Central Oklahoma Bioassessment Study: Evaluation of Stream Health by Using Fish and Macroinvertebrate Communities as Biological Indicators

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Ongoing studies in central Oklahoma collect bioassessment data to evaluate stream health. During the summer and fall of 1997 and 1998, habitat assessments and biotic evaluations were completed on 400 m reaches of streams within metropolitan Oklahoma City. For each stream, an index of biotic integrity (IBI) score was calculated for the fish community, a rapid bioassessment protocol III (RBP III) score was calculated for the macroinvertebrate community, and habitats were scored based on predetermined criteria. Fish and macroinvertebrate communities were then evaluated by comparing them to replicated reference streams. Of 79 stream bioassessments completed in 1997 and 1998, 54 sites had 400 m of continuous water. Eight of these sites were reference streams, and 46 sites were suitable for comparison to the reference database. Of the sites judged unsuitable, 11 sites had less than 275 m of water, nine sites were completely dry, and five sites were impounded. Habitat scores for study streams ranged from 34.5 to 126 (180 possible points), IBI scores ranged from 8 to 32 (40 possible points), and RBP III scores ranged from 10 to 38 (48 possible points). The results of this study show that 74% of the streams assessed within metropolitan Oklahoma City had some level of water quality impairment.

INTRODUCTION

A bioassessment provides valuable biological data and is a direct measure of a lotic ecosystem or biotic community health (*1*). A stream ecosystem's water quality and health can be estimated by examining fish and macroinvertebrate communities and completing a habitat evaluation (*2,3*). This estimate allows the researcher to avoid using resources for chemical-specific analyses on streams identified by their biota as non-impaired by water quality effects, and thus is a cost-effective and ecologically relevant means to assess stream health.

Although chemical analyses of water samples can identify the concentration of a pollutant at the time of sampling, they may not indicate concentrations at other times or concentrations of other pollutants. In addition, chemical-specific analyses do not provide information about the health of aquatic organisms or communities. By completing bioassessments, chemical analyses are, therefore, not necessary for all streams because streams with healthy aquatic communities can be assumed to have adequate water quality. A considerable sum of money can thus be saved by not performing chemical-specific tests on streams that are known to have a water quality that is capable of supporting healthy aquatic communities.

As part of a large ongoing study conducted by the Oklahoma Conservation Commission, bioassessments were conducted on streams in the central Oklahoma area from

May to September 1997 and May to November 1998. We hypothesized that when compared to replicated reference streams in nearby rural areas, streams located within the metropolitan Oklahoma City area would have impaired biotic (fish and macro-invertebrate) communities because of altered water quality and/or habitat. The reference stream comparisons were used to calculate an index of biotic integrity (IBI) score and a rapid bioassessment protocol III (RBP III) score for study streams. IBI and RBP III scoring were used to estimate the quality of individual fish communities (*4-6*), and macroinvertebrate communities (*2*), respectively. The IBI and RBP III data were combined so we could draw a conclusion about the overall biotic quality of a stream. The biotic quality data was then evaluated within the context of habitat to determine whether or not there is any biological impairment, and if so, whether it is due to habitat degradation, water quality, or a combination of both (*2*).

METHODS

Study sites were chosen from watersheds identified by the City of Oklahoma City Public Works Department as part of an urban watershed health program (Fig. 1). The study sites were accessed from a bridge on a section road that provided a distinct starting point within the urban area. Two different types of reference streams were used in this study. First, streams labeled upper reference streams were known from previous studies to have excellent habitat, a healthy aquatic community, and good water quality. Bioassessments from study streams within the Oklahoma City area were then compared to the reference stream data to determine whether they fell within acceptable limits. In this study, West Elm Creek (VMS 1), Bluff Creek (site 14), Mustang Creek (VMS 6), and Bluff Creek (VMS 5) were chosen as upper reference streams. Second, streams termed water quality reference streams were also used for the reference stream database in this study. The water quality reference streams also possessed good water quality, but had degraded habitats. Fish and invertebrate communities in these sites have lower integrity than do those from the upper reference sites, and the difference from the corresponding upper reference community was due primarily to habitat, because the water quality at these sites was better than study sites. An unnamed tributary of the North Canadian River (site 61), East Elm 6 Creek (REF 2), and Coon Creek (REF 1) were used as water quality reference streams in this study (Fig. 1).

Habitat assessments were conducted according to methods described by the Oklahoma Conservation Commission (OCC; 7). Four hundred meters of each stream were assessed. Eleven habitat parameters were recorded: instream cover, pool variability, canopy cover, pool bottom substrate, base level flow, presence of rocky runs and riffles, channel sinuosity, channel alteration, bank stability, vegetation stability, and dominant vegetation. Primary habitat components have the most direct influence on community structure. Secondary components deal with channel morphology and have a lesser influence on community structure. Tertiary components evaluate both riparian and bank condition and, although of lesser importance to aquatic communities, are good predictors of future habitat. Habitat quality classifications, based on habitat scores, were given to study and reference sites. Scores greater than 100 points were classified as excellent, between 90 and 100 as good, between 80 and 90 as marginally adequate, and less than 80 as below marginally adequate.

Fish were collected according to OCC protocol (*8*) by using 4'x10' seines with 1/4" mesh. All areas of each 400 m reach were seined at least once. Large and/or deep pools were seined until the crew felt satisfied that no additional species were being collected. Commonly collected fish such as Centrarchidae and Ictaluridae, *Notropis stramineus* (sand shiner), *Cyprinella lutrensis* (red shiner), and *Gambusia affinis* (mosquito fish), were identified and released in the field. Other fish, mostly members of the minnow family, were collected and preserved in 10% formalin.

With some regional modification, Karr's IBI (*2,4-6*) was followed when determining fish community condition of the study sites

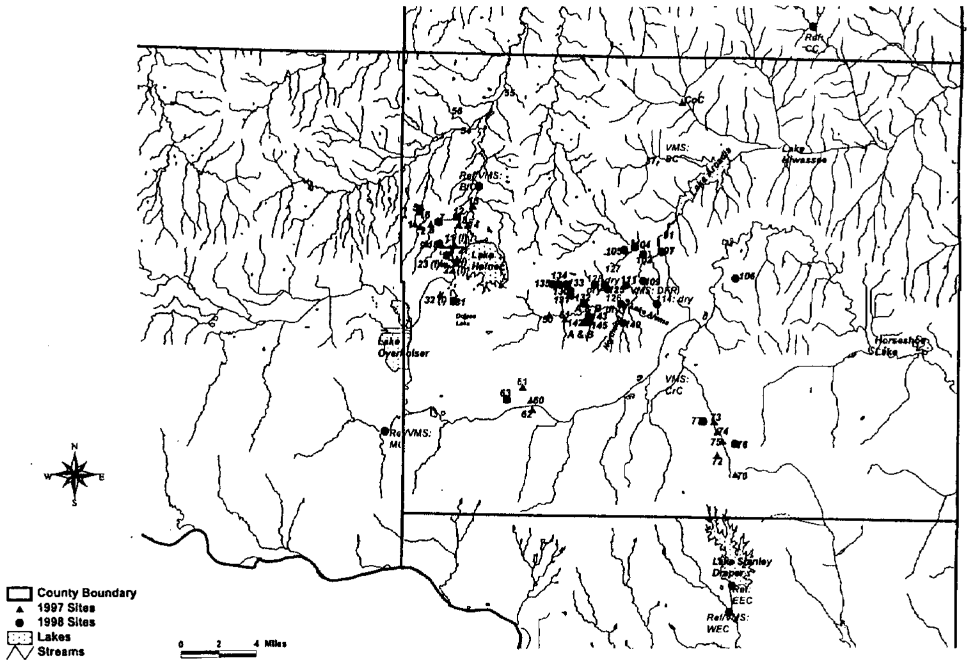

Figure 1. Central Oklahoma area including all 1997 and 1998 stream bioassessment sites.

TABLE 1. Habitat components for all reference and study streams in 1997 and 1998. The first metrics receive a possible 20 points each. The 7 and 8 metrics receive a possible 15 points each. The last 3 metrics receive a possible 10 points each.

	1997 Reference Streams				1998 Reference Streams			
	Mean	Median	Max.	Min.	Mean	Median	Max.	Min.
1. Cover	15.0	16.0	20	9	7.8	8	13	4
2. Pool bottom substrate	5.3	5.0	11	0	9.2	12	13	0
3. Pool variability	9.0	11.0	16	0	9.8	11	14	1
4. Canopy cover	8.0	10.0	14	0	12.0	16	17	2
5. Rocky runs & riffles	2.0	1.0	5	0	8.4	9	12	1
6. Flow	5.3	5.0	11	0	10.0	11	17	1.5
7. Channel alteration	3.7	3.0	8	0	12.0	15	15	6
8. Sinuosity	2.7	3.0	5	0	1.6	1	5	0
9. Bank stability	8.0	7.0	10	7	6.4	7	10	3
10. Vegetative stability	5.3	5.0	10	1	5.4	6	9	1
11. Dominant vegetation	6.3	7.0	7	5	6.8	7	9	4

	1997 Study Streams				1998 Study Streams			
	Mean	Median	Max.	Min.	Mean	Median	Max.	Min.
1. Cover	12.0	11.5	19	4	7.6	6.5	18	2.5
2. Pool bottom substrate	8.0	6.5	15	2	8.3	7.5	17	1
3. Pool variability	10.9	13.5	16	0	8.8	7.0	20	1
4. Canopy cover	12.9	13.5	20	0	11.9	16.0	20	0
5. Rocky runs & riffles	5.9	5.0	16	0	5.2	6.0	13	0
6. Flow	7.0	5.5	17	0	4.0	2.0	17	0
7. Channel alteration	9.9	11.0	15	3	9.9	10.5	15	2
8. Sinuosity	4.3	4.0	8	1	2.2	2.0	5	0
9. Bank stability	5.8	6.0	10	0	5.5	6.0	10	0.5
10. Vegetative stability	4.7	4.5	10	1	5.1	5.0	9	1
11. Dominant vegetation	6.9	7.0	10	2	6.8	7.0	9	4

(*2*). The Intolerant Species metric was used, but the Sensitive Benthic Species metric was deleted because in central Oklahoma this metric indicates the presence or absence of the same fish species. Fish species counted as intolerant were *Campostoma pullum* (central stoneroller minnow) and *Phenacobius mirabilis* (suckermouth minnow; *9*). The fish species counted as tolerant were *C. lutrenis*, *Lepomis cyanellus* (green sunfish) and *G. affinis* (*9*). The Proportion of Hybrids or Exotics and the Proportion of Disease and/or Anomalies metrics were not used. All *Pylodicitis olivaris* (flathead catfish), *Micropterus salmoides* (largemouth bass), and *Micropterus punctulatus* (spotted bass) were counted as top carnivores (*9*). Young of year were not counted in the collections.

Benthic aquatic macroinvertebrates were collected from rocky riffles following OCC protocol (*10*). A 1 m^2 sampling net with a number 30 mesh was used for collections. Macroinvertebrates were sampled by using the riffle kick method. Samples from each site included a high, medium, and slow water velocity riffle. Samples were preserved in 70% ethanol and returned to the laboratory for identification and enumeration. With some regional modification, the United States Environmental Protection Agency rapid bioassessment protocol III (2) was used in determining the benthic macroinvertebrate community condition of the study sites. The Community Loss metric was not used in this study. The ratio of Shredders/Total metric was not used because all reference streams had fewer than 2% shredders. The Shannon-Weiner metric was used to determine taxa diversity in the collections.

RESULTS

Individual aquatic habitat component data for reference and study streams are shown in Table 1. Overall habitat scores for the upper reference streams ranged from 93 to 106, with a mean of 98.8. Of the 35 study streams assessed in 1997, three were dry, five were impounded, and 27 were free flowing with enough water to support fish and macroinvertebrate populations. Aquatic habitat scores for the 27 sites ranged from 45 to 126, with a mean of 87.3. Of the 44 study streams assessed in 1998, six sites were completely dry, eleven had less than 275 m of water, and 27 sites had a continuous flow of water. Aquatic habitat scores for those 27 sites ranged from 34.5 to 101, with a mean of 75.0. In 1997, seven sites were classified as excellent, six sites were classified as good, five sites were classified as marginally adequate, and nine sites were classified as below marginally adequate. In 1998, three sites were classified as excellent, two sites were classified as good, two sites were classified as marginally adequate, and 15 sites were classified as below adequate.

Fish IBI scores for study sites were based on comparisons with the mean IBI score for the upper reference streams (*2*). The upper reference streams in 1997 were site 14, with an IBI score of 30, and VMS 1, with an IBI score of 30. The upper reference streams in 1998 were VMS 5, with an IBI score of 32; VMS 1, with an IBI score of 28; and VMS 6, with an IBI score of 32.

Twenty different fish species were collected in 1997 (Table 2). The most common fish species collected was *C. lutrensis*, with 1,638 individuals. Nine *P. mirabilis* were collected. IBI scores for the 1997 study sites ranged from 8 to 30, with a mean of 14.7. Integrity classes were given to study sites based on comparisons of the IBI scores to the upper reference sites. One site was classified as having an excellent fish community with a score of 97% of the upper reference stream average. Two sites had fish communities classified as good (80-87% of reference mean), four sites were classified as fair (67-73%), six sites were classified as poor (47-57%), and 11 were classified as very poor (< 37%). Six of the 11 sites classified as having very poor fish communities had fewer than 5% of the total number of individual fish compared to the upper reference sites. Three of these sites had no fish collected in the 400 m assessment.

In 1998, 27 different species were collected (Table 2). Sixty-five *P. mirabilis* and 53 *C.pullum* were collected. *Lepomis megalotis* (longear sunfish) was the most common fish species collected, with 1,027 individuals. IBI scores for the 1998 study sites ranged from 8

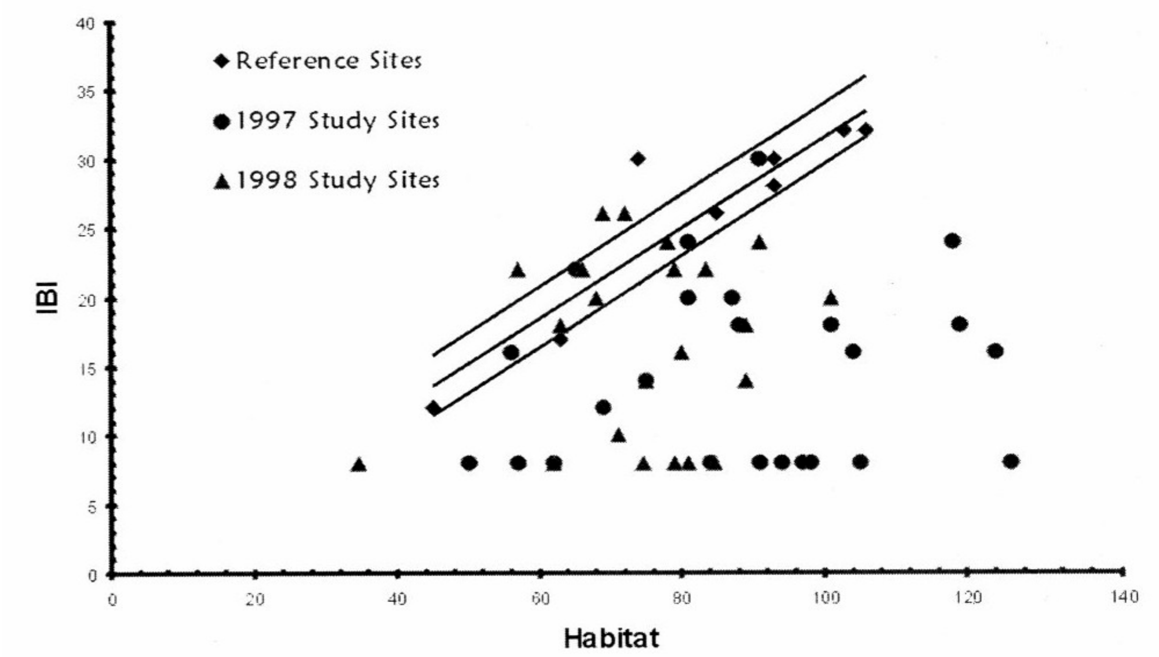

Figure 2. The relationship between habitat scores and the index of biotic integrity (IBI) scores for the 1997 and 1998 collection periods. The regression line was created from all reference streams (R^2 = 0.84). Ninety-five percent confidence intervals are shown. The levels of water quality impairment in study streams were determined by calculating the distance a point is from the regression line.

to 32, with a mean of 15.3. No 1998 study sites had scores in the excellent fish community class. Three sites were classified as good, six sites were classified as fair, five sites were classified as poor, and 14 sites were classified as very poor. Eight of the 14 sites classified as having very poor fish communities had less than 5% of the total number of individual fish compared to the upper reference sites. Two of these sites had no fish collected in the 400 m assessment.

The 1997 upper reference streams used for calculating RBP III macroinvertebrate scores were site 14, with a RBP III score of 30, and VMS 1, with a score of 38. Upper reference streams used in RBP III calculations for 1998 were VMS 5, with a RBP III score of 38, and two different collections taken from the same VMS 1 site; both received 36 points. Benthic macroinvertebrate communities were assessed independently of the habitat score because only a high quality microhabitat (i.e., rocky riffle) was sampled. The 1997 RBP III scores ranged from 10 to 38, with a mean of 16.7 (Table 3). One site was classified as not impaired, with a score of 83% or greater of the upper reference stream average. Six sites were classified as slightly impaired (54-79% of reference mean) and six sites were classified as moderately impaired (21-50%). Five sites were not analyzed because of insufficient samples. Two sites had less than 5% of the individual macroinvertebrates/m^2 compared to the upper reference streams.

Three study site macroinvertebrate collections were completed in 1998 (Table 3). One site had a score of 30 and was classified as having an unimpaired macroinvertebrate community. One site had an insufficient sample to complete the analysis, and the other site had fewer than 5% of the individual macroinvertebrates/m^2 . The small number of samples was due to low levels of flow in 1998, which reduced the amount of rocky riffle available for macroinvertebrate collections.

The overall water quality of each study site was assessed by comparing the IBI and habitat score data pair to the best-fit line for

TABLE 2. Species and common names of all fish collected in 1997 and 1998, along with numbers collected in each year.

Fish Species	1997	1998
sand shiner (*Notropis stamineus*)	563	582
red shiner (*Cyprinella lutrensis*)	1638	956
golden shiner (*Notemigonus crysoleucas*)	25	22
bullhead minnow (*Pimephales vigilax*)	14	115
bluntnose minnow (*Pimephales notatus*)	2	0
fathead minnow (*Pimephales promelas*)	136	217
suckermouth minnow (*Phenacobius mirabilis*)	9	65
central stoneroller minnow (*Campostoma anomalum*)	0	53
longear sunfish (*Lepomis megalotis*)	477	1027
green sunfish (*Lepomis cyanellus*)	147	364
bluegill sunfish (*Lepomis macrochirus*)	351	259
orangespotted sunfish (*Lepomis humilis*)	1	98
redear sunfish (*Lepomis microlophus*)	3	2
warmouth sunfish (*Lepomis gulosus*)	0	12
largemouth bass (*Micropterus salmoides*)	8	22
spotted bass (*Micropterus punctulatus*)	0	15
black crappie (*Poxomis nigromaculatus*)	0	2
white crappie (*Poxomis annularis*)	5	1
channel catfish (*Ictalurus punctatus*)	1	14
black bullhead catfish (*Ictalurus melas*)	18	51
yellow bullhead catfish (*Ictalurus natalis*)	8	14
freshwater drum (*Aplodinotus grunniens*)	0	2
river carpsucker (*Carpoides carpio*)	0	1
brook silverside minnow (*Labidesthes sicculus*)	0	2
mosquito fish (*Gambusia affinis*)	437	244
common carp (*Cyprinus carpio*)	0	2
plains killifish (*Fundulus zebrinus*)	89	325
gizzard shad (*Dorosoma cepedianum*)	0	1
slim minnow (*Pimephales tenellus*)	1	0

all reference streams (Fig. 2). Of 46 streams with adequate data assessed in 1997 and 1998, 34 streams fell below the lower 95% confidence limit of the regression line and thus were considered to have impaired water quality. Four levels of water quality impairment were then established to classify the study streams: no water quality impairment, slight water quality impairment, moderate water quality impairment, and severe water quality impairment (Table 4).

DISCUSSION

Streams within urban areas are often subjected to a wide spectrum of pollutants via runoff, such as fertilizers, herbicides, and pesticides (*11*). Based on a bioassessment protocol that includes examining physical habitat and fish and macroinvertebrate communities, the results of this study indicate that the majority of streams within metropolitan Oklahoma City exhibit some degree of water quality impairment. Furthermore, because of their relative low cost and ability to resolve impaired fish and macroinvertebrate community structures, using such bioassessments to determine overall stream health in urban areas are supported by our data.

Reference streams were chosen from within non-urbanized watersheds with no high intensity agriculture. As expected, the collection of high quality fish and invertebrate communities from these sites verified the presumption of good water quality. The

TABLE 3. Macroinvertebrate rapid bioassessment protocol (RBP III) scores for 1997 and 1998. The reference mean in 1997 was 34, and the reference mean in 1998 was 36.

1997 Site #	Stream Name	RBP III Score
111	Unnamed Tributary to Deep Fork 2	14
125	Unnamed Tributary to Deep Fork 2B1	24
52	Coffee Creek	12
51	Unnamed Tributary to Deep Fork	12
50	Deep Fork	22
74	Soldier Creek	24
7	Unnamed Tributary to Spring Creek	12
10	Unnamed Tributary to Spring Creek	16
13	Spring Creek	24
12	Unnamed Tributary to Spring Creek	18
6	Unnamed Tributary to Spring Creek	18
63	Unnamed Tributary to North Canadian	14
73	Soldier Creek	30

1998 Site #	Stream Name	RBP III Score
-	Spring Creek	30
-	West Elm Creek *	36
-	West Elm Creek *	36
-	Bluff Creek	38

* Two different West Elm collections.

TABLE 4. Classification of water quality impairment levels for 1997 and 1998 streams.

No Level of Water Quality Impairment

1997 Sites	Stream Name	Legal Description
12	Unnamed Tributary to Spring Creek, NW Branch	SW/NW/NW/SW 15 13N 4W
63	Unnamed Tributary to North Canadian River	NW/NE/NW/NE 1 11N 4W
125	Unnamed Tributary to Deep Fork River	SW/SW/NW/NW 1 12N 3W
60	Unnamed Tributary to North Canadian River	SW/SE/SE 31 12N 3W
	Spring Creek	SW/NW/SW/NW 33 14N 2W

1998 Sites	Stream Name	Legal Description
63	Unnamed Tributary to North Canadian River	NW/NE/NW/NE 1 11N 4W
63	Unnamed Tributary to North Canadian River	NW/NE/NW/NE 1 11N 4W
105	Unnamed Tributary to Deep Fork River, 1C1	NW/SW/NW/NW 30 13N 2W
110	Deep Fork River	NW/NW/NE/NW 6 12N 2W
111	Unnamed Tributary to Deep Fork River, 2	SE/SW/SW/SW 31 13N 2W
97	Unnamed Tributary to Deep Fork River	SW/SW/NW/NW 28 15N 2W
91	Unnamed Tributary to Deep Fork River	NE/SE/SE/NE 20 13 N 2W

Slight Level of Water Quality Impairment

1997 Sites	Stream Name	Legal Description
10	Unnamed Tributary to Spring Creek	SE/SW/SW/SW21 13N 4W
15	Bluff Creek	S/SW/SE/SE 10 13N 4W
6	Unnamed Tributary to Spring Creek	NE/NE/NW/NW /NE 20 13N 4W

1998 Sites	Stream Name	Legal Description
125	Unnamed Tributary to Deep Fork River, 2b1	SW/SW/NW/NW 1 12N 3W
12	Unnamed Tributary to Spring Creek, NW Branch	SW/NW/NW/SW 15 13N 4W
VMS 2	Crutcho Creek	SE/SE/SE/NE 32 12N 2W

Table 4. Continued

Moderate Level of Water Quality Impairment

1997 Sites	Stream Name	Legal Description	
	Unnamed Tributary to Unnamed Tributary to		
16	Walnut Creek	SW/SW/SWNW 17	13N 4W
56	Unnamed Tributary to Deer Creek	NW/NW/NW/NE 21	14N 3W
13	Spring Creek	SE/SW/SW/SW 15	13N 4W
54	Deer Creek, West	SW/SW/SW/SW/SW 22	14N 4W
74	Soldier Creek	NW/NW/NW/SW 12	11N 2W
2	Walnut Creek	NE/NE/SE/NE/NE 19	13N 4W
60	Unnamed Tributary to North Canadian River	SW/SE/SE 31	12N 3W
	Coffee Creek	NE/SE/SE/NE 16	14N 2W

1998 Sites	Stream Name	Legal Description	
149	Unnamed Tributary to Deep Fork River	S1/2/SW/SE/SE 12	12N 3W
102	Unnamed Tributary to Deep Fork River, 1A	SW/NW/SW/NW 29	13N 2W
31	Tulakes, Fork of Spring Creek	SE/SW/SW/SE 4	12N 4W
10	Unnamed Tributary to Spring Creek, SW Branch	SE/SW/SW/SW 21	13N 4W
7	Unnamed Tributary to Spring Creek, NW Branch	SE/NE/SE/SE 20	13N 4W
77	Unnamed Drainage To Soldier Creek	NW/NE/NE/NW 11	11N 2W
57	Spring Creek	NE/NE/SE/SE 31	14N 2W
106	Unnamed Tributary to Deep Fork River, 1C2	NE/NE/NE/SE 36	13N 2W
145	Unnamed Tributary to Deep Fork River, 4b	S1/2/SW/SW/SW 11	12N 3W

Severe Level of Water Quality Impairment

1997 Sites	Stream Name	Legal Description	
73	Soldier Creek	NE/NW/NE/NE 11	11N 2W
50	Deep Fork River	SE/NE/SE/NW/SE 8	12N 3W
72	Unnamed Tributary to Soldier Creek	SW/NW/NW/SW 13	11N 2W
75	Soldier Creek	NW/NW/NE/NW 13	11N 2W
77	Unnamed Drainage to Soldier Creek	NW/NE/NE/NW 11	11N 2W
7	Unnamed Tributary to Spring Creek, NW Branch	SE/NE/SE/SE20	13N 4W
31	Tulakes, Fork of Spring Creek	SE/SW/SW/SE 4	12N 4W
9	Unnamed Tributary to Spring Creek	SE/SE/SW/SE/SW 17	13N 4W
57	Spring Creek	NE/NE/SE/SE 31	14N 4W

1998 Sites	Stream Name	Legal Description	
133	Unnamed Drainage to Deep Fork River	NW/NE/NE/NW 4	12N 3W
134	Unnamed Tributary to Deep Fork River, 3a	NW/NE/NE/NW 4	12N 3W

regression line constructed from all reference sites determines the relationship between habitat and biota, and describes the degree by which biotic integrity decreases as habitat becomes poorer (*2*). This relationship was used to distinguish whether a deficiency in biotic condition of a study stream was due to habitat or water quality factors. All study sites were plotted against the best-fit line to determine whether the sites had adequate IBI scores that were consistent with the individual habitat scores. If a point fell within the confidence limits of the regression line, it was concluded that the deficiency, if any, was due to habitat factors. If the biotic condition score fell below the regression line, the vertical distance of the biotic score from the line was concluded to be the deficiency because of water quality effects. The distance from the regression line to the biotic score of the upper reference stream(s) was the deficiency because of habitat (*2*).

Rocky runs and riffles and flow metrics were greatly affected by the record low rainfall in 1998, which was only 36% of the average rainfall for May through August. Lower habitat scores in 1998 could, therefore, be attributed to lower scores for these two primary metrics. Sites that were dry, impounded, or had less than 275 m of water could not be used to determine stream health because not enough data could be collected from these sites (*7*). In addition, streams having fewer than 5% of the total numbers of individuals of the upper reference streams may be affected by toxicants and should, therefore, be reexamined with chemical-specific analyses.

Because all macroinvertebrate communities were collected from adequate habitat, the RBP III score confirmed the results derived from IBI and habitat data. If a study site had a low IBI score and the fish data indicated this score was due to lack of suitable habitat, the macroinvertebrate data should support this assumption, and the same study site should have a high RBP III score. Macroinvertebrate collections in the present study were found to be valuable in assessing stream health, which is similar to previous studies (*12,13*). When a stream with both very low IBI and habitat scores is encountered, it is often impossible to say whether there is water quality impairment in addition to the habitat impairment.

The results of this study reveal that 74% of the study streams in metropolitan Oklahoma City that had adequate habitat and fish data had some level of water quality impairment. It is likely that runoff provides the main input of chemicals such as pesticides and fertilizers into streams in this urban area. By examining fish and macroinvertebrate communities, we made an estimate of this effect, and we recorded valuable knowledge of community structure. Knowledge of community structure will lead to a better understanding of central Oklahoma fish and macroinvertebrate responses to water quality impairment. The bioassessment, which includes the abbreviated habitat assessment, IBI scoring, and RBP III scoring, is an extremely efficient and inexpensive method to determine the overall health of a stream ecosystem.

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