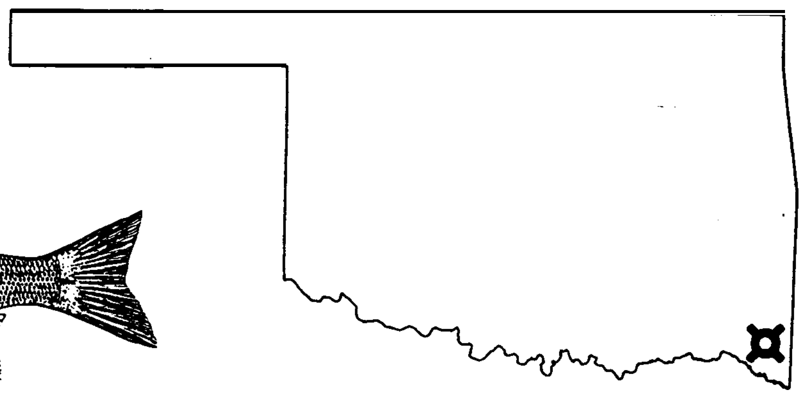
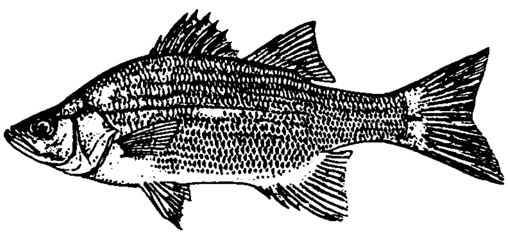
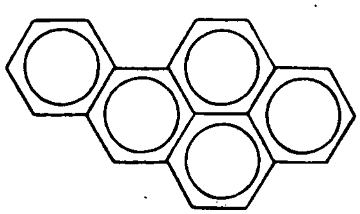
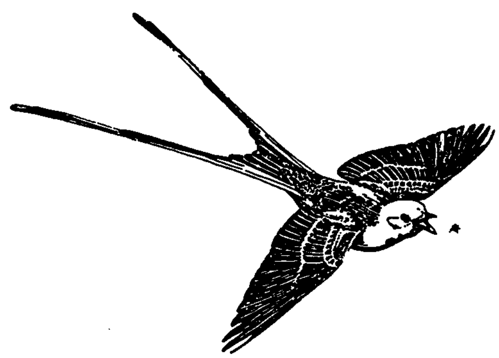
THE USE OF RAPID BIOASSESSMENT PROTOCOLS TO DESCRIBE FISH AND BENTHIC MACROINVERTEBRATE COMMUNITIES IN THREE CREEKS NEAR THE LITTLE RIVER NATIONAL WILDLIFE REFUGE, MCCURTAIN COUNTY, OKLAHOMA

by
Todd Adornato









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Abstract

Selected metrics from the Rapid Bioassessment Protocols (RBPs), published by the U.S. Environmental Protection Agency, were used to describe fish and benthic macroinvertebrate communities from three creeks (Horsehead, Yashau, and Lukfata) upstream and downstream of three industrial sites (Weyerhauser, Dominance Industries, and Tyson Foods, respectively) near the Little River National Wildlife Refuge in southeastern Oklahoma. Instead of a one-time sample as described in the RBPs, four monthly samples each of fish and macroinvertebrates were collected from June through October 1995. Samples were collected in shorter sections of stream than prescribed in the RBPs. Statistical analysis of the data indicated degraded conditions downstream of the Weyerhauser and Dominance sites, with mixed results at the Tyson site. Some seasonal variability in the RBP metrics over time, suggest that a one-time sample may not provide a complete picture of community health of fish and macroinvertebrates in a study stream.

Table of Contents

Introduction

The U.S. Environmental Protection Agency (EPA) published a technical reference (Plafkin et al. 1989) describing the use of Rapid Bioassessment Protocols (RBPs) for conducting quick, cost-effective assessments of lotic systems. These RBPs presumably provide a "snapshot" of fish and benthic macroinvertebrate community structure and function that can be used to evaluate the health of a study stream when compared to a reference condition. EPA is presently encouraging state water quality agencies to adopt modified versions of the RBPs in their development and implementation of biocriteria in water quality standards.

The objective of this study was to use selected parameters (termed "metrics") from the RBPs to describe fish and benthic macroinvertebrate communities upstream and downstream of three industrial sites located near Little River National Wildlife Refuge in southeast Oklahoma. We used a set of habitat assessment procedures developed by the Oklahoma Conservation Commission (1996) to describe the physical habitat at each location. In this report I present the results of this study and the use of each metric in detecting upstream/downstream differences at each site.

Study Area

The Little River originates in LeFlore County and flows through McCurtain County, draining an area of some 1,104,000 hectares before it enters the Red River in southwest Arkansas (U.S. Army Corps of Engineers 1982). The Little River basin in Oklahoma contains several major features, including the Glover and Mountain Fork Rivers, and Pine Creek and Broken Bow Lakes. The Little River basin contains parts of three ecoregions, including the South Central Plains in the southeast, Ouachita Mountains in the north, and the Central Oklahoma / Texas Plains in the west (Omernik 1993). The upper portion of the Little River has bedrock bottoms with large boulders and considerable gradients, while the lower portion has a moderate gradient and finer substrata. Streams throughout the area generally have moderate to high flows and narrow floodplains, except where they enter the Little River in its lower reaches.

The Little River NWR (LRNWR) extends along the Little River from Holly Creek, just north of Idabel, east to Goodwater Creek, near the Arkansas state line (Figure 1). The refuge is comprised of high-quality bottomland hardwoods, which are scarce in Oklahoma, plus aquatic habitats unique to the area. These habitats support Federally listed species such as the endangered Ouachita rock-pocketbook mussel (*Arkansia wheeleri*) and the candidate crystal darter (*Ammocrypta asprella*) and Ouachita shiner (*Lythrurus snelsoni*). The refuge also provides habitat for nesting and migrating waterfowl.

A good portion of the Little River watershed is dedicated to intensive silvicultural practices. Weyerhauser operates several forestry-related industries in the watershed, including a wood processing plant in Wright City. Poultry and swine feeding operations are present throughout the area, as well as cattle grazing. A large workforce is employed at several industries including the Tyson poultry processing plant south of Broken Bow, and the Dominance fiberboard plant just west of Broken Bow. Industrial discharges from these operations enter the LRNWR via tributaries of the Little River, or the Little River itself.

Methods

We chose six paired sites on three tributaries of the Little River near the LRNWR, for RBP assessments (Figure 1). They were:

1) Above and below the Weyerhauser plant in Wright City (SE¼ Section 3, T6S, R22E; NE¼ Section 10, T6S, R24E, respectively) on Horsehead Creek
2) Above and below the Dominance fiberboard plant west of Broken Bow (NE¼ Section 11, T6S, R24E; NW¼ Section 24, T6S, R24E, respectively) on Yashau Creek
3) Above and below the Tyson plant south of Broken Bow (NE¼ Section 11, T7S, R24E; NE¼ Section 14, T7S, R24E, respectively) on Lukfata Creek

We labeled these sites AW, BW, AD, BD, AT, and BT, respectively.

All three streams are typical of the area, with moderate gradients, narrow courses, and a mixture of cobble/gravel and sandy substrates. We considered each upstream site to be a reference site for the corresponding downstream site. We chose sites that were near the relevant discharge point and on the downstream side of road bridges, except for the downstream site at Horsehead Creek, which was located just downstream of the Weyerhauser holding lagoons. Each site included 40-70 meters of creek, enough to include a pool and a riffle habitat.

To collect fish, we seined the pool at each site three times from bank to bank, starting at the downstream edge of the pool and working upstream. We deployed a block net across the lower edge of the pool to prevent fish from escaping downstream; the upstream riffle helped prevent escape in that direction. To sample riffles, we deployed a kick net near the lower end of the riffle, and with the hands and feet overturned one square meter of substrate immediately upstream of the net to dislocate benthic-dwelling fish into the net. We repeated this until we had collected at least 100 fish (when possible), and either identified the fish in the field or fixed them in formaldehyde for later identification in the laboratory. We then selected seven RBP metrics from Protocol V of Plafkin et al. (1989) to describe the fish communities at each site. These included:

1) Total number of fish species
2) Total number of darter species
3) Total number of sunfish species
4) Total number of minnow species (in place of sucker species)
5) Percentage of all fish as tolerant individuals
6) Percentage of all fish as intolerant individuals (a modification of #5)
7) Percentage of all fish as insectivorous cyprinids

To collect macroinvertebrates, we placed the kick net at the lower edge of the riffle, and with the hands and feet, overturned one square meter of substrate upstream of the net to displace macroinvertebrates into the net. We also collected leaf litter and other detritus, if present. We scoured debris by hand and with brushes, with the kick net placed directly downstream or underneath. By hand or with tweezers, we collected macroinvertebrates found on large rocks, taking care not to concentrate on the larger-sized animals. We then fixed all macroinvertebrates in ethanol. We continued sampling until a minimum of 100 benthic macroinvertebrates were collected, when possible. We selected six metrics from Protocol III of Plafkin et al. (1989) to describe benthic macroinvertebrate communities. These were:

1) Total number of macroinvertebrate families
2) Modified Family Biotic Indices
3) Ratio of EPT and chironomid abundances
4) Percent contribution of dominant taxon
5) EPT Index
6) Community Loss Indices

We collected biota biweekly starting in June 1995. Collections alternated between fish and macroinvertebrates, so that we made one fish and one macroinvertebrate collection per month. Inclement weather and logistical problems precluded sampling in September, so the sampling period ended in October 1995. We made a total of four fish and four macroinvertebrate collections at each site.

To assess habitat quality, we marked transects at 5-meter intervals along each watercourse, for the length of the sampling site. Using a flow meter, a graduated 2-meter pole, and a surveyor's tape at each transect, we measured the eleven metrics described by the Oklahoma habitat assessment guidelines (Oklahoma Conservation Commission 1996). We took measurements once in January 1996, when water flows were comparable to those that occurred during the biota sampling period.

In the laboratory, we transferred all specimens to fresh solutions of ethanol. We identified invertebrates to family using Pennak (1978) and Merritt and Cummins (1984).; and fish to species using Miller and Robison (1973), Robison and Buchanan (1988), and Etnier and Starnes (1993) .

We reviewed the metrics described in the EPA RBPs and selected a set based on their relevance to our study area. We then calculated the metrics from the data to produce an estimate of aquatic community health at each site. We compared each pair of sites (upstream and downstream) to determine whether downstream communities were degraded. We used Wilcoxon's signed rank test to determine the statistical significance of each metric when upstream and downstream sites were paired, based on the assumption that all three streams were comparable in physical and chemical structure.

Results and Discussion

Habitat Assess- (Table 1)

We used eleven metrics, which take into consideration instream habitat parameters and streamside habitat condition, to assess each site (Oklahoma Conservation Commission 1996). Each parameter, which was estimated along 5-meter transects, was averaged and assigned a score. Metric scores were then added for an overall (total) score. The overall scores indicated similarity in habitat for the two sites at Lukfata Creek, and to a lesser extent for those at Horsehead Creek. The two sites at Yashau Creek differed by 25 points (out of a possible 180), with the upstream site scoring higher. Among all sites, the upstream site at Yashau Creek scored highest, followed by the upstream site at Horsehead Creek; the downstream sites at Horsehead Creek and Yashau Creek scored lowest. There was considerable variability in individual metrics between sites, suggesting that some differences in specific habitat parameters were probably more important than that indicated by the overall scores. These differences could have influenced specific metrics within the fish and macroinvertebrate communities described later.

Fish Communities

We collected a total of 2,545 fish, representing 28 species, during the study (Table 2). The results of the seven selected metrics follow.

Total number of fish species (Table 3)

With the exception of the June sampling date on Horsehead Creek, as many or more species of fish were collected at the downstream sites as were collected upstream. Wilcoxon's signed rank test indicates that overall, this difference was significant ($p < 0.01$). The range in number of species extended from 3 to 12 with an overall average of 8.5. The downstream sites all averaged 9.5 species per collection (range 8-12) while the upstream sites averaged from 5.25

to 8.75 species per collection (range 3-12). According to Plafkin et al. (1989), this metric reflects community health, generally in response to habitat and water quality; however, water body size strongly influences the number of fish species in small streams. This metric may reflect such an influence in this study, where stream size varied markedly over short distances. The effect of discharge volume on stream flow did not appear to influence the number of fish species in the downstream sites, because the volume was not consistently greater at all upstream or all downstream sites.

Mr. Jimmied Pigg (personal communication 1997) of the Oklahoma Department of Environmental Quality collected fish from the Little River basin for more than 30 years (starting about 1963), including about the same sites as ours in Lukfata Creek (Table 4). During this period, Pigg collected from 5 to 27 species in lower Lukfata Creek. We collected 9 to 10 species from this site during our study; however, the maximum and minimum from Pigg's collections occurred in two successive years, indicating that this metric may be highly variable from year to year. This metric should be interpreted only in the context of a multi-metric assessment.

Total number of darter species (Table 5)

Darters are benthic dwellers and complete their life cycles in a relatively small area, and are considered moderately sensitive to degradation in habitat and water quality. Overall, there were significantly more species of darters collected at downstream sites ($p < 0.01$) in our study; this indicates better conditions downstream than upstream. Plafkin et al. (1989) reported that this metric is dependent on stream size. In addition, we collected only 0, 1, or 2 darter species. Comparison of our data with Pigg's indicated that the number of darter species caught in this study was not unusual; therefore, sampling error was not considered a factor. In larger, more consistently-sized streams with more species of darters, this metric may be useful in detecting slight differences in habitat quality. However, in situations such as ours, where few species of darters were present and where stream size varies considerably over short distances, this metric may not be as useful.

Total number of sunfish species (Table 6)

This metric considers the response of pool-dwelling species to habitat degradation. A maximum of 3 species was collected at any one site. There was no significant difference between sites overall. Comparison with Pigg's data indicates that sampling error may have been significant, since Pigg collected 2 to 7 species. Sunfish may evade capture more readily than other species of fish, especially in creeks with slippery bottoms or large amounts of snags and boulders which hinder seining efforts. Consequently, sampling must be thorough to ensure the relevance of this metric.

Total number of minnow species (Table 7)

This metric considers the feeding habits of sensitive minnow species. Degradation in water quality stresses these species through a reduction of their food base. Total numbers of minnow species collected in our study ranged from 1 to 6 species. Overall, there was no significant difference between sites. As with the other metrics discussed thus far, Plafkin et al. (1989) indicated that stream size can be an important factor in determining minnow species richness. Pigg collected 2 to 8 species over the years, suggesting that sampling error in this study is probably not a significant variable. By itself, this metric does not appear to be a useful metric in our study.

Percentage of all fish as tolerant individuals (Table 8)

This metric is an indicator of degraded conditions when high percentages of tolerant species are present. Unlike the community-type metrics discussed so far, this metric is species-specific. Of all species present at all sites during the study, the most tolerant species, the mosquitofish (*Gambusia affinis*: Jester et al. 1992, Etnier and Starnes 1993), was selected for calculation of this metric. No other species considered highly tolerant were present at all sites. *G. affinis* was present in significantly higher numbers ($p < 0.01$) at all downstream sites on all sampling dates. This indicates degraded conditions at all downstream sites. Plafkin et al. (1989) advise caution when this metric is based on a single species, since variance in the number of that species could affect overall interpretation of the results. Pigg's collections contained between 0% and 91% G. *affinis* in two consecutive years, which suggests that this metric is highly variable.

Percentage of all fish as intolerant individuals (Table 9)

This metric, while not specifically described in Plafkin et al. (1989), is the inverse of the tolerant- individuals metric, and theoretically should provide a similar interpretation of habitat quality. The incidence of intolerant species of fish will decrease in proportion to more tolerant species when their habitat or water quality is degraded. No highly intolerant species were present in abundance at any site during the study. Two other species, the bigeye shiner (*Notropis boops*) and the redfin shiner (*Lythrurus umbratilis*) were chosen. These moderately intolerant (Jester et al. 1992) species were present in almost all of our collections. The incidence of these two species was significantly higher ($p < 0.01$) at all upstream sites on all sampling dates. This supports the finding that using the tolerant-individuals metric indicates degradation in downstream habitat, compared to upstream sites. The use of two species reduces the risk of error that was previously mentioned when results are based on a single species. Pigg's collections contained up to 34% of these two species in lower Lukfata Creek in the early 1970s, whereas none were found below Tyson in our study. This suggests that the quality of lower Lukfata Creek may have degraded during this period, although this metric, as with all others in this study, should not be used alone.

Percentage of all fish as insectivorous cyprinids (Table 10)

This metric is similar to one that considers the total number of minnow species, except that the incidence of individuals, not species, is used. This metric is a measure of trophic composition in the community. As water quality is degraded, the incidence of insectivorous cyprinids decreases relative to the incidence of omnivorous fish species due to a shift to more generalized feeding (Plafkin et al. 1989). There was a significantly higher ($p < 0.01$) incidence of insectivorous cyprinids at upstream sites on all sampling intervals. This indicates less favorable conditions at downstream sites. The use of individuals rather than species appears to be less sensitive to minor fluctuations in community composition. Pigg's collections contained from 5% to 80% insectivorous cyprinids, with one collection from upper Lukfata Creek containing twice the maximum incidence in our study. The maximum incidence in Pigg's collections in lower Lukfata Creek was also twice the maximum incidence in our study. This suggests deterioration in water quality over time. As previously stated, this metric should not be used alone.

Overall RBP Scores (Table 11)

Each metric of the downstream site in each creek was divided by the corresponding metric of the upstream (reference) site. After multiplying the quotients by 100, the percentages were compared to the guidelines set forth by Plafkin et al. (1989) and assigned a score of 1 (poor), 3 (average), or 5 (good). The scores were then added for each downstream site on each date, and averaged by site for all sampling dates. The averages were divided by 35, the maximum score possible. After multiplying the quotients by 100, the percentages were interpreted for site condition, using the index score interpretations in Plafkin et al. (1989). Site condition scores indicated some degradation downstream at all three creeks relative to their respective upstream sites.

Macroinvertebrate Communities

A total of 2,515 individuals, in 66 families and 21 orders, of macroinvertebrates were collected and identified (Table 12). The results of the six selected metrics follow.

Total number of macroinvertebrate families (Table 13)

This metric, measuring taxonomic richness, is an indicator of community health. The total number of families usually increases with increased water quality and habitat diversity (Plafkin et al. 1989). However, organic enrichment can sometimes encourage the occurrence of more tolerant taxa at the expense of more intolerant macroinvertebrates. Consequently, this metric should not be used alone, but rather in the context of a multi-metric approach. There were no significant differences between any of the upstream and downstream sites.

Modified Family Biotic Indices (Table 14)

This metric utilizes the tolerance values (shown in Table 12) listed by Bode (1988) and Hilsenhoff (1988) and is most commonly used for evaluating the effects of organic pollution on sensitive communities inhabiting rock or gravel riffles. Low scores indicate better site conditions. Scores for all sites were similar, with no significant differences. This metric alone does not contribute to the overall interpretation of site integrities in this study.

Ratio of EPT and Chironomid Abundances (Table 15)

The ratio of EPT (Ephemeroptera, Plecoptera, and Trichoptera) families to EPT + chironomids is an indicator of community balance (Plafkin et al. 1989). Scores range from 0 to 1, with low values indicating a disproportionately high number of chironomids and degraded habitat conditions. Chironomids were absent from several collections, probably as a result of being overlooked during picking due to their diminutive size. There were no significant trends in the data between upstream and downstream sites.

Percent contribution of dominant taxon (Table 16)

This metric measures community health at the family level, indicating stress when only a few families dominate the community; higher values suggest more degradation of the habitat. There were no significant differences between sites in our study.

EPT Index (total number of distinct families) (Table 17)

This metric measures the total number of families within the orders Ephemeroptera, Plecoptera, and Trichoptera. In general, the index should increase with increasing water quality, and summarizes taxa richness based on macroinvertebrates considered to be intolerant of pollution. Differences between upstream and downstream sites were not significant.

Community Loss Indices (Table 18)

This metric measures the loss of benthic families between the paired sites (Plafkin et al. 1989). The index is based on the number of taxa present at each site, and the number of taxa common to both sites. The index increases with increased degradation at the sample site. There were no significant differences between upstream and downstream sites.

Overall RBP Scores (Table 19)

Each metric of the downstream site in each creek was divided by the corresponding metric of the upstream (reference) site. After multiplying the quotients by 100, the percentages were compared to the guidelines set forth by Plafkin et al. (1989) and assigned a score of 0 (poor), 3 (average), or 6 (good). The scores were then added for each downstream site on each date, and averaged by site for all sampling dates. The averages were divided by 36, the maximum score possible. After multiplying the quotients by 100, the percentages were interpreted for site condition, using the index score interpretations in Plafkin et al. (1989). Site condition scores indicated some degradation downstream at Horsehead and Yashau Creeks, but no degradation downstream at Lukfata Creek, relative to their respective upstream sites.

Conclusions

The RBP described by Plafkin et al. (1989) requires one collection of fish and macroinvertebrates taken along 100-200 m of stream, in order to provide a snapshot of the condition of the biotic communities in a stream. This RBP was modified in our study in two ways: 1) smaller sections of streams above and below a discharge were sampled; and 2) four collections were made over a five-month period. In this manner, the potential loss of information by sampling a smaller section of stream may have been offset by the increased number of samples taken over time. The data in this study and in Pigg's fish collections indicate that metrics can vary considerably among samples from the same site. Consequently, a single collection might not be representative of the biotic communities in a study stream.

The emphasis on rapid assessment using abbreviated versions of the RBP sampling and collection methods has been validated in other studies. For example, Eaton and Lenat (1995) took fewer samples than called for by the State of North Carolina's guidelines (a precursor to the EPA RBPs), and limited their collections to EPT, yet their abbreviated method still produced accurate water quality ratings. This study was an extension of these modifications to tailor the RBPs on a case-specific basis.

In this study, the overall fish and macroinvertebrate scores (Tables 11 and 19) produced similar pictures of diminished community health of aquatic biota at the downstream sites of Horsehead and Yashau Creeks, with conflicting results at Lukfata Creek. There was a lack of overall agreement between habitat and fish community scores at Lukfata Creek. Hannaford and Resh (1995) reported a similar lack of agreement between habitat and biotic scores, where habitat rankings did not correlate with biotic rankings. Some species-specific metrics indicated significant differences in community health between upstream and downstream sites, while community-specific metrics tended not to be significantly different.

There is one potential drawback to repeated sampling in the same pool/riffle. The biotic community, especially fish, may be modified due to removal through sampling. Table 9 suggests that this may have occurred in this study, since scores generally dipped during the middle of the sampling period, when water flows were low. This may be less of a problem when stream flows remain high through the summer months. Another mitigating factor to sample depletion might occur when the pool/riffle area is recharged by a large pool immediately upstream. This may have occurred at the upstream sites at Horsehead and

Lukfata Creeks, where scores remained high through the sampling period. Invertebrate populations were apparently not affected by sampling and removal of individuals, as several sites ranked higher during later rounds of collections. Increased water flows in the fall, during the last round of collections, may have allowed the migration of biota past the riffle barriers into the sampling areas. This may also account for the increase in some fish and macroinvertebrate scores at this time.

Recommendations

The use of limited sampling areas in a series of collections has potential as a screening tool, where time and manpower allow. The use of multiple sampling dates may provide more information on community health than a single collection. However, careful selection is necessary in order to obtain sampling sites that are as similar as possible. Hannaford and Resh (1995) noted the likely influences of site selection and non-random sampling on variability in RBP results. Inclusion of as much stream within each site as possible is also recommended, to more completely sample the resident biota. Habitat assessments should be conducted before the biota collections are made in order to highlight any metric-specific deficiencies of a potential sampling site. To assess variability, further studies could also include a sampling design where abbreviated sampling sites are located in a connected series along each creek. By comparing results from each site in a serial fashion, variation caused by the abbreviation of a sampling site might be better assessed.

The use of EPA's RBPs in this study appeared to be somewhat useful in delineating subtle and possibly dynamic differences between biotic communities upstream and downstream of an industrial site. By using multiple collections (except on small, low-flow streams), conducting habitat assessments before collecting biota, and collecting samples from a series of sites along the same creek, the RBPs could become more sensitive to differences present in this study. However, the extra time and effort necessary might render the multiple-date approach infeasible where rapid assessments are required. More work will be necessary to fine-tune the use of EPA's RBPs for the interpretation of discharge effects at the sites studied in the Little River basin.

Acknowledgments

I thank the staff of the U.S. Fish and Wildlife Service, Tulsa, Oklahoma Field Office for their assistance with the field collections. Berlin Heck, manager of the Little River National Wildlife Refuge, provided information on the study area. Dr. Dan Martin, also of the Tulsa FO, provided invaluable assistance in the initial planning of this project, as well as in reviewing the manuscript. Further reviews were provided by Dr. George Allen of the USFWS Manhattan, Kansas Field Office and by Kirke Ring of the USFWS Phoenix, Arizona Field Office. Dan Butler of the Water Quality Division, Oklahoma Conservation Commission not only reviewed the manuscript but also provided additional insights on the use of the EPA RBPs.

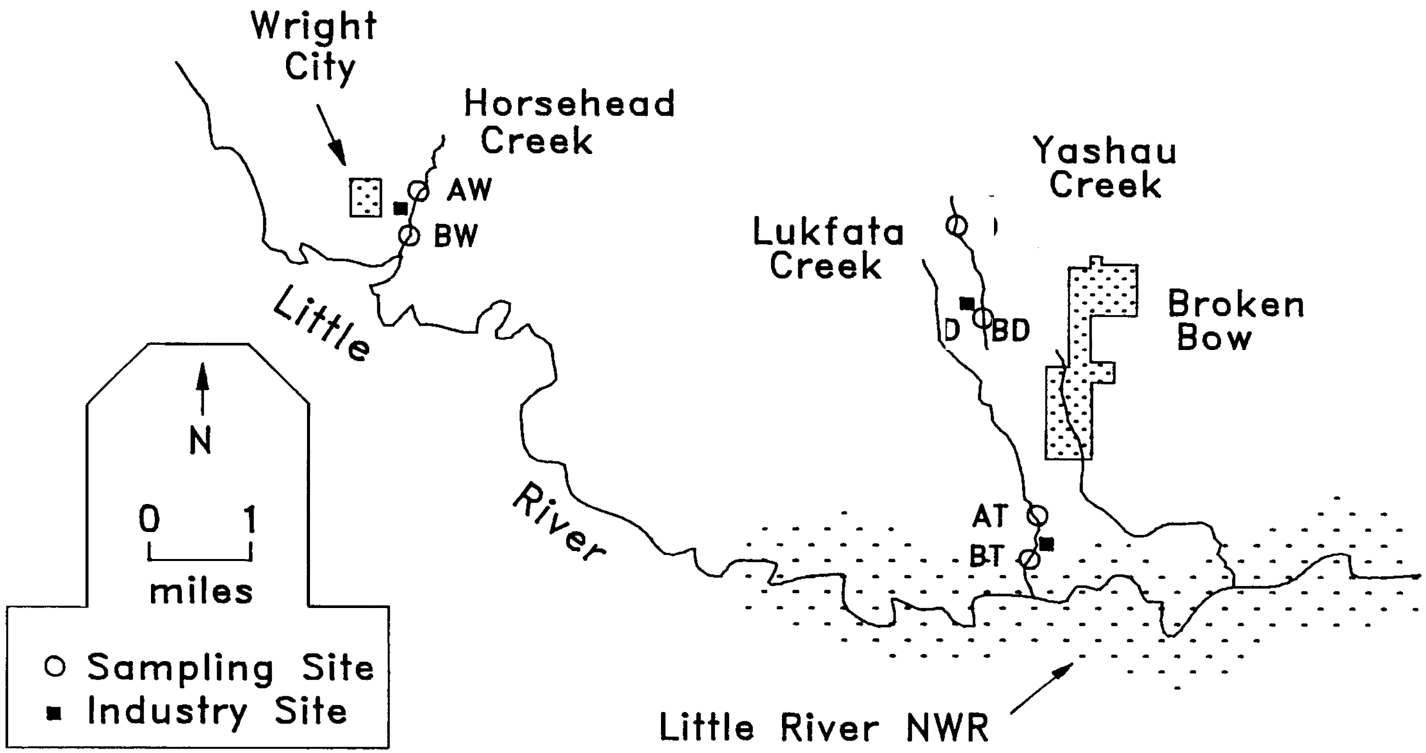

Figure 1. Sampling Locations in the Little River Basin

Table 1. Stream habitat assessment scores for each of six sampling sites, January 2-3, 1997.

Metric (maximum possible score)	Horsehead Creek		Yashau Creek		Lukfata Creek	
	AW[1]	BW	AD	BD	AT	BT
1: Intsream Cover (20)	9	1	17	8	7	8
2: Pool Bottom Substrate (20)	18	9	16	15	18	15
3: Pool Variability (20)	8	14	16	16	16	16
4: Canopy Cover Shading (20)	20	18	18	18	20	19
5: Presence of Rocky Runs / Riffles (20)	11	9	12	11	12	11
6: Flow at Representative Low Flow (20)	17	18	12	12	18	18
7: Channel Alteration (15)	11	14	12	10	5	13
8: Channel Sinuosity (15)	7	5	4	5	4	5
9: Bank Stability (10)	8	8	9	5	7	5
10: Bank Vegetation Stability (10)	7	9	8	4	3	1
11: Streamside Cover (10)	5	5	9	4	5	5
Total (180)	121	110	133	108	115	116

[1] AW = Above Weyerhauser; BW = Below Weyerhauser; AD -Above Dominance; BD = Below Dominance; AT = Above Tyson; BT = Below Tyson

Table 2. Fish collected during the study, grouped by water quality tolerances according to Jester et al. (1992)

Tolerant species		Count
Gambusia affinis	Mosquitofish	518
Lepomis humilis	Orangespotted Sunfish	3
Moderately Tolerant Species		
Cyprinella venusta	Blacktail Shiner	240
Dorosoma cepediunum	Gizzard Shad	1
Etheostoma gracile	Slough Darter	1
Fundulus notatus	Blackstripe Topminnow	56
Fundulus olivaceus	Bkackspotted Topminnow	145
Labidesthes sicculus	Brook Silverside	141
Lepomis macrochirus	Bluegill	30
Lepomis megalotis	Longear Sunfish	138
Lepomis microlophus	Redear Sunfish	3
Micropterus salmoides	Largemouth Bass	21
Notropis atrocaudalis	Blackspot Shiner	1
Pimephales notatus	Bluntnose Minnow	1
Moderately Intolerant Species		
Ammocrypta vivax	Scaly Sand Darter	1
Campostoma anomalum	Central Stoneroller	56
Cyprinella whipplei	Steelcolor Shiner	233
Esox americanus	Grass Pickerel	2

Etbeostoma radiosum	Orangebelly Darter	49
Etheostoma spectabile	Orangethroat Darter	146
Etbeostoma wbipplei	Redfin Darter	13
Luxilus chrysocephalus	Striped Shiner	107
Lythrurus umbratilis	Redfii Shiner	443
Micropterus punctulatus	Spotted Bass	1
Notropis boops	Bigeye Shiner	178
Intolerant Species		
Elassoma zonatum	Banded Pygmy Sunfish	2
Etbeostoma histrio	Harlequin Darter	2
*Notopis suttkusi**	Rocky Shiner	13

*** Not listed in Jester et al. (1992), placed according to Humphries and Cashner (1994) and professional judgement**

Table 3. Total number of fish species collected from each sampling site, June through October 1995.

Date	Horsehead Creek		Yashau Creek		Lukfata Creek	
	AW[1]	BW	AD	BD	AT	BT
6/27-6/29	9	8	7	12	9	10
7/18-7/19	12	12	3	8	9	9
8/22-8/23	5	8	5	8	9	10
10/5-10/6	9	10	6	9	8	9
Arithmetic Mean	8.75	9.50	5.25	9.50	8.75	9.50
Minimum	5	8	3	8	8	9
Maximum	12	12	7	12	9	10

[1] AW - Above Weyerhauser; BW - Below Weyerhauser; AD -Above Dominance; BD - Below Dominance; AT -Above Tyson; BT - Below Tyson

Table 4. Range of selected RBP metrics calculated from from Pigg's (1963-1993) fish collections in Lukfata Creek, Oklahoma. Values are Minimum / Maximum followed by (Date of Collection').

Metric	Above Tyson	BelowTyson
Total # of species	13	5 / 27 (1971 / 1970)
Total # of darter species	0	0 / 5 (1971 / 1963)
Total # of sunfish species	2	0 / 6 (1965 / 1963)
Total # of minnow species	6	2 / 8 (1971 / 1978)
% as tolerant individuals[2]	8%	0% / 91% (1965, 1970, 1971/ 1971)
% as intolerant individuals[3]	1%	0% / 34% (1969, 1971 / 1971)
% as insectivorous cyprinids	36%	5% / 80% (1971 / 1970)'

There was only one collection made above Tyson, in 1993.
[2] *Gambusia affinis*
[3] *Notropis boops* and *Lythrurus umbratilis*

Table 5. Total number of darter species at each sampling site, June through October 1995.

Date	Horsehead Creek		Yashau Creek		Lukfata Creek	
	AW[1]	BW	AD	BD	AT	BT
6/27-6/29	0	2	0	2	2	2
7/18-7/19	1	2	0	0	1	2
8/22-8/23	0	1	0	1	1	1
10/5-10/6	1	2	0	1	1	2
Arithmetic Mean	0.5	1.75	0	1	1.25	1.75

[1] AW = Above Weyerhauser; BW = Below Weyerhauser; AD = Above Dominance; BD = Below Dominance; AT = Above Tyson; BT = Below Tyson

Table 6. Total number of sunfish species at each sampling site, June through October 1995.

Date	Horsehead Creek		Yashau Creek		Lukfata Creek	
	AW[1]	BW	AD	BD	AT	BT
6/27-6/29	3	2	2	3	1	2
7/18-7/19	3	1	0	2	0	0
8/22-8/23	1	1	0	3	0	1
10/5-10/6	1	1	0	1	1	0
Arithmetic Mean	2	1.25	0.50	2.25	0.50	0.75
Minimum	1	1	0	1	0	0
Maximum	3	2	2	3	1	2

[1] AW = Above Weyerhauser; BW = Below Weyerhauser; AD -Above Dominance; BD = Below Dominance; AT = Above Tyson; BT -Below Tyson

Table 7. Total number of minnow species collected from each sampling site, June through October 1995.

Date	Horsehead Creek		Yashau Creek		Lukfata Creek	
	AW[1]	BW	AD	BD	AT	BT
6/27-6/29	3	1	2	3	5	5
7/18-7/19	4	4	1	3	6	4
8/22-8/23	2	2	2	1	5	5
10/5-10/6	4	4	2	4	5	4
Arithmetic Mean	3.25	2.75	1.75	2.75	5.25	4.50
Minimum	2	1	1	1	5	4
Maximum	4	4	2	4	6	5

[1] AW - Above Weyerhauser; BW - Below Weyerhauser; AD -Above Dominance; BD -Below Dominance; AT -Above Tyson; BT - Below Tyson

Table 8. Percent of all fish as ***Gambusia affinis*** at each sampling site, June through October 1995.

Date	Horsehead Creek		Yashau Creek		Lukfata Creek	
	AW[1]	BW	AD	BD	AT	BT
6/27-6/29	6	43	0	13	2	16
7/18-7/19	17	39	0	61	11	40
8/22-8/23	17	26	8	27	16	37
10/5-10/6	7	46	7	53	0	22
Arithmetic Mean	11.75	38.5	3.75	38.5	7.25	28.75
Minimum	6	26	0	13	0	16
Maximum	17	46	8	61	16	40

[1] AW - Above Weyerhauser; BW - Below Weyerhauser; AD -Above Dominance; BD - Below Dominance; AT-Above Tyson; BT -Below Tyson

Table 9. Percent of all fish *as Notropis hops* and *Lythrurus umbratilis* at each sampling site, June through October 1995.

Date	Horsehead Creek		Yashau Creek		Lukfata Creek	
	AW[1]	BW	AD	BD	AT	BT
6/27-6/29	70	33	37	26	19	0
7/18-7/19	36	16	42	7	18	0
8/22-8/23	0	0	55	0	6	0
10/5-10/6	54	9	50	13	14	0
Arithmetic Mean	40	15	46	12	14	0
Minimum	0	0	37	0	6	0
Maximum	70	33	55	26	19	0

[1] AW - Above Weyerhauser; BW - Below Weyerhauser; AD -Above Dominance; BD -Below Dominance; AT -Above Tyson; BT - Below Tyson

Table 10. Percent of all fish as insectivorous cyprinids at each sampling site, June through October 1995.

Date	Horsehead Creek		Yashau Creek		Lukfata Creek	
	AW[1]	BW	AD	BD	AT	BT
6/27-6/29	84	33	37	27	75	56
7/18-7/19	50	36	42	8	74	42
8/22-8/23	13	24	55	0	71	22
10/5-10/6	56	25	50	15	88	49
Arithmetic Mean	50.75	29.5	46	12.5	77	42.25
Minimum	13	24	37	0	71	22
Maximum	84	36	55	27	88	56

[1] AW - Above Weyerhauser; BW - Below Weyerhauser; AD -Above Dominance; BD -Below Dominance; AT -Above Tyson; BT -Below Tyson

Table 11. Summarized metric scores and site classifications calculated from the fish data collected from June through October 1995.

	Horsehead Creek	Yashau Creek	Lukfata Creek
	BW[1]	BD	BT
6/27-6/29	25	31	29
7/18-7/19	25	23	23
8/22-8/23	25	21	25
10/5-10/6	25	25	25
Total	100	100	102
Arithmetic Mean	25	25	26
Classification[2]	Fair	Fair	Fair

[1] BW = Below Weyerhauser; BD -Below Dominance; BT -Below Tyson
[2] according to Plafkin et al. (1989)

Table 12. Macroinvertebrates collected and water quality tolerances according to Bode (1988) and Hilsenhoff (1988).

Order	Family	Tolerance'	count
Acarina	"Hydracarina"		2
Amphipoda	Gammaridae		5
	Taltridae	MT	3
Bassomatophora	Ancyclidae		3
	Lymnaeidae	MT	75
	Physidae	MT	33
	Planorbidae		15
Coleoptera	Dryopidae	MI	99
	Dytiscidae		1
	Elmidae	MI	33
	Gyrinidae	MI	31
	Haliplidae		3
	Helodidae		
	Hydrophiliidae		27
	Psephenidae	MI	118
Collembola	Isotomidae		3
	Sminthuridae		2
Decapoda	Cambaridae	MT	31
	Palemonidae		1
Diptera	Chironomidae	MT	88
	Culicidae		2
	Tabanidae	MT	3
	Tipulidae	MI	26
Ephemeroptera	Baetidae	MI	2
	Caenidae	MT	25
	Ephemerellidae	I	4
	Ephemeridae	MI	2
	Heptageniidae	MI	542
	Leptophlebiidae	I	7
	Siphlonuridae	MT	9
Haplotaxida	Naididae	MT	1
	Tubificidae		19

Hemiptera	Corixidae		3
	Gerridae		1
	Hydrometridae		2
	Naucoridae		17
	Nepidae		3
	Notonectidae		3
	Saldidae		1
	Veliidae		18
Isopoda	Asellidae	MT	4
Lepidoptera	Pyralidae	MI	1
Megaloptera	Corydalidae	I	183
	Sialidae	MI	4
Mesogastropoda	Pleuroceridae		1
Odonata	Calopterygidae	MI	1
	Coenagrionidae		30
	Gomphidae	I	28
	Libellulidae		1
	Macromiidae	MI	6
Pharyngobdellida	Erpobdellidae	T	18
Plecoptera	Perlidae	I	72
Rhynchobdellida	Glossiphoniidae	T	7
Trichoptera	Brachycentridae	I	2
	Hydropsychidae	MI	525
	Hydroptilidae	MI	1
	Leptoceridae	MI	5
	Limnephilidae	MI	3
	Molannidae	MT	1
	Philopotamidae	MI	121
	Phryganeidae	MI	4
	Polycentropodidae	MT	20
	Psychomyiidae	I	4
Unionoida	Unionidae		1
Veneroida	Corbiculidae		116
	Sohaeriidae		3

[1] I-Intolerant; MI-Moderately Intolerant; MT-Moderately Tolerant; T-Tolerant; all others are unclassified

Table 13. Total number of macroinvertebrate families at each sampling site, July through October 1995.

Date	Horsehead Creek		Yashau Creek		Lukfata Creek	
	AW[1]	BW	AD	BD	AT	BT
7/11-7/12	19	6	12	13	10	22
8/8-8/9	13	6	12	12	12	14
9/11-9/12	16	12	11	6	14	24
10/11-10/12	16	14	7	13	10	14
Arithmetic Mean	16	9.5	10.5	11	11.5	18.5
Minimum	13	6	7	6	10	14
Maximum	19	14	12	13	14	24

[1] AW - Above Weyerhauser; BW - Below Weyerhauser; AD -Above Dominance; BD - Below Dominance; AT-Above Tyson; BT - Below Tyson

Table **14.** Modified Family Biotic Indices for macroinvertebrates at each sampling site, July through October 1995.

Date	Horsehead Creek		Yashau Creek		Lukfata Creek	
	AW[1]	BW	AD	BD	AT	BT
7/11-7/12	**4.46**	**4.07**	**3.04**	**4.02**	**4.95**	**5.61**
8/8-8/9	**4.07**	**4.02**	**4.21**	**3.73**	**4.41**	**3.96**
9/11-9/12	**4.06**	**6.25**	**4.22**	**4.05**	**5.64**	**3.71**
10/11-10/12	**5.17**	**4.95**	**4.00**	**3.51**	**4.28**	**5.52**
Arithmetic Mean	**4.44**	**4.82**	**3.87**	**3.83**	**4.82**	**4.7**
Minimum	**4.07**	**4.02**	**3.04**	**3.51**	**4.28**	**3.71**
Maximum	**5.17**	**6.25**	**4.22**	**4.05**	**5.64**	**5.61**

[1] AW -Above Weyerhauser; BW - Below Weyerhauser; AD -Above Dominance; BD -Below Dominance; AT -Above Tyson; BT -Below Tyson

Table 15. Ratio of EPT and chironomid abundance at each sampling site, July through October 1995.

Date	Horsehead Creek		Yashau Creek		Lukfata Creek	
	AW[1]	BW	AD	BD	AT	BT
7/11-7/12	0.83	0.99	0.99	1.00	1.00	1.00
8/8-8/9	0.93	1.00	1.00	0.98	0.99	0.95
9/11-9/12	0.96	0.82	1.00	1.00	1.00	1.00
10/11-10/12	0.53	0.46	0.95	0.40	0.92	0.92
Arithmetic Mean	0.81	0.82	0.99	0.85	0.98	0.97
Minimum	0.53	0.46	0.95	0.40	0.92	0.92
Maximum	0.96	1.00	1.00	1.00	1.00	1.00

[1] AW - Above Weyerhauser; BW - Below Weyerhauser; AD -Above Dominance; BD - Below Dominance; AT-Above Tyson; BT - Below Tyson

Table **16.** Percent contribution of dominant **taxon,** for macroinvertebrates collected from each sampling site, July through October 1995.

Date	Horsehead Creek		Yashau Creek		Lukfata Creek	
	AW[1]	BW	AD	BD	AT	BT
7/11-7/12	35	87	43	25	58	35
8/8-8/9	47	82	56	40	44	62
9/11-9/12	40	36	78	86	64	18
10/11-10/12	22	34	65	40	69	26
Arithmetic Mean	36	59.75	60.5	47.75	58.75	35.25
Minimum	22	34	43	25	44	18
Maximum	47	87	78	86	69	62

[1] AW = Above Weyerhauser; BW = Below Weyerhauser; AD -Above Dominance; BD -Below Dominance; AT-Above Tyson; BT = Below Tyson

Table 17. EPT Index (total number of distinct families) at each sampling site, July through October 1995.

Date	Horsehead Creek		Yashau Creek		Lukfata Creek	
	AW[1]	BW	AD	BD	AT	BT
7/11-7/12	6	3	6	6	4	8
8/8-8/9	5	3	5	6	6	6
9/11-9/12	3	3	1	1	2	3
10/11-10/12	3	3	4	2	3	3
Arithmetic Mean	4.25	3	4	3.75	3.75	5
Minimum	3	3	1	1	2	3
Maximum	6	3	6	6	6	8

[1] AW = Above Weyerhauser; BW = Below Weyerhauser; AD -Above Dominance; BD = Below Dominance; AT -Above Tyson; BT = Below Tyson

Table **18.** Community Loss Indices[1] for macroinvertebrates at each sampling site, July through October 1995.

Date	Horsehead Creek		Yashau Creek		Lukfata Creek	
	AW[2]	BW	AD	BD	AT	BT
7/11-7/12	**0.05**	**2.33**	**0.50**	**0.38**	**1.50**	**0.14**
8/8-8/9	**0.15**	**1.50**	**0.67**	**0.67**	**0.67**	**0.43**
9/11-9/12	**0.44**	**0.92**	**0.27**	**1.33**	**1.14**	**0.25**
10/11-10/12	**0.31**	**0.50**	**1.57**	**0.38**	**0.90**	**0.36**
Arithmetic Mean	**0.24**	**1.31**	**0.75**	**0.69**	**1.05**	**0.30**
Minimum	**0.05**	**0.50**	**0.27**	**0.38**	**0.67**	**0.14**
Maximum	**0.44**	**2.33**	**1.57**	**1.33**	**1.50**	**0.43**

[1] Community Loss Index = [(# spp. in one paired site)-(# spp. common to both sites)] / (# spp. in the other paired site)

[2] AW = Above Weyerhauser; BW = Below Weyerhauser; AD-Above Dominance; BD -Below Dominance; AT-Above Tyson; BT = Below Tyson

Table 19. Summarized metric scores calculated from the macroinvertebrate data, July through October 1995.

	Horsehead Creek	Yashau Creek	Lukfata Creek
	BW[1]	BD	BT
7/11-7/12	15	30	30
8/8-8/9	18	30	24
9/11-9/12	21	24	33
10/11-10/12	27	21	33
Total	81	105	120
Arithmetic Mean	20	26	30
Condition[2]	Moderately Impaired	Moderately Impaired	Non-Impaired

[1] BW = Below Weyerhauser; BD = Below Dominance; BT -Below Tyson

[2] according to Plafkin et al. (1989)

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