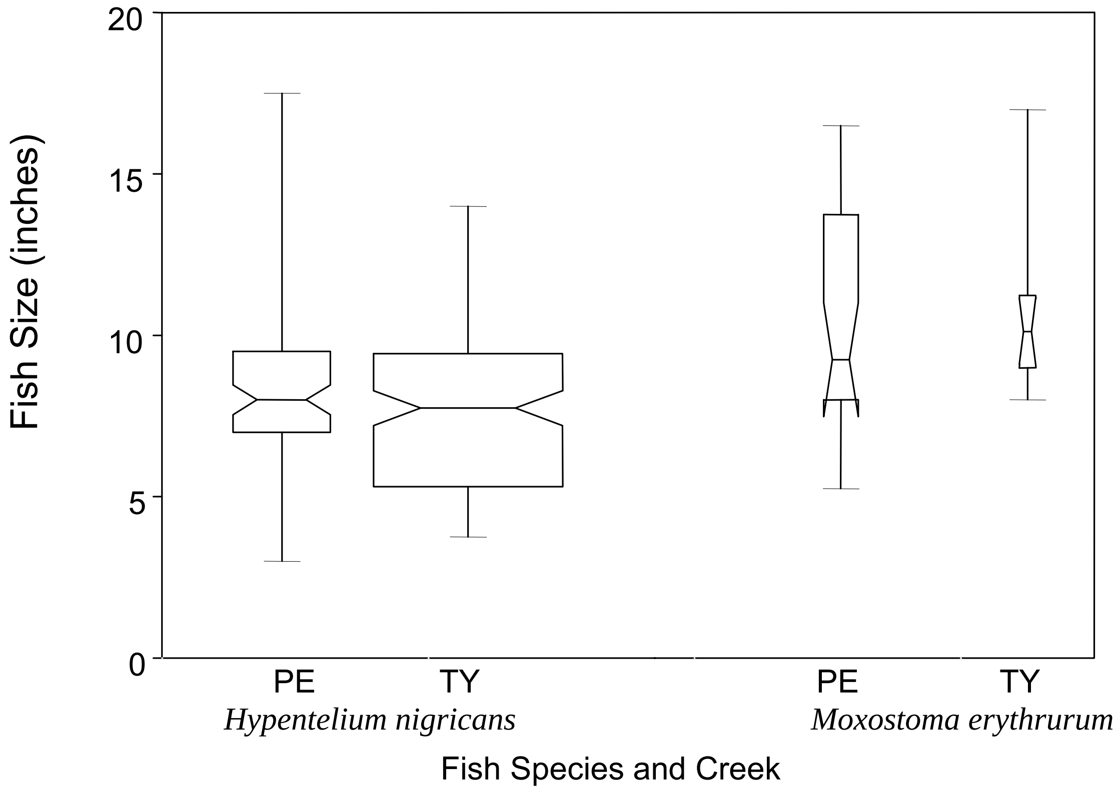


Figure 27. Size Comparison of Catostomidae Species in Peacheater and Tyner Creeks.

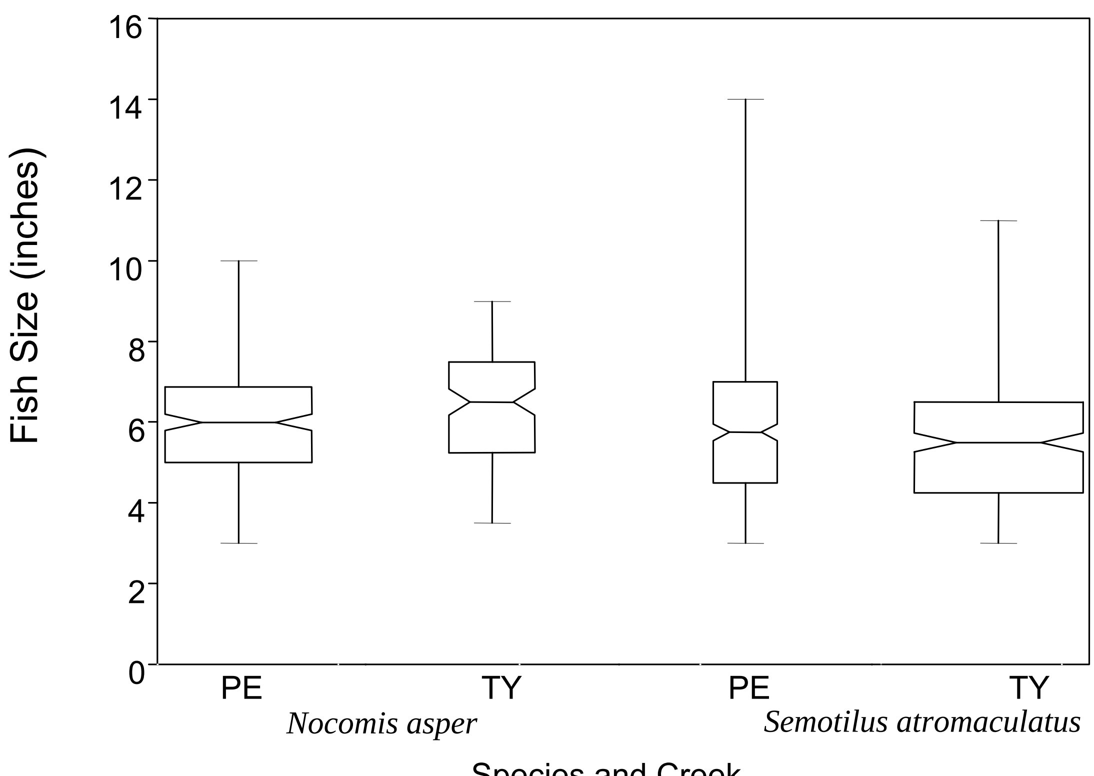


Figure 28. Comparison of Cyprinidae Species Lengths in Peacheater and Tyner Creeks.

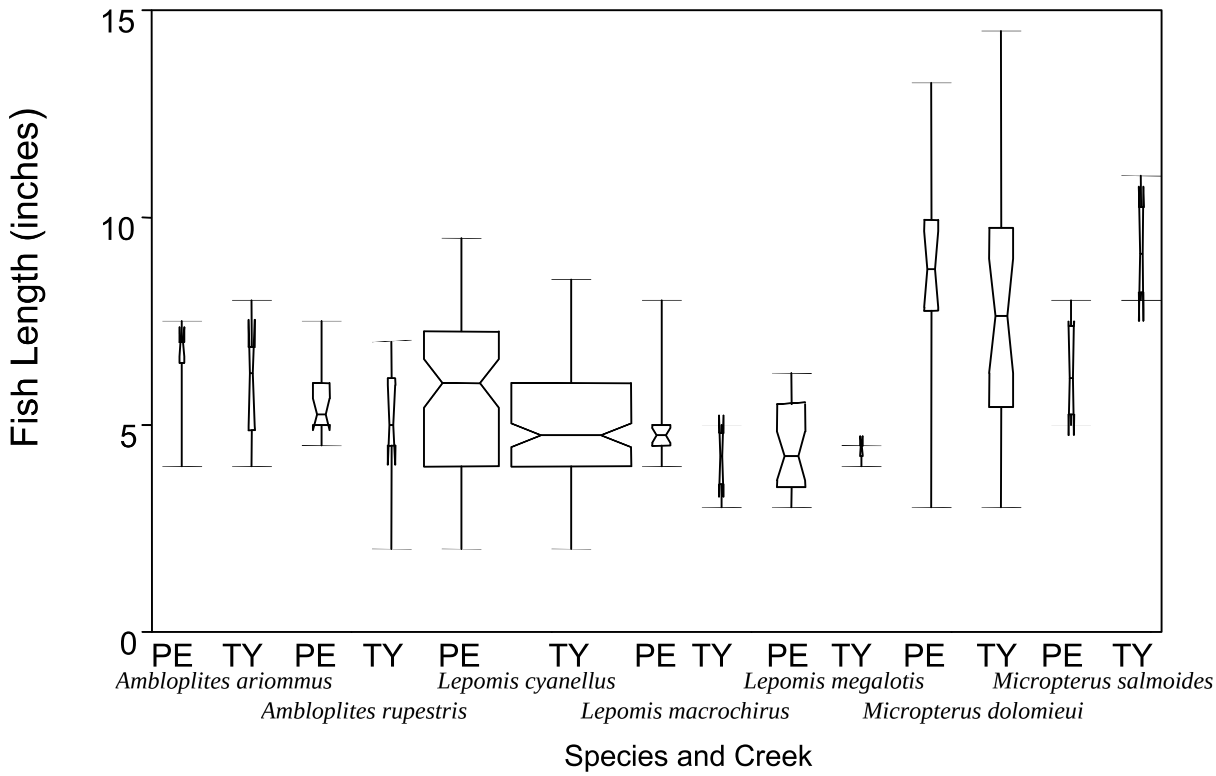


Figure 29. Comparison of Centrarchidae Species Lengths in Peacheater and Tyner Creeks.

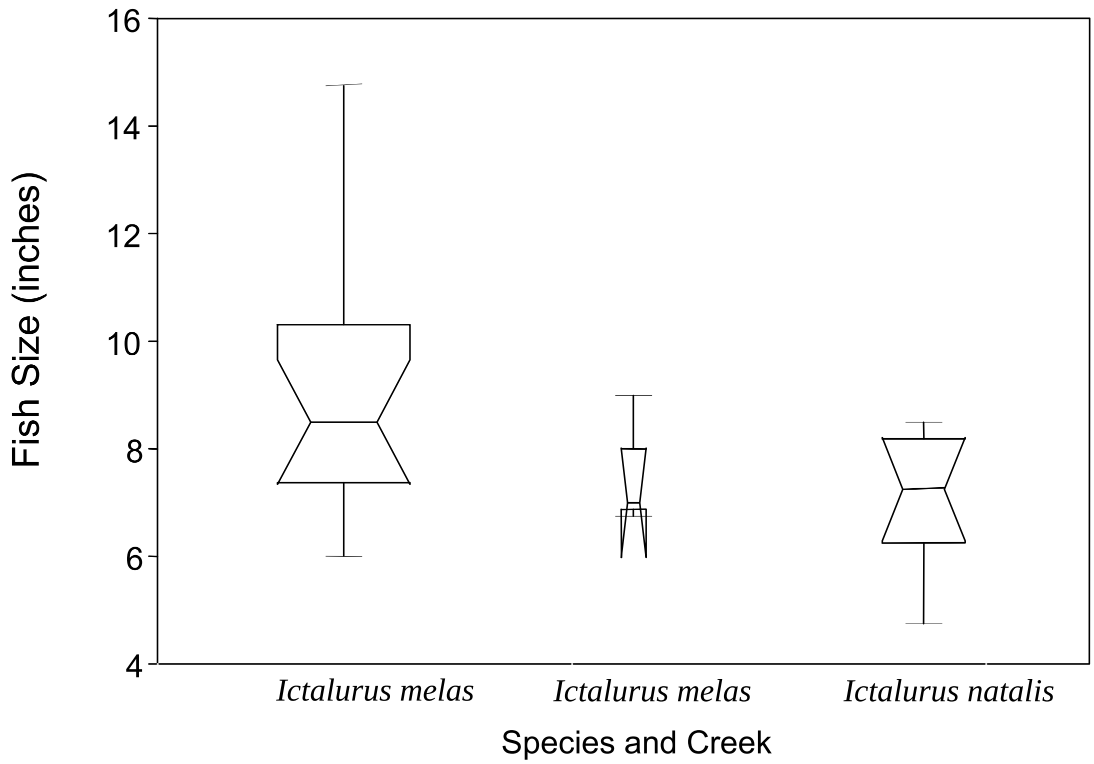


Figure 30. Comparison of Ictaluridae Species Lengths in Peacheater and Tyner Creeks.

In conclusion, fish communities were similar in Peacheater and Tyner Creeks. Although ratings differed at some sites during four of the eight sampling periods, only 7 of the 34 (21%) sites sampled received different ratings. Median fish length was also similar between creeks. Only three of the 12 species compared had significantly different lengths between creeks. These results suggest sufficient similarity in fish communities of the two creeks to qualify as treatment and control systems.

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