FY-2005 Section 104(b)3 (CA# CP-966144-01)—Water Quality Cooperative Agreement

Probabilistic Monitoring in the Illinois River Watershed to Determine Multi-Assemblage Biotic Condition and Stressor Relationships

the water agency

Final Report

September 30, 2010

FY-2005 Section 104(b)3 (CA# CP-966144-01)—Water Quality Cooperative Agreement**:** Probabilistic Monitoring in the Illinois River Watershed to Determine Multi-Assemblage Biotic Condition and Stressor Relationships

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EXECUTIVE SUMMARY

The United States Environmental Protection Agency (USEPA) released guidance in 2003 establishing the "10 Required Elements of a State Water Monitoring and Assessment Program". Among other things, the document suggests, "A State monitoring program will likely integrate several monitoring designs (e.g., fixed station, intensive and screening-level monitoring, rotating basin, judgmental and probability design) to meet the full range of decision needs. The State monitoring design should include probability-based networks (at the sub-basin or state-level) that support statistically valid inferences about the condition of all state water types, over time. EPA expects the State to use the most efficient combination of monitoring designs to meet its objectives." Oklahoma currently has several monitoring programs that meet these requirements including the Beneficial Use Monitoring Program (BUMP), the Rotating Basin Monitoring Program (RBMP), and the Statewide Probabilistic Survey (with both a planning basin and statewide draw). However, the state currently does not have any probability-based networks that are centered on specific sub-basins. Sub-basin probability networks can be beneficial in answering several questions ranging from regional based estimates of water quality to providing information for the refinement of biocriteria and potential nutrient standards. The Illinois River sub-basin is currently an area of specific interest. The USEPA has specifically listed the sub-basin as a "High Priority Area for Funding Consideration". Furthermore, the Arkansas-Oklahoma Arkansas River Compact Commission has a specific interest in the sub-basin. The Compact's statement of Joint Principles and Actions between Oklahoma and Arkansas states:

> *The States of Arkansas and Oklahoma, acting through their environmental agencies, will coordinate monitoring in partnership with the Arkansas/Oklahoma Arkansas River Compact Commission throughout the shared Oklahoma Scenic Rivers watersheds based on a common protocol and will share all information/data resulting from such monitoring. The States will hold discussions aimed at arriving at the agreed upon monitoring protocol by August 2004. The States will submit the agreed upon design to EPA for review and endorsement. EPA has committed to seek to obtain federal funding for the agreed upon monitoring.*

The area of study is the Illinois River sub-basin, and the target population is all streams within the sub-basin with an equal number of samples across the represented Strahler order categories and groupings of categories: 1st, 2nd, 3rd, 4th-5th, and 6th -8th. Sampling occurred over three years from 2007-2009. One sample per station visit was collected to characterize the chemical and physical properties of the water. In addition, during defined index periods, fish (one collection during spring/summer), benthic macroinvertebrates (one collection during summer index and one collection during winter index), and benthic and sestonic algae (one collection during winter index, one collection during late spring/early summer index, and one collection during late summer index) were collected. The probability-based survey was designed to assist Oklahoma's water quality managers in several ways. Furthermore, in keeping with the environmental goals of the state as outlined in the comprehensive water plan, an effective long-term management strategy based on sound science and defensible data can be developed using this data. The four over-arching goals were::

1. Make a statistically valid assessment of the condition of all streams/rivers miles within the sub-basin in support of Section 305(b) of the Clean Water Act (CWA). This assessment provides a baseline water quality assessment for the Illinois River Watershed.

2. Assist in long- and short-range planning and resource allocation within the basin. When integrated with the fixed-station and the statewide probabilistic networks and landuse data, data can assist in identifying local areas of concern.

3. Provide data that may be used in the refinement of both numerical and narrative water quality standards.

4. Under the guidelines of the Integrated Listing Methodology, allow for the assessment of the Fish & Wildlife Propagation beneficial use on more waters of the state.

At the end of the 3-year project period, there were fifty-one (51) sites available for inclusion in data analyses. This sample size allowed for a watershed estimate of fish, macroinvertebrate (BMI), and algal condition. Condition for fish and BMI were developed using published indices of biological integrity (IBI) and reference condition for Oklahoma freshwater streams. Algal biomass chlorophyll-a screening limits were developed using the Oklahoma Water Quality Standards (OWQS), the Oklahoma Use Support Assessment Protocols (USAP), and the distribution of historical data from the Ozark Highlands ecoregion. Additionally, extent was evaluated for a number of potential environmental stressors, including nutrients, general water quality, and habitat. Stressors were developed from scholarly journals, the OWQS, the Oklahoma USAP, and the distribution of historical data from the Ozark Highlands ecoregion. Lastly, under the guidelines of the Integrated Listing Methodology (ODEQ, 2006), data allow for the assessment of the Fish & Wildlife Propagation beneficial use on more waters of the state. Although currently limited to certain beneficial uses and associated criteria, the support status of more waters can be determined.

To develop relationships between biotic condition and stressor extent, relative risk analysis was used. The concept of using relative risk to develop a relationship between biological condition and stressor extent was developed initially for the USEPA's National Wadeable Streams Assessment,, and drew upon a practice commonly used in medical sciences to determine the relationship of a stressor (e.g., high cholesterol) to a medical condition (e.g., heart disease). The method calculates a ratio between the number of streams with poor biological condition/high stressor concentration and those with poor biological condition/low stressor concentration. If the ratio is above 1, it indicates that biological condition is likely affected by high stressor concentrations (i.e., concentrations above a preset level). As the ratio increases beyond 1, the relative risk of the stressor increases.

The relative risk analyses produced widely variable results depending upon both biotic condition and stressor. For the most part, the attempt to draw relationships of stressors to fish and condition using relative risk produced mixed results depending on stressor category.

- For nutrients, only the USAP screening level for total nitrogen and available nitrogen produced significant associated risk to fish condition. With a highly inconsistent relationship of stressor to biological condition, nutrients become a poor predictor of fish and BMI condition.
- Habitat stressors had some predictive capacity when considering fish and BMI. Fish condition was significantly related to both the overall habitat score and percentage of deep pools. The BMI-Riffle habitat was significantly related to the percentage of deep pools. Habitat does show more predictive capacity and appears to be related to overall habitat change and/or loss.
- General water quality stressors demonstrated the greatest predictive capacity when considering fish and BMI. Dissolved oxygen and turbidity related to water quality standards was significant for each assemblage, but it should be noted that only one site exceeded the respective criteria. However, the historical 75th percentile of dissolved oxygen (DO) percent saturation shows promising predictive capacity. It is significant for BMI-Riffle condition, but also produced non-significant relative risks for the other two conditions. In fact, for all conditions, a number of stressors were above 1.0 but not significant.
- **When comparing both fish and BMI to a broad spectrum of stressors, it appears that stressor/condition relationships are difficult to pin down.** This study looked at a very

diverse set of stressors that represented a broad range of nutrient and general water quality values. Regardless of site concentrations, some notable relationship should have been formed between condition and stressor condition. This study also used IBI's as well as reference conditions that have been widely published in studies by both the OWRB and OCC. However, either the IBI or reference may not be sensitive enough. Streams in the watershed are generally cool water aquatic communities and have exceptional habitat, including substrate and flow. In fact, habitat was likely the most relevant stressor for both BMI and fish. Because habitat is so exceptional, fish and BMI assemblages are often much more diverse and have many more sensitive species than other parts of Oklahoma. Using an IBI that is more refined to the particular characteristics of the Ozark Highlands may allow for a better defined relationship between condition and stressors,

For sestonic algal biomass, a number of notable significant relationships exist between stressor and condition.

- For nutrients, it appears that using the either the historical median or 25th percentile of chlorophyll-a for algal condition produces the most significant results. Each condition is highly related to total phosphorus in ranges from 0.018 mg/L to near 0.10 mg/L, and the highest relative risks are associated with the total phosphorus in the range of 0.018 mg/L to the 0.037 mg/L scenic river criterion. Low level total phosphorus appears to function well as a predictor of potential degradation due to increasing algal biomass.
- Similarly, all general water quality stressors, with the exception of pH, are significantly related to poor sestonic algal condition. Increasing temperatures, turbidity, and DO saturation all have significant predictive capacity.
- Habitat has no predictive capacity.

Conversely, benthic algal biomasses shows very few significant relationships.

- Significant risk relationships are present between nitrogen and DO percent saturation
- The most interesting significant relationship occurs when the percentage of deep pools is acting as a stressor. As pool width to depth ratios decrease, the stream area providing a suitable photic zone for algal growth may increase.

Recommendations for future work include:

- Further development of regional IBI's and reference condition should be funded through the Clean Water Act to develop more sensitive tools for determining biotic condition. IBI's in Oklahoma to date have been developed with a one-size fits all approach in terms of metrics and scoring. Due to Oklahoma's vast ecological diversity, this approach may not be appropriate for the long-term.
- The further development of nutrient and habitat-based criteria to protect waterbodies from future and increased eutrophication. Studies such as this one when coupled with fixed station network data provide a valuable dataset from which to begin setting these criteria. Although relative risk showed varying relationships between condition and stressors, correlation, discriminant, and regression analyses may demonstrate that a moderate to large portion of biotic condition variance can be explained by the nutrients, general water quality, and habitat
- Watershed characterizations utilizing probabilistic design should continue to be funded and utilized throughout the state. Current study should be repeated in 2-4 years to determine how implementation work in the watershed has affected condition and stressor extent.

Introduction

The United States Environmental Protection Agency (USEPA) released guidance in 2003 establishing the "10 Required Elements of a State Water Monitoring and Assessment Program" (USEPA, 2005). Among other things, the document suggests, "A State monitoring program will likely integrate several monitoring designs (e.g., fixed station, intensive and screening-level monitoring, rotating basin, judgmental and probability design) to meet the full range of decision needs. The State monitoring design should include probability-based networks (at the sub-basin or state-level) that support statistically valid inferences about the condition of all state water types, over time. EPA expects the State to use the most efficient combination of monitoring designs to meet its objectives." Oklahoma currently has several monitoring programs that meet these requirements including the Beneficial Use Monitoring Program (BUMP), the Rotating Basin Monitoring Program (RBMP), a Statewide Probabilistic Survey (with both a planning basin and statewide draw) (OWRB, 2008c; OCC, 2005a; OCC, 2008; OWRB, 2010a). However, until this study, the state did not have a probability-based network that centered on a specific watershed.

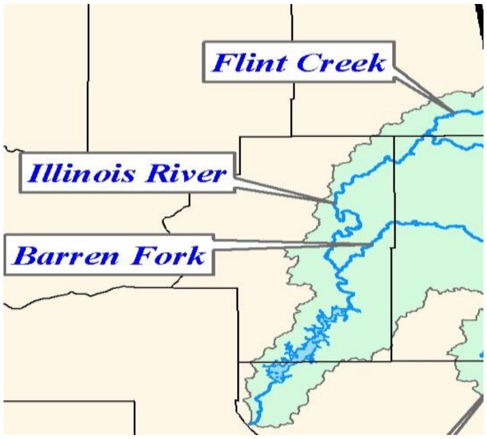
Watershed probability networks can be beneficial in answering several questions ranging from regional based estimates of water quality to providing information for the refinement of biocriteria and potential nutrient standards. The Illinois River watershed is currently an area of specific interest. The USEPA has specifically listed the watershed as a "High Priority Area for Funding Consideration". Furthermore, the Arkansas-Oklahoma Arkansas River Compact Commission has a specific interest in the watershed (AOARCC, 2003). The statement of Joint Principles and Actions between Oklahoma and Arkansas states:

> *The States of Arkansas and Oklahoma, acting through their environmental agencies, will coordinate monitoring in partnership with the Arkansas/Oklahoma Arkansas River Compact Commission throughout the shared Oklahoma Scenic Rivers watersheds based on a common protocol and will share all information/data resulting from such monitoring. The States will hold discussions aimed at arriving at the agreed upon monitoring protocol by August 2004. The States will submit the agreed upon design to EPA for review and endorsement. EPA has committed to seek to obtain federal funding for the agreed upon monitoring.*

Technical staff with the states of Oklahoma and Arkansas convened in the fall of 2004 as the Scenic River Monitoring Technical Workgroup. The product from this workgroup was a "Joint Arkansas/Oklahoma Scenic River Monitoring Proposal" which lists special studies that should be funded over and above the general water quality monitoring in the basin (AOARCC, 2004). Specifically, the document suggests, "Studies could address issues, such as, … 2. Biological response including measurement of algal biomass or characterization of community health of multiple assemblages (fish, macroinvertebrates, algae)."

The area of study was the Illinois River watershed (Figure 1). In accordance with the probabilistic survey design provided to Oklahoma by the EPA's National Health and Environmental Effects Research Laboratory (NHEERL) in Corvallis, OR, fifty-one (51) randomly chosen stations were sampled in the watershed with a 5 randomly chosen station revisits conducted over the two years (Olsen, 2006). The survey desing was A Generalized Random Tessellation Stratified (GRTS) survey designfor a linear resource was used. The GRTS design includes reverse hierarchical ordering of the selected sites. The target population was all streams within the watershed with an equal number of samples across multi-density categories, represented Strahler order categories. The category groupings were 1st, 2nd, 3rd, 4th, 5th, and 6th+.

Figure 1. Illinois River Sub-basin (Oklahoma).



The probability-based survey was designed to assist Oklahoma's water quality managers in several ways. Furthermore, in keeping with the environmental goals of the state as outlined in the Oklahoma's Water Quality Monitoring Strategy (OWRB, 2009b), an effective long-term management strategy based on sound science and defensible data can be developed using this data. The four over-arching goals were:

1. Make a statistically valid assessment of the condition of all streams/rivers miles within the sub-basin in support of Section 305(b) of the Clean Water Act (CWA). This assessment provides a baseline water quality assessment for the Illinois River Watershed.

2. Assist in long- and short-range planning and resource allocation within the basin. When integrated with the fixed-station and the statewide probabilistic networks and landuse data, data can assist in identifying local areas of concern.

3. Provide data that may be used in the refinement of both numerical and narrative water quality standards.

4. Under the guidelines of the Integrated Listing Methodology, allow for the assessment of the Fish & Wildlife Propagation beneficial use on more waters of the state.

The current assessment allows the state to make a statistically valid assessment of the condition of all of Illinois River watershed streams/rivers, as required under Section 305(b) of the Clean Water Act (CWA) (ODEQ, 2008). At the end of the 3-year project period, there were fifty-one (51) sites available for inclusion in data analyses. The sample size allows for a watershed estimate of fish, macroinvertebrate, and algal condition. Additionally, extent is evaluated for a number of potential environmental stressors, including nutrients, general water quality, and habitat. Lastly, under the guidelines of the Integrated Listing Methodology (ODEQ, 2006), data allow for the assessment of the Fish & Wildlife Propagation beneficial use on more waters of the state. Although currently limited to certain beneficial uses and associated criteria, the support status of more waters can be determined.

Furthermore, the survey provides information that will allow for better long- and short-range planning and resource allocation. A benefit of probabilistic design is that data results can be applied in a much broader context. For example, the relationship of condition can be associated with stressor extent through methodologies like relative risk analysis. The current study yields a wealth of biological, chemical, and physical data across a gradient of environmental conditions, supporting evaluation of these indicator relationships. Data can be used to calibrate existing biocriteria ranges, establish reference condition, and assist in nutrient criteria development. When integrated with fixed-station networks, it will assist in identifying local areas of concern. Also, although not accomplished by this report, landscape metrics can be associated with stressors and condition to develop predictive models. Third, probabilistic data will assist in efforts to regionalize environmental concerns. A bottom up approach to management identifies not only statewide issues but allows managers to identify local and regional concerns first, which often lead to issues farther down the watershed, and put resources where they are needed. The probabilistic methodology adds a valuable layer to that management approach.

METHODS

Study Design

An generalized random tessellation stratified (GRTS) survey design (Stevens 1997, Stevens and Olsen 2004) was used to select stream sample sites across the Illinois River watershed (Olsen, 2006). The sample design was weighted by multi-density categories, represented by Strahler stream order categories. The categories give an approximately equal sample size across stream order categories 1st, 2nd, 3rd, 4th, 5th and 6th+. This stratification ensured that larger order streams were represented, and all perennial waterbodies were included in the design. The design also included an "oversample" to provide alternate sites for those that do not fit the target population, or where access is prohibited by landowners. The survey was originally scheduled for a two-year period but was lengthened to a three-year study (study years 2007-2009) with 51 total sites sampled (Table 1).

The study was spatially, temporally and hydrologically limited. Spatially, the study excluded all the Arkansas portion of the Illinois River Watershed as well as Tenkiller Reservoir and the Illinois River below Tenkiller. Temporal limitations were defined by biological index periods. The index period for the fish assemblage in Oklahoma was May 15 through September 15 with an optional extension to October 1st, if the stream had not risen above summer seasonal base flow (OWRB, 2004a). Both summer and winter index habitat periods were used for the macroinvertebrate assemblage in Oklahoma. The summer index period was June 1 through August 30, while the winter index period was from January 1 through March 15 (OWRB, 2006c). For both periods, collections were completed in as short a time period as possible to increase comparability of results. For algae, index periods were established for this study in late spring/early summer, middle/late summer, and winter. The middle/late summer and winter algal collections coincided with benthic macroinvertebrate sampling. Hydrologically, the study was limited by both an extended drought in SY-2005 as well as excessive rains and flooding in SY-2006-2008. This impeded study progress in several ways. Sites originally verified as target sites were removed and an oversample site visited because of site changes between the period of reconnaissance and sampling. Additionally, several sites had partial collections because conditions changed between the period of macroinvertebrate/water sampling and fish sampling, or vice-versa. In several instances site assemblages were collected during different sampling seasons because of heavy rains extending into or past the index period. All winter benthic macroinvertebrate samples were collected during winter 2009 because of temporal and hydrological interferences during 2008.

Site Reconnaissance

Limited accessibility is the most serious problem with any probabilistic study. Unlike a fixed station design, study sites are typically not accessible by public roads and may only be accessed by foot. Compounding the problem is private ownership of land and the need to respect a landowner's choice of who may or may not access the property. Finally, probabilistic sites are selected from data frames that are not 100% accurate and may include non-candidate sites. Fortunately, proper planning and having an excess of available oversample sites can alleviate these issues. During the EPA's Wadeable Streams Assessment (USEPA, 2006) and the initial Oklahoma Statewide Probabilistic survey (OWRB, 2010a), the OWRB developed (with assistance from EPA documentation) and implemented a three-stage reconnaissance plan.

Table 1. Verified target site sampled with locations weights.

siteID	Waterbody Name	Latitude	Longitude	Strahler Order	Original Weight	Final Adjusted Weight
OKI06594-002	Illinois River	35.9469	-94.8988	6th+	23.21	13.27
OKI06594-005	Illinois River	36.0922	-94.8319	6th+	23.21	13.27
OKI06594-008	Flint Creek	36.2126	-94.6198	4th	11.06	5.03
OKI06594-009	Illinois River	36.1671	-94.7214	6th+	23.21	13.27
OKI06594-011	Tyner Creek	35.9984	-94.7490	5th	9.63	4.82
OKI06594-012	Barren Fork	35.9064	-94.5271	4th	11.06	5.03
OKI06594-018	Steely Hollow	35.9772	-94.9182	3rd	30.94	15.47
OKI06594-019	Bidding Creek	35.8492	-94.7881	4th	11.06	5.03
OKI06594-020	Barren Fork	35.9599	-94.7259	5th	9.63	4.82
OKI06594-021	Illinois River	36.1113	-94.8144	6th+	23.21	13.27
OKI06594-024	Flint Creek	36.2196	-94.5889	4th	11.06	5.03
OKI06594-025	Dripping Springs Branch	36.1554	-94.6908	3rd	30.94	15.47
OKI06594-026	Trib to Waltrip Branch	35.9105	-94.8321	2nd	60.76	27.34
OKI06594-028	Evansville Creek	35.8691	-94.5657	4th	11.06	5.03
OKI06594-029	Tyner Creek	36.0686	-94.6817	4th	11.06	5.03
OKI06594-030	Tailholt Creek	35.8220	-94.8324	3rd	30.94	15.47
OKI06594-031	Barren Fork	35.9513	-94.6843	5th	9.63	4.82
OKI06594-032	Evansville Creek	35.8151	-94.5656	4th	11.06	5.03
OKI06594-033	Flint Creek	36.2119	-94.6714	4th	11.06	5.03
OKI06594-035	Tributary to Smith Hollow	35.8203	-94.7394	2nd	60.76	27.34
OKI06594-038	Tributary to Barren Fork	35.9355	-94.8353	1st	195.91	110.20
OKI06594-041	Flint Creek	36.1758	-94.7113	4th	11.06	5.03
OKI06594-042	Barren Fork	35.8858	-94.8699	6th+	23.21	13.27
OKI06594-043	Peacheater Creek	36.0013	-94.6391	3rd	30.94	15.47
OKI06594-044	Peavine Creek	35.8911	-94.6321	3rd	30.94	15.47
OKI06594-046	Tahlequah Creek	35.8886	-94.9468	4th	11.06	5.03
OKI06594-047	Barren Fork	35.9370	-94.6441	5th	9.63	4.82
OKI06594-048	Evansville Creek	35.8103	-94.5607	4th	11.06	5.03
OKI06594-049	Black Fox Hollow	36.1468	-94.8182	3rd	30.94	15.47
OKI06594-053	Illinois River	36.1335	-94.7561	6th+	23.21	13.27
OKI06594-056	Ballard Creek	36.0984	-94.5866	1st	195.91	110.20
OKI06594-057	Illinois River	36.1207	-94.7662	6th+	23.21	13.27
OKI06594-060	Barren Fork	35.9040	-94.5830	5th	9.63	4.82
OKI06594-061	Illinois River	36.0016	-94.9220	3rd	30.94	15.47
OKI06594-062	Barren Fork	35.8669	-94.8985	6th+	23.21	13.27
OKI06594-063	Tyner Creek	35.9775	-94.7647	5th	9.63	4.82
OKI06594-064	Barren Fork	35.9239	-94.6267	5th	9.63	4.82
OKI06594-066	Illinois River	35.9726	-94.8739	6th+	23.21	13.27
OKI06594-067	England Hollow	35.8913	-94.6679	2nd	60.76	27.34
OKI06594-071	Barren Fork	35.9508	-94.7007	5th	9.63	4.82
OKI06594-072	Evansville Creek	35.8114	-94.5325	4th	11.06	5.03
OKI06594-076	Beaver Creek	36.1422	-94.5845	1st	195.91	110.20
OKI06594-079	Barren Fork	35.9333	-94.6380	5th	9.63	4.82
OKI06594-080	Evansville Creek	35.8267	-94.5727	4th	11.06	5.03
OKI06594-081	Flint Creek	36.2167	-94.6333	4th	11.06	5.03
OKI06594-086	Barren Fork	35.9298	-94.8271	6th+	23.21	13.27
OKI06594-090	Barren Fork	35.9034	-94.8607	6th+	23.21	13.27
OKI06594-092	Peavine Creek	35.8539	-94.6078	2nd	60.76	27.34
OKI06594-093	Park Hill Branch	35.8495	-94.9851	3rd	30.94	15.47
OKI06594-094	Town Branch	35.9089	-94.9676	1st	195.91	110.20
OKI06594-100	Crazy Creek	36.2430	-94.6140	2nd	60.76	27.34

The first stage of planning was a “desk top” reconnaissance to determine if the proposed site was a candidate site. Candidate sites must meet certain criteria, including: 1) perennial flow, 2) not within normal pool elevation of a lake (oxbows or reservoirs), 3) not a wetland/swamp dominated river, 4) accessible by foot, and 5) landowner permission granted. Initially, each site was located using a variety of resources including topographic maps (OWRB, 2005c), and other GIS mapping tools. For each site, a site reconnaissance and tracking form (Figure 2) was created with the ultimate determination made to “accept” or “reject”. At the outset, required hydrological characteristics were verified, and if not met, the site was rejected without further consideration. Then, a series of site maps containing at least two geographic scales were included with the site tracking form, and the necessary information to determine landowner was collected, including legal description of site and county. County assessor offices were the main source of landowner information. However, for some problem sites, staff used a variety of other resources including development of relationships with local realtors/developers, personal visits to nearby residences, and Mr. Ed Fite, Executive Director of the Oklahoma Scenic Rivers Commission (OSRC). Finally, a landowner permission packet was sent to each landowner, including a standardized permission letter (Figure 3), maps, a study brochure, and self addressed/stamped envelope for them to review and mail back to the OWRB either approving or disallowing access to their property. Based on landowner response, the site was accepted, accepted with restrictions/further instructions, or rejected. However, even when good landowner information was available, response to permission requests was occasionally slow for a variety of reasons, and therefore, a two stage process was developed to deal with slow responses. After two to three weeks, staff attempted contact by phone, and if unsuccessful, would send a reminder postcard. If still unsuccessful, in-person contact was attempted. If each of these attempts failed, the site was rejected. Mr. Fite and his agency and staff proved invaluable in helping staff to locate some landowners and to “sell” the study to some reticent local participants.

Once site accessibility was verified (i.e., accepted) and a site was labeled as a study target site, a second planning stage was initiated. The planning objective was simply to collect thorough, well-documented information to assist field crews in locating and accessing the sampling reach. Because of color aerial satellite imagery, much of this information was gathered from the desktop. Notes were made and included in the tracking form of special considerations including hazards, best route of entry, time of travel, etc. Unfortunately, some sites required an on-site initial visit to complete the planning phase. Concerns did arise about the cost versus benefit of an extra site visit. However, over time, crews have discovered that information collected during initial on-site planning visits was of great benefit during sampling days. Furthermore, because sites could be visited in batches and only one staff member was required, not much expense was incurred.

The final planning stage involved all activities up to the first sampling visit, and involved compiling a complete site packet. The packet incorporated all information gathered in stages one and two, including a completed tracking form, landowner permission letter, and pertinent pictures and maps. In addition, all necessary field forms and labels were compiled and a checklist of equipment needed was completed.

Probabilistic Monitoring – Site Reconnaissance & Tracking Form

Stream Name: **Little Creek**

Site ID: **OKPB01-*027***

Lat/Long: **34^0 46' 50.8" / 99^0 23' 33.5"**

Site Type: **target** or oversample

Sample Status: **Accepted** or Rejected

If rejected, what is the reason:

[ ] Landowner Denied Permission
[ ] Site is Dry
[ ] Site is impounded (part of a lake)
[ ] Site is not riverine habitat (i.e., wetland, swamp, etc.)
[ ] Site is not physically accessible
[ ] Other, please explain:

If rejected, what site replaces this one:

Landowner Contact Information:

John Doe (Doe Land & Cattle Co.)
P.O. Box A
Your Town, OK 11111
(580)555-2222

Landowner Requests:

None. You can drive down to the site if you need. (see attached permission letter)

Directions/Access to Site:

From Your Town, go west on SH 1 for 3.25 miles. The property is South of this point. Walk or drive across pasture to get to the X-site. (see attached maps)

Figure 2. Template site reconnaissance and tracking form used during study.

April 2, 2007

Joe & Susan Willard
6009 S Atlanta Ct
Tulsa, OK 74105

Dear Sir or Madam:

The Oklahoma Water Resources Board (OWRB) is conducting a two-year project to perform biological assessments on 50 randomly selected streams throughout the Illinois River basin. This effort involves on-site visits by OWRB personnel to a stream adjacent to your property to take samples of the water, fish and other aquatic life, and to gather other information concerning stream habitat such as measurements of stream width and depth and observations of stream bed and vegetation characteristics. The findings of the study are not intended for enforcement or regulatory purposes.

One of the sites that we would like to assess is a point on your land. A legal Description of the site we wish to sample and a map of the site are enclosed.

We are writing to ask for your permission to come onto your property to visit the site and conduct sampling activities. We realize that working on your property is a privilege and we will respect your landowner rights at all times. If you grant us permission, we will make approximately four visits to your land. The first visit will be for site reconnaissance and will occur sometime between April and May of 2007. A crew of one to two people will use your land to access the site and only gather information about site accessibility. In addition, three more visits will be made between May and October of 2007 for sampling and collection. We expect to have a crew of no more than four OWRB employees or its contractors coming on site during the sample collection visits.

Once a sampling date is set, OWRB employees will contact you, either by telephone or in person, before entering onto your land. After OWRB staff contact you, they will access the site either on foot or by vehicle and collect the necessary samples and data. Other than driving or walking across your land and walking in and around the stream site, we expect that staff will not leave any trace of their activity. Staff will honor any special instructions you have, such as accessing land only by foot, driving on pasture roads only, and opening and closing gates responsibly.

If you are agreeable to the activities described above, please complete and sign one copy of the "Landowner Permission" page and mail it back to us in the enclosed, stamped return envelope by May 01, 2007. We have enclosed a duplicate of this page, which you may keep for your records. Please include contact information so that we may contact you by

phone. If you would rather us not access your land please respond, indicating permission no granted, so that we can move to the next site on the list. Thank you for your consideration. If you have any questions about this request, please contact Project Coordinator or myself at 405-530-8800.

Sincerely,

onitoring Coordinator

Enclosures: Site tracking sheet
Site map
Permission form
Project brochure
Return envelope

LANDOWNER PERMISSION

I grant permission to the employees of the Oklahoma Water Resources Board to come onto my property and conduct stream sampling activities as described in this letter.

_________ Permission granted
_________ Permission granted, subject to the following restrictions or instructions:
____
____
____
_________ Permission not granted

Landowner's Name (please print): ____

Landowner's Signature: ____

Date

Landowner's Daytime Phone No.

Figure 3. Template landowner permission letter used during study.

Data Collection

To assess ecological health, up to three collections were made for a variety of biological, chemical, and physical parameters (Table 2). When sites were verified as target, a sampling schedule was implemented. All target sites were visited three times during a late spring to early summer, a middle to late summer, and a winter index period. During these visits, fish were collected once within the spring to summer timeframe and a comprehensive suite of physical habitat measurements was made (OWRB, 2004a; OWRB, 2005a). During the summer season within one of the two periods and during the winter, benthic macroinvertebrates were collected and a shortened habitat collection form was completed (OWRB, 2006b). Lastly, sestonic and benthic chlorophyll were collected during each of the three visits (OWRB, 2006a). In addition, nutrient and *in-situ* water quality collections were made during each site visit including measurements for sample variables in Table 2 (OWRB, 2006c). All collections were made in baseflow conditions. Additionally, macroinvertebrate collections were collected for all sites over as short a time period as reasonably possible to avoid temporal bias.

Table 2. Water quality variables included in study.

SAMPLE VARIABLES		
***In situ* Variables**		
Dissolved Oxygen (D. O.)	% D. O. Saturation	PH
Water Temperature	Specific Conductance	
Field Variables		
Nephelometric Turbidity	Total Alkalinity	Total Hardness
Instantaneous Flow	Stage	
Laboratory Variables--General Chemistry		
Total Kjeldahl Nitrogen	Ortho-Phosphorus	Total Phosphorus
*Nitrate Nitrogen	*Nitrite Nitrogen	Ammonia Nitrogen
Biological Variables and Habitat		
Fish	Macroinvertebrates	Sestonic Chlorophyll-a
Habitat--Long Form	Habitat--Short Form	Benthic Chlorophyll-a

Data for water quality variables was collected in one of two ways (OWRB, 2006c). Several variables (pH, dissolved oxygen, water temperature, and specific conductance) were monitored *in-situ* utilizing a Hydrolab® Minisonde or YSI® multi-probe instrument. Regardless of instrumentation and in accordance with manufacturer's specifications and/or published SOP's, all instruments and probles (except water temperature) were calibrated at least weekly and verified daily with appropriate standards. The measurement was taken at the deepest point of the channel at a depth of at least 0.1 meters and no greater than one-half of the total depth. The data were uploaded from the instrument and saved to a data recorder, transferred manually to a field log sheet, and manually entered into the OWRB Water Quality Database (OWRB, 2010b). Data for all other variables were amassed from water quality samples collected at the station. Grab samples were collected by one of two methods—a grab or a composite grab. The most common method employed was a grab sample, which was used in streams with a single, well-mixed channel. The sample was collected at the deepest, fastest flowing portion of the horizontal transect by completely submerging the bottle, allowing it to fill to the top, and capping the bottle underwater. Composite grabs were collected in rivers with multiple and/or poorly mixed channels and were aliquotted into sample bottles using a clean splitter-churn. Each sample included two bottles for general chemistry analyses (one ice preserved and one sulfuric acid preserved) and one bottle each for field chemistry analyses and sestonic chlorophyll-a filtration (ice preserved and kept dark). For benthic chlorophyll-a, a sample was composited, placed on ice to be preserved, and kept dark. The Oklahoma Department of

Environmental Quality(ODEQ) State Environmental Laboratory (SEL) in accordance with the ODEQ's Quality Management Plan (QTRACK No. 00-182) (ODEQ, 2007) analyzed samples for most parameters listed in Table 2. OWRB personnel measured hardness and alkalinity using Hach® titration protocols (OWRB, 2005), nephelometric turbidity using a Hach® Portable turbidometer (OWRB, 2005), and ammonia nitrogen and ortho-phosphorus using a Hach® DR890 colorimeter (OWRB, 2009).

Samples for algal biomass were collected in both the sestonic and benthic zones of each waterbody and processed in accordance with standard procedures outlined (OWRB, 2006a). Sestonic, or water column, samples were processed from water collected during the general water quality collection. A benthic sample was processed from a reach-wide composite. Benthic filters were extracted using an alternate method, whereby filters are placed in a standard aliquot of ethanol (25 mL) and extracted at room temperature for at least 72 hours. All chlorophyll-a samples were analyzed by the ODEQ-SEL under the previously mentioned QMP (ODEQ, 2007).

Additional biological assemblages included aquatic macroinvertebrates and fish that were collected in accordance with Oklahoma's Rapid Bioassessment Protocols (RBP) (OWRB, 1999) and the OWRB's biological collection protocols (OWRB, 2004a). Collections were completed over a 400-1000 meter reach depending on wetted width, with 400 meters serving as the default reach length. Fish were primarily collected using a pram or boat electrofishing unit depending on wadeability. Each fishing unit consisted of a Smith-Root 2.5 generator powered pulsator (GPP) attached to a 3000W Honda generator, and were operated with AC output current at 2-4 amps. Using two netters with ¼ inch mesh dipnets, collections were made in an upstream direction with a target effort of 2000-4000 units depending on reach length. When habitats existed that could not be effectively electrofished, supplemental collections were made using 6' X 10' seines of ¼ inch mesh equipped with 8' brailes. Fish were processed at several intervals during each collection. Fish that were too large for preservation and/or readily identifiable were processed in the field, including identified to species and enumerated along with appropriate photo-documentation and representative vouchers. Voucher samples and non-field identified fish were fixed in a 10% formalin solution and interior and exterior labels were added to each sample jar. Samples were fixed for at least one week and eventually taken through a graduated formalin removal/hydration/preservation process that terminated in 90% ethanol preservation. Preserved fish were either identified/enumerated by qualified OWRB staff or Dr. Anthony Echelle, Regents Professor and Curator of Fishes, in the Department of Zoology at Oklahoma State University (OSU). Additionally, a detailed habitat assessment was made targeting in-stream substrate, habitat, width and depth as well as bank and riparian measurements (OWRB, 2005b).

Aquatic macroinvertebrate collections were made during both winter and summer index periods (OWRB, 2006b). Each sampling event targeted three habitats (when available)—streamside vegetation, wood, and rocky riffles—that theoretically should be species rich. The streamside vegetation and wood collections were semi-qualitative samples collected over flowing portions of the reach for total collection times of three and five minutes, respectively. The streamside sample was collected using a 500-micron D-frame net to agitate various types of fine structure sample including fine roots, algae, and emergent and overhanging vegetation. Likewise, the wood sample was collected using a 500-micron D-frame net to agitate, scrape, and brush wood of any size in various states of decay. Additionally, wood that could be removed from the stream was scanned for additional organisms outside the 5-minute sampling time. The riffle collection was a quantitative sample compositing three kicks representing slow, medium and fast velocity rocky riffles within the reach. Each sub-sample was collected by fully kicking one square meter into a 500-micron Zo seine. All samples were field post-processed in a 500-micron sieve bucket to remove large material and silt in an effort to reduce sample size to no more than ¾ of a quart sample jar. Additionally, all nets and buckets were thoroughly scanned to ensure that no organisms were lost. After processing, each sample type was preserved independently in quart wide mouth polypropylene jars with ethanol and interior and exterior labels were added. Prior to taxonomic analysis, all samples were laboratory processed by study personnel to obtain a representative 100-count subsample with a large/rare scan (OWRB, 2006b). After sorting, the "100-count subsample" and large/rare scan were sent to the OWRB's contracted macroinvertebrate taxonomic laboratory for identification and enumeration. During the initial study year, EcoAnalysts, Inc. (Moscow, Idaho) was the contractor, but since 2008, the taxonomic contract has been with Environmental Services and Consulting of Blacksburg, West Virginia. The majority of samples were identified by Environmental Services and Consulting and its sub-contractor, Dr. Joe Bidwell, Assistant Professor and Director of the Ecotoxicology and Water Quality Research Laboratory, in the Department of Zoology at OSU. Taxonomic data for each sample were grouped by the contractor and metrics were calculated for both the "100-count subsample" and the "100-count subsample with large/rare organisms". In general, most organisms were identified to genera with midges identified to tribe.

Discharge and/or stage data were also collected at each station (OWRB, 2005b). Flow was determined through several methods including direct measurement of instantaneous discharge using a flow meter, interpolation of flow from a stage/discharge rating curve developed by the United States Geological Survey (USGS), or through estimation of discharge using a float test (OWRB, 2004b).

For a more detailed discussion of sampling procedures, please contact the OWRB/Water Quality Programs Division at (405) 530-8800 for copy of the BUMP Standard Operating Procedures (SOP) or visit the OWRB website at http://www.owrb.state.ok.us/quality/monitoring/monitoring.php#SOPs. All data were managed, graphs created, and statistical analyses made using R Statistical Software, Minitab v.16, or Microsoft Excel©.

Extent Estimates

For the study, a total of one hundred (100) randomly chosen sites were evaluated for candidacy representing a total of 2,912 stream miles. Study extent estimates are illustrated in Figure 4. Stream miles determined to be target, or sampleable, totaled 961 miles (33%, +/- 10%) and were represented by 51 sampling locations. Stream miles that did not meet the target criteria were divided into two categories—non-sampleable and no access. The non-sampleable category was further sub-divided by characteristic, including dry channel, impounded, and no visible channel. Stream miles determined to be non-sampleable due to a dry channel totaled 538 miles (19%, +/- 11%) and were represented by 10 evaluated sites. Stream miles determined to be non-sampleable due to impounded or no visible channels totaled 152 miles (5%, +/- 11%) and were represented by 4 evaluated sites. The no access category can be represented by several sub-categories including natural or temporary barriers and permission denied, but for this study, only the permission denied sub-category was used. Landowners denied permission for access on 1,261 stream miles (43%, +/- 15%), which were represented by 35 evaluated sites.

Analysis of Fish Biological Condition

Fish data were analyzed using two indices of biological integrity (IBI) commonly used in Oklahoma bioassessment studies. Primarily, state biocriteria methods are outlined in Oklahoma's Use Support Assessment Protocols (USAP) (OWRB, 2008b). In addition, an IBI commonly used by the OCC's Water Quality Division was used to provide an alternative bioassessment (OCC, 2005a; OCC, 2005b; OCC, 2008). Henceforth, the USAP and OCC IBI's will termed as the OKFIBI and OCCFIBI, respectively. All metrics and IBI calculations were made using the OWRB's "Fish Assessment Workbook", an automated calculator OWRB staff built in Microsoft Excel (OWRB, 2008a).

Oklahoma's biocriteria methodology (OKFIBI) uses a common set of metrics throughout the state (Table 3). Each metric is scored a 5, 3, or 1 depending on the calculated value, and scores are summed to reach two subcategory totals for sample composition and fish condition (OWRB, 2008b). The two subcategories are then summed for a final IBI score. The score is compared to ecoregion biocriteria to determine support status. For Cool Water Aquatic Communities (Fish and Wildlife Beneficial Use subcategory) in the Ozark Highlands Ecoregion (Woods, et al., 2005), if the final IBI score is between 30-36, the status is deemed undetermined. Likewise, for scores greater than 36 and less than 30, the status is supported or not supported, respectively. For Warm Water Aquatic Communities in the ecoregion, the undetermined range is 23 to 30, with scores above 30 and below 23 categorized as supporting and non-supporting, respectively.

The OCCFIBI uses "a modified version of Karr's Index of Biotic Integrity (IBI) as adapted from Plafkin et al., 1989" (OCC, 2005b; OCC, 2008). The metrics as well as the scoring system are in Table 4. Metric scores are calculated in two ways for both the test site and composite reference metric values of high-quality streams in the ecoregion (OCC, 2005a). Species richness values (total, sensitive benthic, sunfish, and intolerant) are compared to composite reference value to obtain a "percent of reference". A score of 5, 3, or 1 is then given the site depending on the percentages outlined in Table 4, while the reference composite is given a default score of 5. Proportional metrics (% individuals as tolerant, insectivorous cyprinids, and lithophilic spawners) are scored by comparing the base metric score for both the test site and the reference composite to the percentile ranges given in Table 4. After all metrics are scored, total scores are calculated for the test and composite reference sites. Finally, the site final score is compared to the composite reference final score and a percent of reference is obtained. The percent of reference is compared to the percentages in Table 5 and an integrity classification is assigned with scores falling between assessment ranges classified in the closest scoring group.

Figure 4. Study extent estimates representing considered and sampled stream miles and percentages (total miles = 2912).

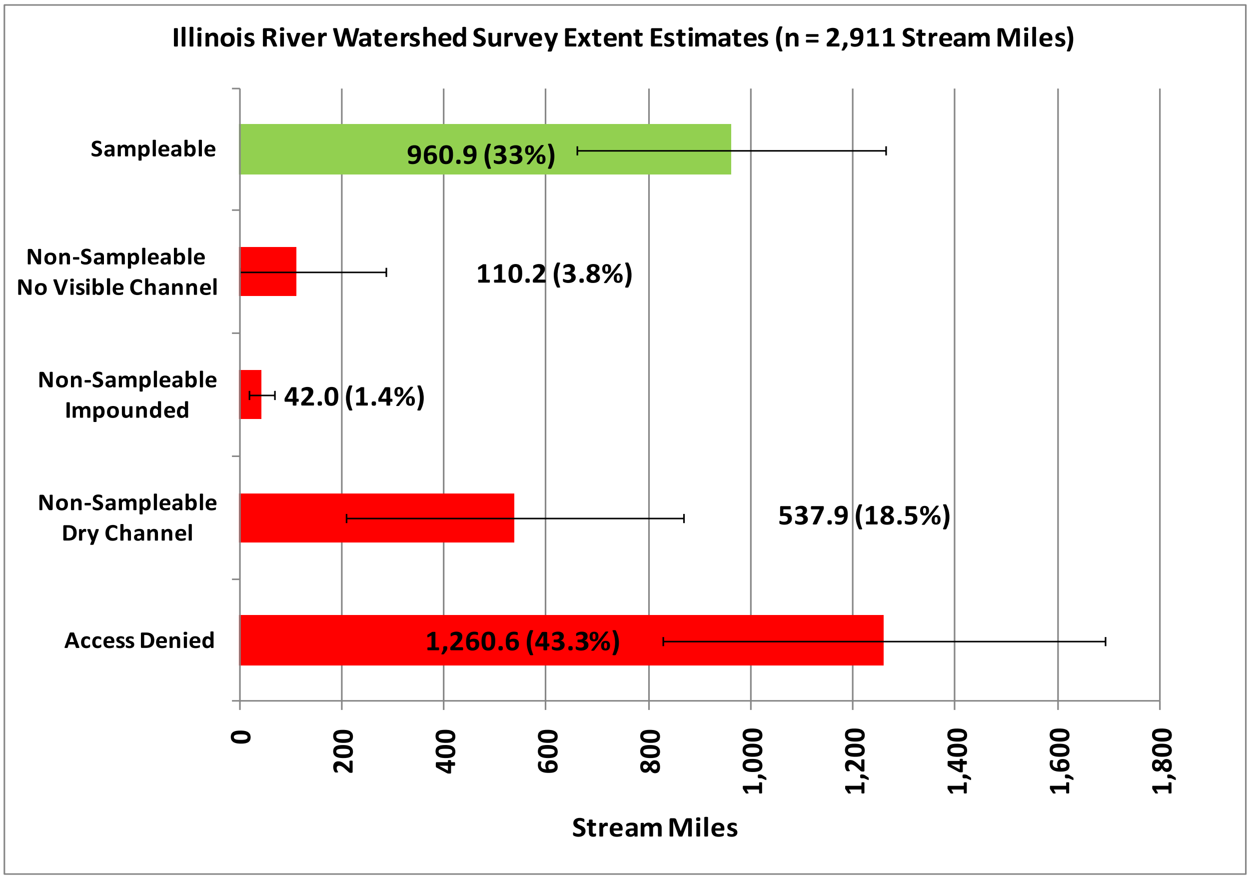


Table 3. Index of biological integrity used to calculate scores for Oklahoma's biocriteria. Referenced figures may be found in OAC 785:15: Appendix C (OWRB, 2008b).

Metric	Value	Scoring 5	Scoring 3	Scoring 1	Score
Total # of species		fig 1	fig 1	fig 1	
Shannon's Diversity based upon numbers		>2.50	2.49-1.50	<1.50	
# of sunfish species		>3	2 to 3	<2	
# of species comprising 75% of sample		>5	3 to 4	<3	
# of intolerant species		fig 2	fig 2	fig 2	
Percentage of tolerant species		fig 3	fig 3	fig 3	
TOTAL SCORE FOR SAMPLE COMPOSITION					0
Percentage of lithophils		>36	18 to 36	<18	
Percentage of DELT anomalies		<0.1	0.1-1.3	>1.3	
Total individuals		>200	75 to 200	<75	
TOTAL SCORE FOR FISH CONDITION					0
TOTAL SCORE					0

Table 4. Metrics and scoring criteria used in the calculation of OCC's index of biological integrity (OCC, 2008).

Metrics	5	3	1
Number of species	>67%	33-67%	<33%
Number of sensitive benthic species	>67%	33-67%	<33%
Number of sunfish species	>67%	33-67%	<33%
Number of intolerant species	>67%	33-67%	<33%
Proportion tolerant individuals	<10%	10-25%	>25%
Proportion insectivorous cyprinid individuals	>45%	20-45%	<20%
Proportion individuals as lithophilic spawners	>36%	18-36%	<18%

Table 5. Integrity classification scores and descriptions used with OCC's index of biological integrity (OCC, 2008).

% Comparison to the Reference Score	Integrity Class	Characteristics
>97%	Excellent	Comparable to pristine conditions, exceptional species assemblage
80 - 87%	Good	Decreased species richness, especially intolerant species
67 - 73%	Fair	Intolerant and sensitive species rare or absent
47 - 57%	Poor	Top carnivores and many expected species absent or rare; omnivores and tolerant species dominant
26 - 37%	Very Poor	Few species and individuals present; tolerant species dominant; diseased fish frequent

Fish taxonomic results for each site were analyzed to produce a raw score for the OKFIBI and a percent of reference score for the OCCFIBI. From these scores, biological integrity classifications were assigned and condition estimates were calculated for each index. The OKFIBI condition estimates are presented using the three classifications discussed previously, including supporting, undetermined, and reference (Figure 5). Likewise, the OCCFIBI condition estimates are presented using four classifications (Figure 6). For ease of reporting condition estimates, fair and reference are reported as individual classes, and in essence, are synonymous with undetermined and supporting classifications for the OKFIBI. Additionally, excellent/good and poor/very poor are presented as grouped classifications, and can be considered synonymous with supporting and non-supporting. Each IBI gives a somewhat different estimate (Figures 5 and 6).

For the sampled target population (2,912 stream miles), the OKFIBI estimates that fish condition is supported in 48% (1,397 stream miles) of the population, not supported in 32% of the population (927 stream miles), and undetermined in 20% (587 stream miles) of the population. Conversely, using the same sampled target population, the OCCFIBI estimates that fish condition is supported in 40% (1,176 stream miles) of the population, not supported in 42% of the population (1,225 stream miles), and undetermined in 18% (510 stream miles) of the population.

Figure 5. Fish condition estimated in the Illinois River watershed using the OKFIBI.

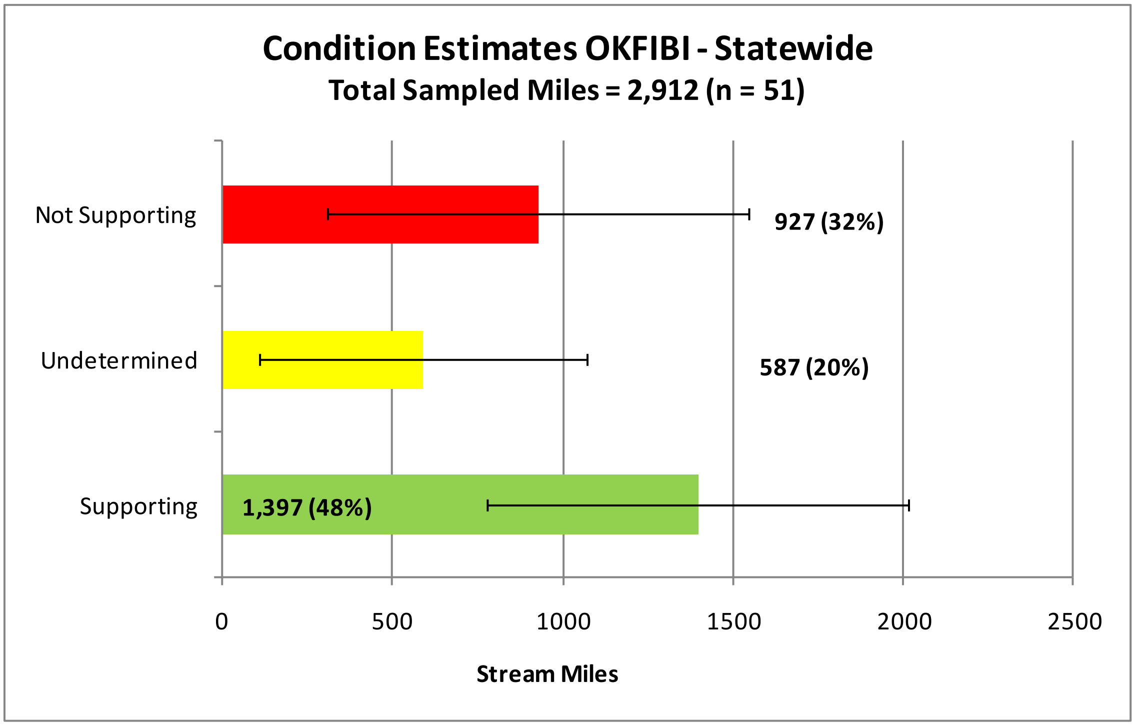
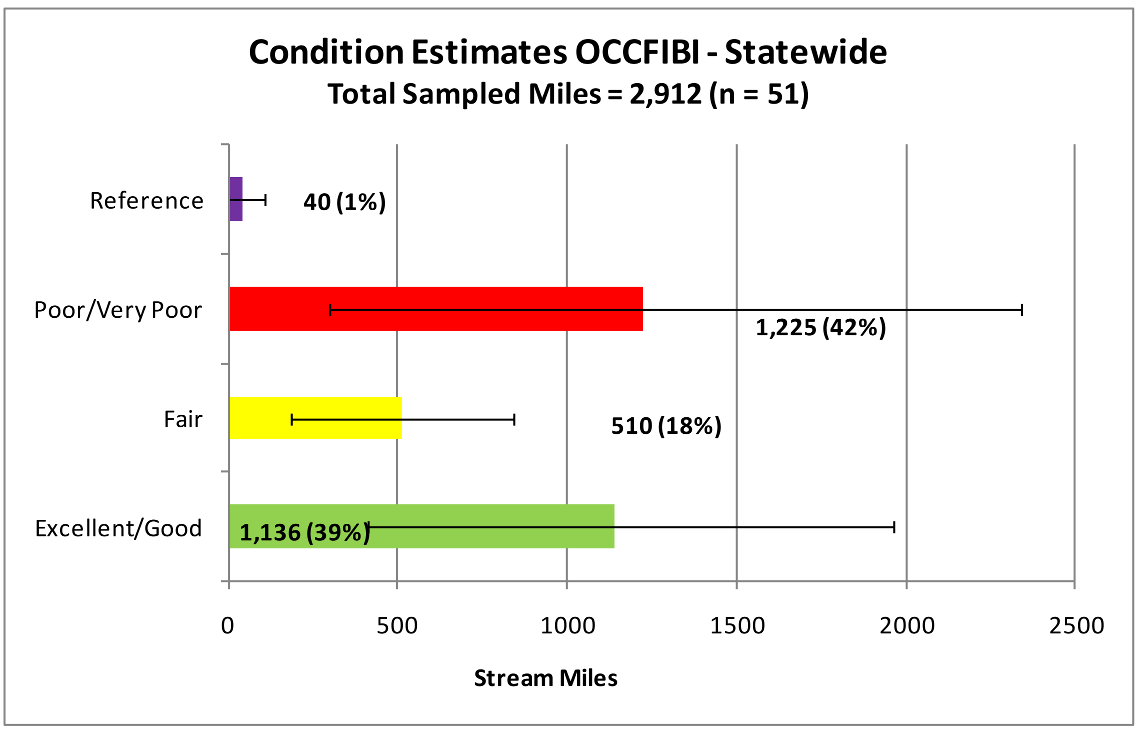


Figure 6. Fish condition estimated in the Illinois River watershed using the OCCFIBI.



Analysis of Macroinvertebrate Biological Condition

Macroinvertebrate data were analyzed using a Benthic-IBI (OKBIBI) developed for Oklahoma benthic communities (OCC, 2005a) and commonly used by the OCC and OWRB Water Quality Divisions (OCC, 2005,b; OCC, 2008; OWRB, 2009a; OWRB, 2009b). The metrics and scoring criteria (Table 6) are taken from the original "Rapid Bioassessment Protocols for Use in Streams and Rivers" (Plafkin et al., 1989) with slight modifications to the EPT/Total and Shannon-Weaver tolerance metrics (OCC, 2009). Metrics were calculated by the OWRB's contract taxonomic laboratories and IBI calculations were made using the OWRB's "Macroinvertebrate Assessment Workbook", an automated calculator built by OWRB Staff in Microsoft Excel (OWRB, 2008a).

Calculation of the OKBIBI is similar to the fish OCCFIBI discussed previously. Metric scores are calculated in two ways for both the test site and the composite reference metric values of high-quality streams in each ecoregion (OCC, 2005a; OCC, 2005b; OCC, 2008). Species richness (total and EPT) and modified Hilsenhoff Biotic Index (HBI) values are compared to the composite reference value to obtain a "percent of reference" (OCC, 2009). A score of 6, 4, 2 or 0 is then given the site depending on the percentages outlined in Table 6, while the reference composite is given a default score of 6. Proportional metrics (% dominant 2 taxa and %EPT of total) as well as the Shannon-Weaver Diversity Index are scored by comparing the base metric score for both the test site and the reference composite to the percentile ranges given in Table 6. After all metrics are scored, total scores are calculated for the test and composite reference sites. The site final score is then compared to the composite reference final score and a percent of reference is obtained. The percent of reference is compared to the percentages in Table 7 and an integrity classification is assigned with scores falling between assessment ranges classified in the closest scoring group.

Table 6. Metrics and scoring criteria used in the calculation of the OKBIBI (OCC, 2008).

B-IBI Metrics	6	4	2	0
Taxa Richness	>80%	60-80%	40-60%	<40%
Modified HBI	>85%	70-85%	50-70%	<50%
EPT/Total	>30%	20-30%	10-20%	<10%
EPT Taxa	>90%	80-90%	70-80%	<70%
% Dominant 2 Taxa	<20%	20-30%	30-40%	>40%
Shannon-Weaver Diversity Index	>3.5	2.5-3.5	1.5-2.5	<1.5

Table 7. Integrity classification scores and descriptions used with OKBIBI (OCC, 2008).

% Comparison to the Reference Score	Biological Condition	Characteristics
>83%	Non-impaired	Comparable to the best situation expected in that ecoregion; balanced trophic and community structure for stream size
54 - 79%	Slightly Impaired	Community structure and species richness less than expected; percent contribution of tolerant forms increased; loss of some intolerant species
21 - 50%	Moderately Impaired	Fewer species due to loss of most intolerant forms; reduction in EPT index
<17%	Severely Impaired	Few species present; may have high densities of 1 or 2 taxa

Macroinvertebrate taxonomic results for each site were analyzed to produce a percent of reference score for each sampling period and habitat sampled. Based upon the results, site samples were reduced to several composite scores for comparison to the OKBIBI. The OKBIBI condition estimates for the target population (total sampled stream miles) are presented using four classifications discussed previously—reference, non-impaired, slightly impaired, and moderately impaired. None of the target population scored as severely impaired. The first composite sample consists of only the averaged summer/winter riffle samples from each site (Figure 7). For the several sites where riffles were not available, a combined score of other habitats was substituted. For the sampled target population (2,912 stream miles), the OKBIBI-Riffle estimates that benthic macroinvertebrate condition is non-impaired in 31% (886 stream miles) of the population, slightly impaired in 41% of the population (1,205 stream miles), and moderately impaired in 28% (821 stream miles) of the population.

The second composite sample averages of all summer/winter samples from each site (Figure 8). Prior to combining samples, several collections were removed because of lack of representative habitat. For example, a wood collection may have been made, but the presence of wood within the sample reach was scarce. If the collection scored below other habitats sampled at the site, it was removed from the final combined scoring to prevent an unwarranted negative bias from occurring. Only streamside vegetation and wood samples were removed, and the collection characteristics considered included frequency of habitat, flow, type of streamside sampled (fine roots given preference), and wood state of decay. For the sampled target population (2,912 stream miles), the OKBIBI-Combined estimates that benthic macroinvertebrate condition is non-impaired in 27% (796 stream miles) of the population, slightly impaired in 46% of the population (1,326 stream miles), and moderately impaired in 27% (790 stream miles) of the population. The OKBIBI-Combined condition estimates show a slightly lower percent of the population in a non- or moderately impaired condition, while a slightly higher number of stream miles are considered slightly impaired.

Figure 7. Benthic macroinvertebrate riffle condition estimated in the Illinois River watershed using the OKBIBI.

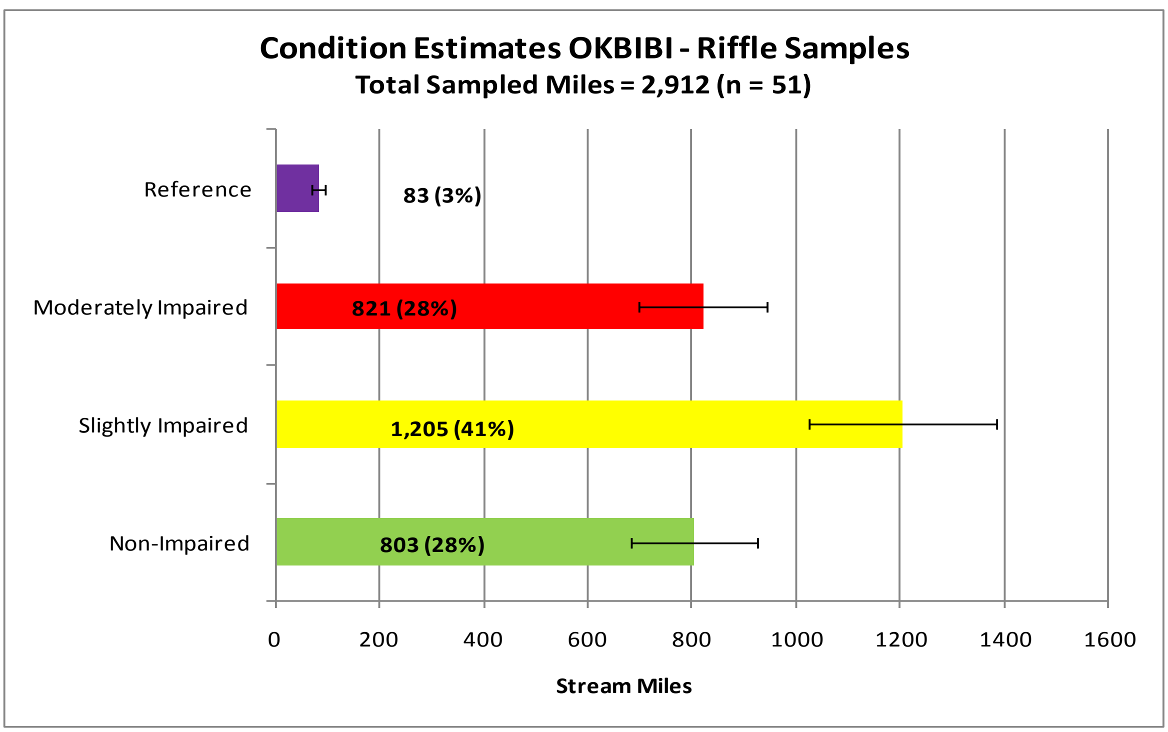
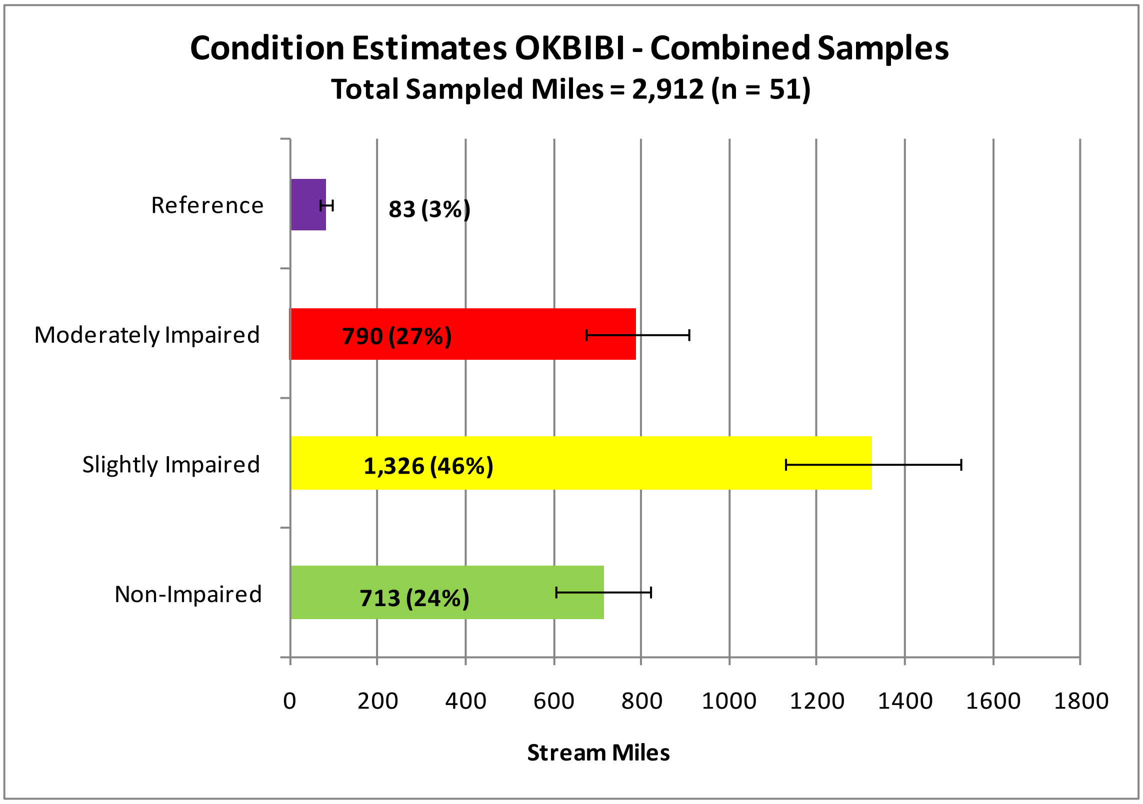


Figure 8. Benthic macroinvertebrate combined habitat condition estimated in the Illinois River watershed using the OKBIBI.



Analysis of Algal Biomass

Algae are important in aquatic ecology acting as an important primary producer in aquatic food webs providing a food source for a wide variety of fish and macroinvertebrates. Furthermore, algae are indispensable producers of oxygen for aquatic organisms. However, algal blooms are also an important indicator of water quality perturbance and nutrient productivity. Introduction of nutrients to waterbodies occurs through a number of both point and non-point sources including runoff from urban and agricultural areas, wastewater treatment discharges, and a variety of other sources. As nutrient concentrations increase, uptake by primary producers increases and leads to algal blooms as well as an increased standing crop. As eutrophication happens, aquatic life and human health beneficial uses can become impaired as well as the aesthetic and recreational appeal of waterbodies being drastically reduced.

In order to quantify eutrophication, algal biomass was measured in both the benthic (i.e., periphyton) and water column (i.e., sestonic) areas of all study streams. Various measures exist to determine algal biomass including chlorophyll-a and ash free dry mass. For this study, chlorophyll-a concentrations were calculated because the USAP (OWRB, 2008b) provides screening levels for both periphyton and sestonic chlorophyll-a. Additionally, the OWRB has a moderately large chlorophyll-a dataset allowing for the exploration of various screening levels (OWRB, 2003; OWRB, 2005c).

To estimate condition of algal biomass, chlorophyll-a concentrations were compared to multiple screening levels (Table 8). For benthic chlorophyll-a, five screening levels were used. First, USAP (OWRB, 2008b) provides a screening level for periphyton chlorophyll-a in the Aesthetic beneficial use. A value of 100 mg/m^2 represents a nuisance level for periphyton algae (BenChl100). Second, the OWRB has collected periphyton chlorophyll-a across the state for several programs throughout the years. To provide several alternate screening levels, the quartiles of combined historic and study benthic data were calculated for the Ozark Highlands (OWRB, 2008c; OWRB, 2010b). Likewise, five screening levels were established for sestonic chlorophyll-a. In addition the quartiles of historic and study sestonic data, the Oklahoma Water Quality Standards (OWQS) includes a standard for sensitive water supplies of 10 mg/m^3 (SesChl10) of chlorophyll-a (OWRB, 2007).

Data from each site were compared to each screening level. Estimates of the stream miles exceeding each screening level are presented in bar charts for each sestonic and benthic screening level (Figures 9 and 10). For both benthic and sestonic populations, the greater majority of the population is not exceeding the screening limits promulgated in rule—SesChl10 and BenChl100—with only 14% and 1% exceeding, respectively. Both values greatly exceed any probable average of the study population. Conversely, when considering the lower quartiles of the each distribution (the median and 25^{th} percentile, approximately 68-89% of the population exceeds the screening limit. Interestingly, approximately 40% of the population exceeds the mean and 75^{th} percentile of the sestonic distribution, while only one in four of the population exceeds the 75^{th} percentile of the benthic distribution. The benthic mean is closely related to the nuisance level in rule and is only exceeded in 1% of the population.

Table 8. Benthic and sestonic chlorophyll-a screening levels used for study.

Condition Screening Limit	Condition Screening Limit Description	Sestonic (mg/m^3) or Benthic (mg/m^2)
SesChl10	OWQS sensitive water supply sestonic chlorophyll-a criterion	10.00
SesChlMean	Mean of historic sestonic chlorophyll-a data (lotic waterbodies)	2.48
SesChl75	75th percentile of historic sestonic chlorophyll-a data (lotic waterbodies)	2.11
SesChlMed	Median of historic sestonic chlorophyll-a data (lotic waterbodies)	0.90
SesChl25	25th percentile of historic sestonic chlorophyll-a data (lotic waterbodies)	0.43
BenChl100	USAP nuisance screening level for benthic chlorophyll-a	100.00
BenChlMean	Mean of historic benthic chlorophyll-a data (lotic waterbodies)	99.12
BenChl75	75th percentile of historic benthic chlorophyll-a data (lotic waterbodies)	77.99
BenChlMed	Median of historic benthic chlorophyll-a data (lotic waterbodies)	30.73
BenChl25	25th percentile of historic benthic chlorophyll-a data (lotic waterbodies)	12.81

Figure 9. Sestonic algal chlorophyll-a condition estimated for all geographic scales. Upper and lower bounds represent a 90% confidence interval. Bars represent the # of miles exceeding the respective chlorophyll-a screening level.

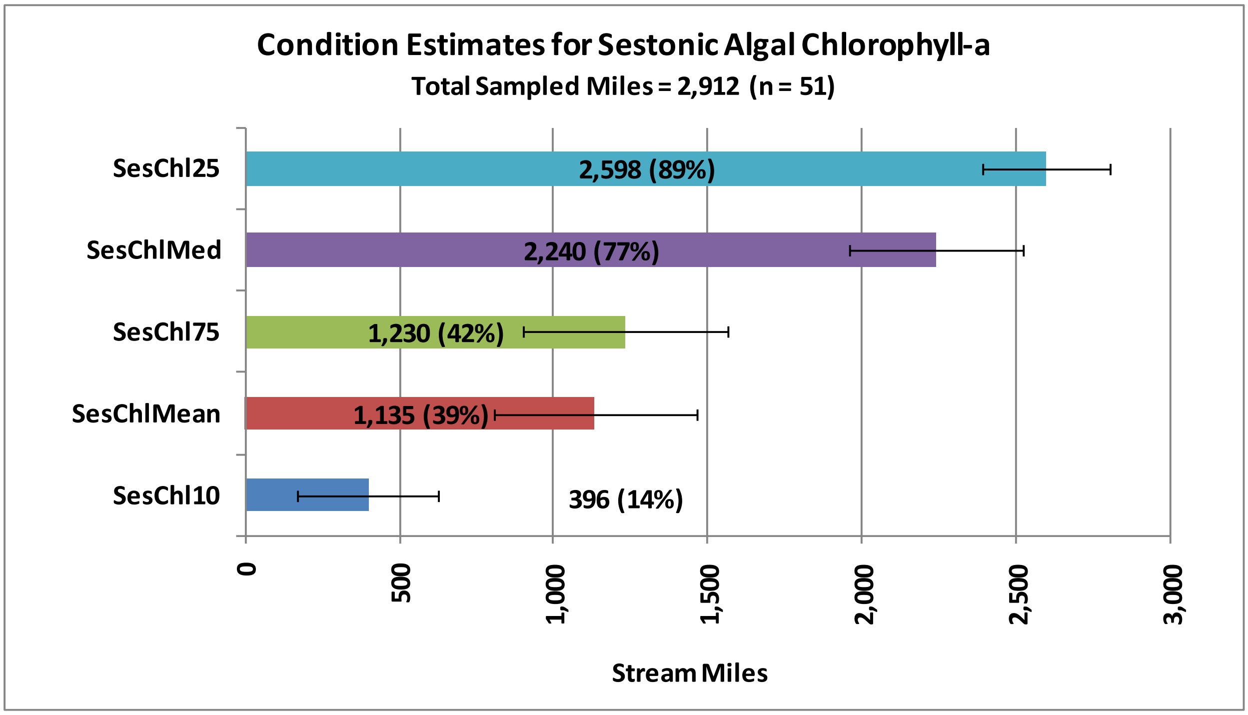
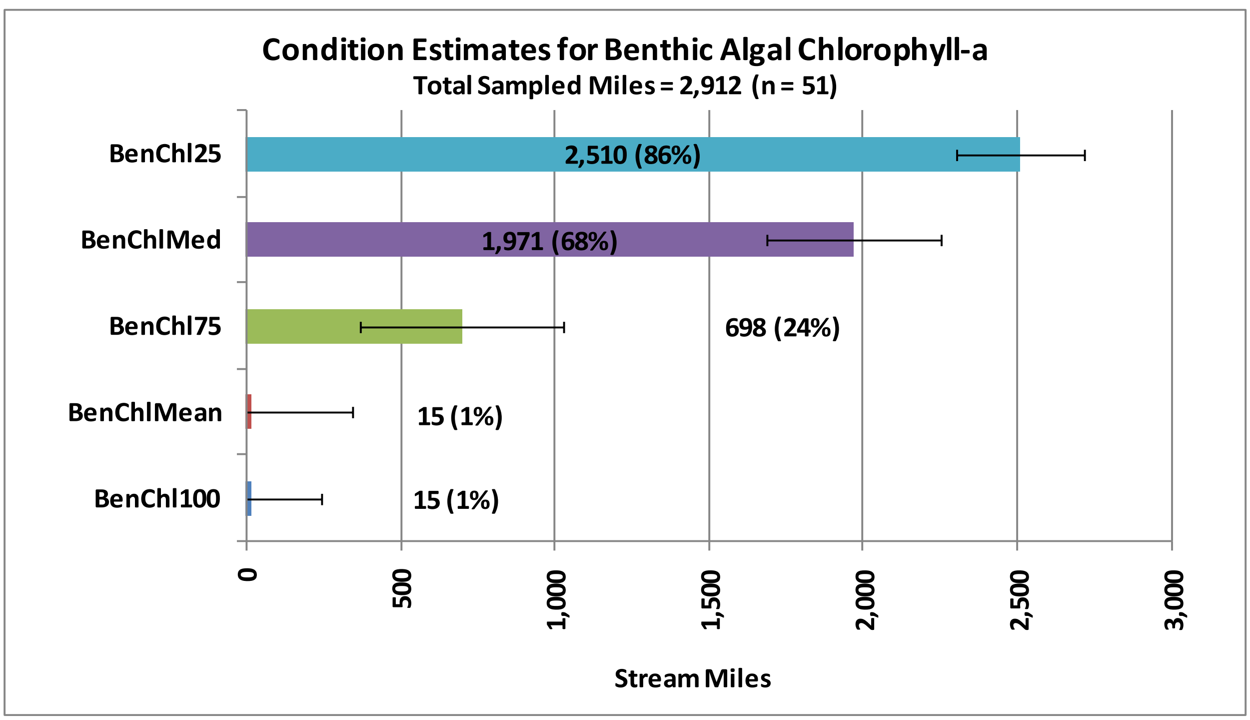


Figure 10. Benthic algal chlorophyll-a condition estimated for all geographic scales. Upper and lower bounds represent a 90% confidence interval. Bars represent the # of miles exceeding the respective chlorophyll-a screening level.



Stressor Methodology

During each visit both nutrient and general water quality parameters were collected. These included phosphorus, nitrogen, dissolved oxygen, pH, turbidity, conductivity, and water temperature. Each of these may have some effect on the conditions analyzed in the previous results section. This effect can lead to decreased biological integrity (e.g., the effect of low dissolved oxygen on fish condition) or may be responsible for the increase in a negative condition (e.g., the effect of total phosphorus on algal biomass concentration). Quantifying stressor extent is important for a variety of reasons including development and refinement of water quality screening levels and criteria, location of hotspots, and understanding the cause and effect relationship between stressors and indicators of biological integrity and human health concerns. The following analyses compare these parameters to a variety of criteria and screening levels. Weighted extent estimates of exceedances are then developed for the population.

Analysis of Nutrient Stressors

Nutrient stressors include measures of total phosphorus, total nitrogen (nitrate + nitrite + total Kjeldahl nitrogen), and available nitrogen (nitrate + nitrite). For comparison, several sources were used to determine screening levels for each parameter giving a variety of nutrient levels. The values represent regional and size variation within the Ozark Highlands Ecoregion, promulgated screening levels and criterion, and comparison values developed for various studies studying the effect on biological assemblages. All values considered are described in Table 9.

Nutrient screening levels and the and Oklahoma Scenic Rivers total phosphorus criterion are housed under the Aesthetics beneficial use in USAP (OWRB, 2008b) and the OWQS (OWRB, 2007), respectively (Table 9), The Oklahoma USAP has screening limits for both nitrogen (4.65 mg/L) and phosphorus (0.24 mg/L), which are based upon Strahler order and gradient. Although the nitrogen limits are for nitrate/nitrite, the following analyses will use the screening levels to compare to total nitrogen and available nitrogen. Additionally, a total phosphorus criterion (OWQSTP) of 0.037 mg/L was promulgated into the OWQS, in 2003. Although the criterion relates only to scenic rivers (e.g., the Illinois River, Barren Fork Creek, and Flint Creek), it is used as a general screening level for all study sites, in an effort at both consistency and site comparability.

Four different nutrient screening levels have been developed and/or published based upon available data from the Ozark Highlands Omernick Level III Ecoregion (Table 9) (Omernik, 1987; Woods, et al., 2005). First, statewide nutrient screening levels were developed by the OCC for use in the Rotating Basin Monitoring Program as well as for implementation efforts (OCC, 2005b). The values represent the mean of all data collected at high quality sites. Likewise, the USEPA developed proposed regional nutrient criteria based on Omernik Level III Ecoregions (Omernik, 1987), which represent the 25th percentile of data from a variety of sources (USEPA, 2000). Additionally, the USEPA developed total phosphorus and total nitrogen screening levels for use in the 2004 National Streams Assessment (Herlihy and Sifneos, 2008; USEPA, 2006). These values reflect the 75th percentile of data from least-impacted study sites. Lastly, period of record data from a variety of sources, including the OWRB, OCC, United States Geological Survey, and the Oklahoma State Department of Health (OSDH), were evaluated specifically for this study (OWRB, 2010b; OCC, 2010; USGS, 2010; ODEQ, 2010). Based on quartile distributions, screening levels were established at both the median and 25th percentile for total phosphorus, total nitrogen, and available nitrogen for small (Strahler Order < 3), medium (Strahler Order 4-6), and large (Strahler Order > 6) stream reaches. A summary of the data is in Table 10.

Finally, several studies have investigated the relationship of nutrients to various biotic assemblages including algae, fish, and macroinvertebrates (Table 9). Dodds et al. (1998) investigated the differences in algal productivity between oligotrophic and mesotrophic temperate streams. A number of studies have also characterized nutrient concentrations across a geographical variety of streams and assigned "reference" values based for various regions including the Ozarks (Clark et al., 2000; Smith et al., 2003). Lastly, nutrient indices have been developed to investigate biotic assemblages in relationship to nutrient enrichment (Smith et al., 2007; Justus et al., 2010).

Weighted extents of all general water quality stressors are illustrated Figures 11, 12, and 13. Stressor extents were calculated using final adjusted weights, which are based upon an individual site's stream miles in relation to the evaluated and sampled populations. Several patterns are discernible from the data. First, the USEPA regional criteria are exceeded over 95-100% of stream miles, while the USAP values are exceeded in 0-1% of stream miles. In both instances, these stressor sets may lose predictive capacity because neither are sensitive enough to discern between high and low quality sites. Second, both historically based data and other stressors (e.g., Oklahoma regional screening limits and the OWQS phosphorus criterion) will likely have good predictive capability. Depending upon the parameter, stressor extents range from the low 20% to upper 70% range.

Table 9. Potential nutrient stressors related to biological condition.

Condition Screening Limit	Condition Screening Limit Description	Stressor Value (mg/L)
EPARegTP	USEPA Regional Total Phosphorus Screening Limit	0.007
NITP	Nutrient Index for Low-Level Nutrient Enriched Ozark Streams-Total Phosphorus	0.018
DoddsTP	Total Phosphorus Corresponding to Oligotrophic Streams (Dodds)	0.025
OWQSTP	OWQS Scenic River Total Phosphorus Criterion	0.037
HistTP25	Ozark Highlands Total Phosphorus Historical Data--25th percentile	see Table 10
HistTPMed	Ozark Highlands Total Phosphorus Historical Data--Median	see Table 10
OKRegTP	OK Regional Total Phosphorus Screening Limit	0.070
USAPTP	USAP Total Phosphorus Screening Limit	0.240 (<3)/1.0 (>3)
EPARegTN	USEPA Regional Total Nitrogen Screening Limit	0.289
NSATN	USEPA Nationa Streams Assessment p75 Least Impaired Sites for Total Nitrogen	0.310
NITN	Nutrient Index for Low-Level Nutrient Enriched Ozark Streams-Total Nitrogen	0.400
DoddsTN	Total Nitrogen Corresponding to Oligotrophic Streams (Dodds)	0.700
HistTN25	Ozark Highlands Total Nitrogen Historical Data--25th percentile	see Table 10
HistTNMed	Ozark Highlands Total Nitrogen Historical Data--Median	see Table 10
OKRegTN	OK Regional Total Nitrogen Screening Limit	1.500
USAPTN	USAP Total Nitrogen Screening Limit	4.95 (<3)/4.65 (>3)
EPARegAN	USEPA Regional Available Nitrogen Screening Limit	0.239
HistAN25	Ozark Highlands Available Nitrogen Historical Data--25th percentile	see Table 10
HistANMed	Ozark Highlands Available Nitrogen Historical Data--Median	see Table 10
OKRegAN	OK Regional Available Nitrogen Screening Limit	1.000
USAPAN	USEPA Regional Available Nitrogen Screening Limit	4.95 (<3)/4.65 (>3)

Table 10. Summary of historical nutrient data used to set certain levels for nutrient stressors.

Variable	Strahler Order	n	Historical Mean	Historical p25	Historical Median	Historical p75
Total Nitrogen	<4	1467	2.685	1.120	2.233	3.380
	>3	1186	2.328	1.290	2.129	3.073
	>6	1264	2.106	1.400	2.070	2.710
Available Nitrogen	<4	1468	2.392	0.840	2.000	3.118
	>3	1186	1.986	0.960	1.760	2.700
	>6	1264	1.592	0.930	1.599	2.138
Total Phosphorus	<4	2120	0.697	0.022	0.059	0.169
	>3	1709	0.139	0.034	0.084	0.172
	>6	2367	0.161	0.060	0.110	0.200

Figure 11. Extent estimates of stressors related to total phosphorus concentrations. Upper and lower bounds represent a 90% confidence interval. (Refer to Table 9 for stressor descriptions.)

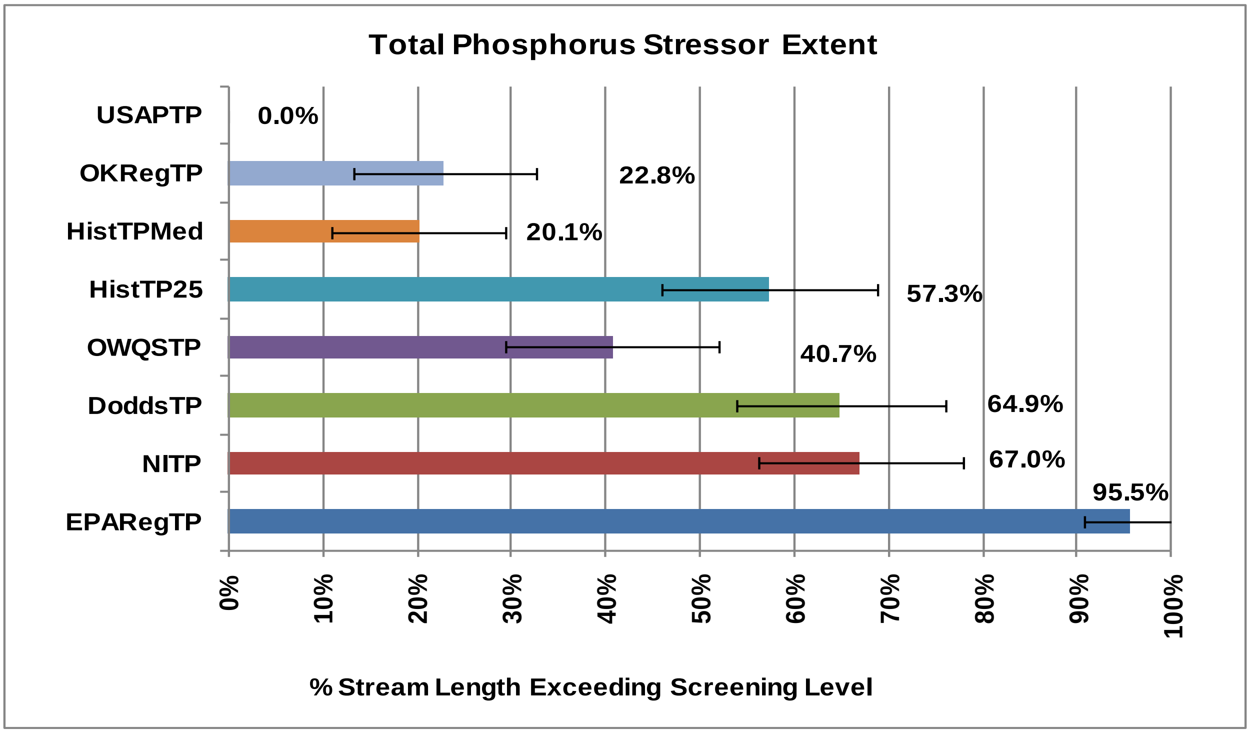


Figure 12. Extent estimates of stressors related to total nitrogen concentrations. Upper and lower bounds represent a 90% confidence interval. (Refer to Table 9 for stressor descriptions.)

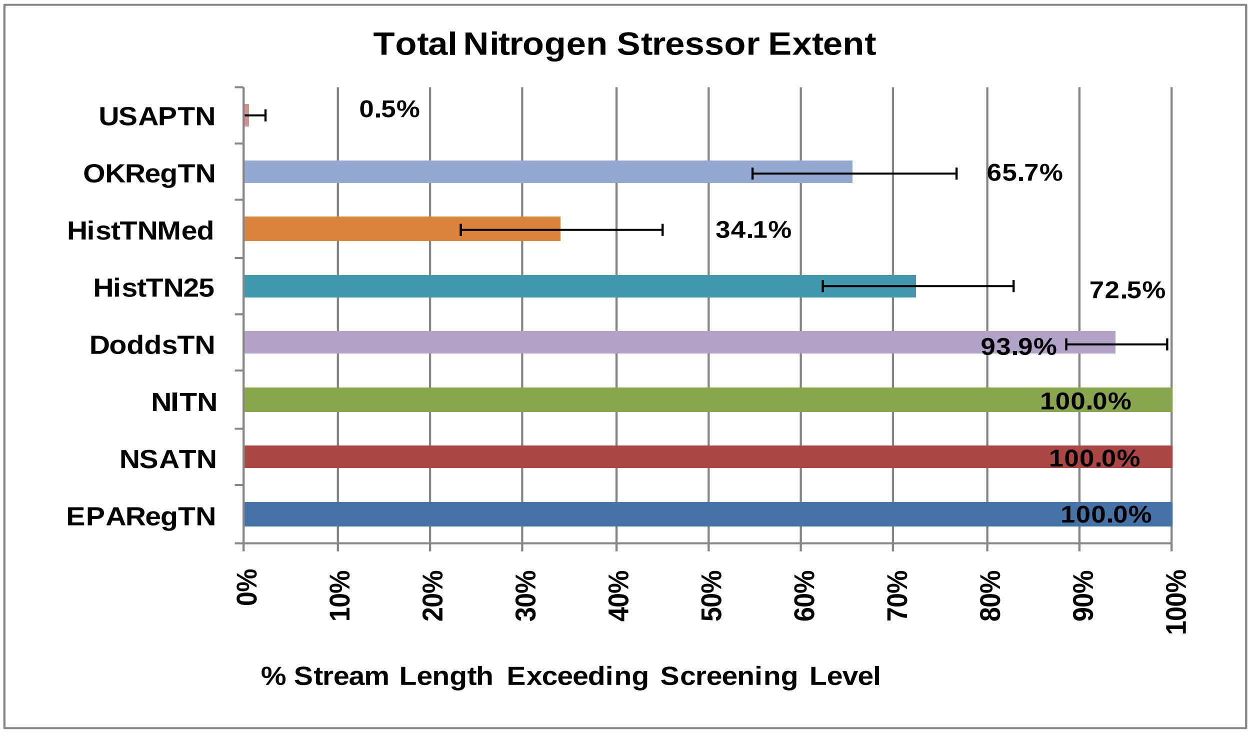
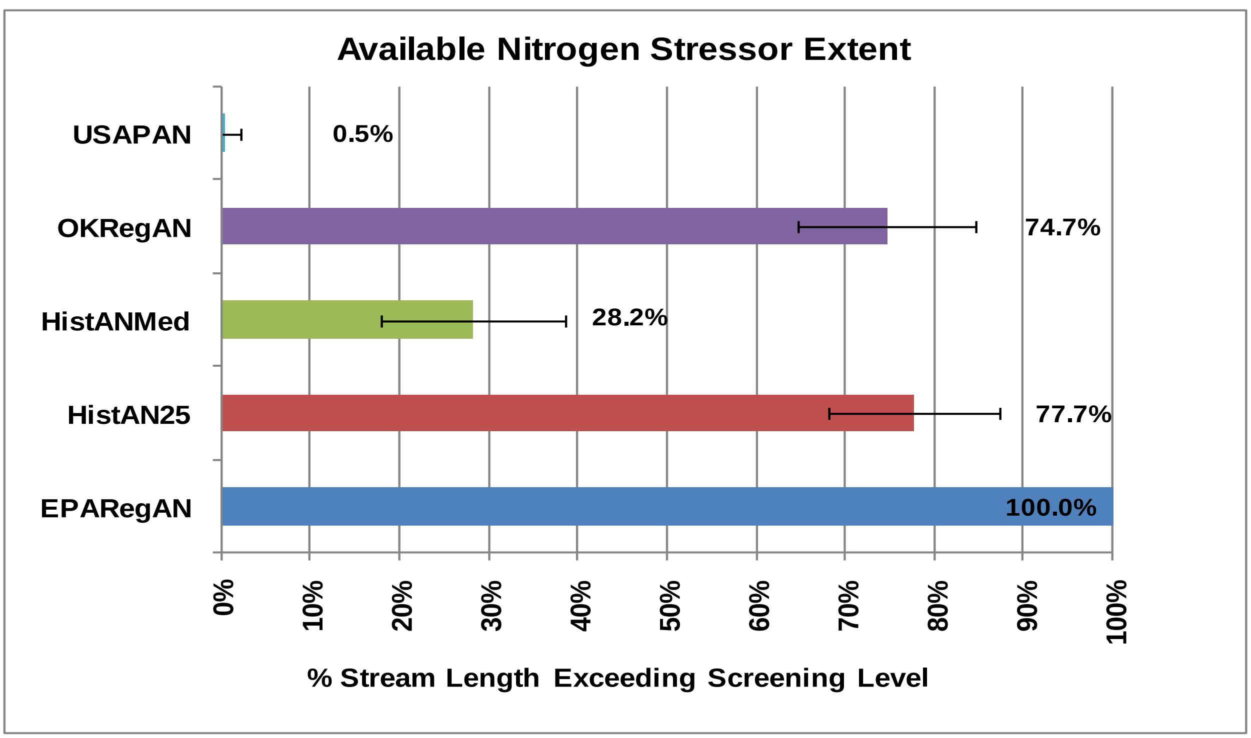


Figure 13. Estimated extents of stressors related to total nitrogen concentrations. Upper and lower bounds represent a 90% confidence interval. (Refer to Table 9 for stressor descriptions.)



Analysis of General Water Quality Stressors

General water quality stressors represent a diverse group of parameters (Table 11). *In situ* parameters include pH, dissolved oxygen, turbidity, water temperature, and conductivity. For comparison, several sources were used to determine screening levels for each parameter giving a variety of nutrient levels. The values represent variation within the Ozark Highlands Ecoregion as well as promulgated screening levels and criterion.

Criteria for each of these are housed under the Fish and Wildlife Propagation beneficial use of the OWQS (OWRB, 2007), and protocols for assessment are included in Oklahoma's USAP (OWRB, 2008b) (Table 11). For pH, the OWQS gives a statewide range of 6.5-9.0 standard units statewide. Dissolved oxygen (DO) criteria are varied based on aquatic life tiers and time of year. Screening levels housed in the USAP are based on a 1 mg/L excursion from criteria. With the lower value being applicable during warmer months, warm water communities vary between 4 and 5 mg/L, cool water communities between 5 and 6 mg/L, and habitat limited communities between 3 and 4 mg/L. Turbidity and water temperature criteria are based upon aquatic life tiers. The criteria are 50 NTU and 32.2 ^{o}C for warm water and habitat limited communities and 10 NTU and 28.8^{o}C for cool water communities. Conductivity is not specifically listed in the OWQS. However, total dissolved solids (TDS) criteria for assessment of the Agriculture beneficial use are housed in Appendix F of OWQS (OWRB, 2007), and protocols for assessment of the use are included in Oklahoma's USAP (OWRB, 2008b). The criteria are based upon 6-digit management segments, as defined in Appendix A of OWQS, and were developed from data at one or more stations located in each 6-digit segment. They include both a mean standard and sample standard for each segment. Because the sample standard is compared to single samples as defined by the USAP, it is used to determine extent estimates. Furthermore, so that conductivity may be used, the TDS criterion was translated in conductivity using a conversion factor (1.65) that is commonly accepted and relevant to conductivity/TDS ratios in the Ozark Highlands.

Table 11. Potential general water quality stressors related to biological condition.

Condition Screening Limit	Condition Screening Limit Description	Stressor Value
DOSatP75	Ozark Highlands DO percent saturation Historical Data--75th percentile	115.0 percent
DOConcWQS	OWQS DO Criterion	6.0 mg/L
DOConcP25	Ozark Highlands DO Historical Data--25th percentile	8.0 mg/L
pHP25	Ozark Highlands pH Historical Data--25th percentile	7.5 units
CondOWQS	OWQS Conductivity Criterion (based on TDS)	260 uS/cm
TuMedian	Ozark Highlands Turbidity Historical Data--Median	1.3 NTU
TuOWQS	OWQS Turbidity Criterion	10.0 NTU
TempOWQS	OWQS Temperature Criterion	28.8^{o}C
TempMed	Ozark Highlands Water Temperature Historical Data--Median	21.2^{o}C

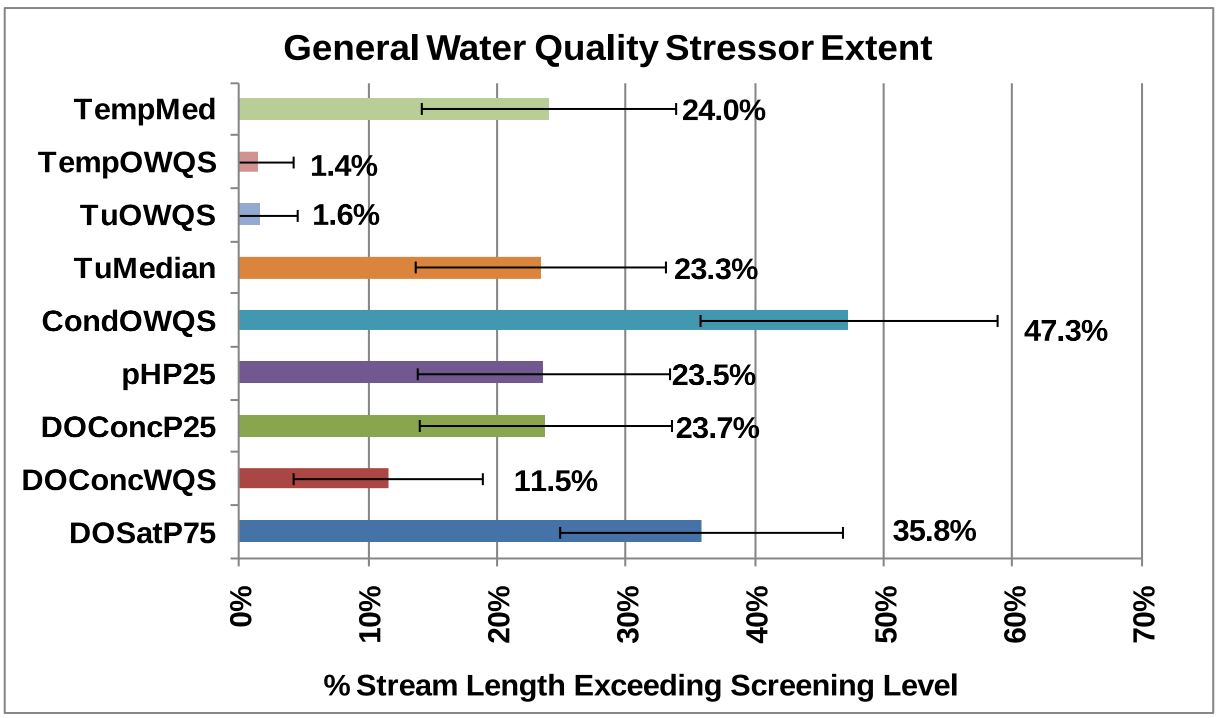
Several additional screening levels were developed using published data from the Ozark Highlands Omernick Level III Ecoregion (Table 11). As with nutrients, period of record data from a variety of sources, including the OWRB, OCC, United States Geological Survey (USGS), and the Oklahoma State Department of Health (OSDH), were evaluated specifically for this study (OWRB, 2010b; OCC, 2010; USGS, 2010; ODEQ, 2010). Based on quartile distributions, screening levels were established at various quartiles for dissolved oxygen percent saturation, dissolved oxygen, turbidity, and water temperature. Summary of data is in Table 12 and parameters are described in Table 11.

Table 12. Summary of historical general water quality data used to set certain levels for stressors.

Variable	n	Historical Mean	Historical p25	Historical Median	Historical p75
DO percent Saturation	197	102.3	91.2	103.3	115.8
DO Concentration (mg/L)	197	9.9	8.0	9.7	11.7
pH (units)	195	7.7	7.5	7.8	8.1
Specific Conductivity (uS/cm)	196	252.2	217.1	246.5	286.1
Turbidity (NTU)	199	2.3	0.7	1.3	3.0
Water Temperature (°C)	197	18.0	8.7	21.2	25.6

Weighted extents of all general water quality stressors are illustrated Figure 14. Stressor extents were calculated using final adjusted weights, which are based upon an individual site's stream miles in relation to the evaluated and sampled populations. Several patterns are discernible from the data. First, screening limits based on historical data have higher extents than OWQS counterparts. Second, historically based data are seemingly valid stressors because not all stream miles are impaired, but in each case, approximately 25-50% of stream miles are above or below a screening level leading to a poor designation for the stressor. Lastly, turbidity and water temperature based on OWQS criteria perform poorly as stressors.

Figure 14. Estimated extents of stressors related to general water quality variables. Upper and lower bounds represent a 90% confidence interval. (Refer to Table 11 for stressor descriptions.)



Analysis of Habitat Stressors

Habitat stressors include total habitat score, several individual habitat metrics, and an index for sedimentation (Table 13). A total habitat score (HTPts) was calculated for each site based on habitat metrics in Oklahoma's Rapid Bioassessment Protocol (OWRB, 1999, 2005a). The assessment consists of a variety of measures including flow, stream width and depth, substrates, embeddedness, habitat classification (i.e., pool, run, and riffle), fish cover, presence of point bars, erosion, and riparian structure. Metrics are scored based on predetermined ranges and a total score is obtained. Additionally, several metrics used to calculate HTPts were included as stressors. Oklahoma's USAP (OWRB, 2008b) contains a protocol for determining sedimentation based upon loose bottom substrates (%LBS), embeddedness (%Emb), presence of deep pools (%DP), and presence of non-vegetated point bars (%NVPB). Screening levels for habitat scores and sedimentation metrics are determined by comparing final site scores to a percent of reference condition. The reference condition (Table 14) is derived from the habitat scores for ecoregionally based high quality sites developed by the OCC (2005a). Also, sites used to determine reference condition are required to be within 2 Strahler orders of the test stream. Finally, sedimentation is deemed to be impaired if one or more habitat metrics deviate from reference conditions. For this study, two additional stressors are included based upon sedimentation. The USAPSed1 and USAPSed2 are based upon 1 or 2 habitat metrics deviating from reference.

Table 13. Potential habitat stressors related to biological condition.

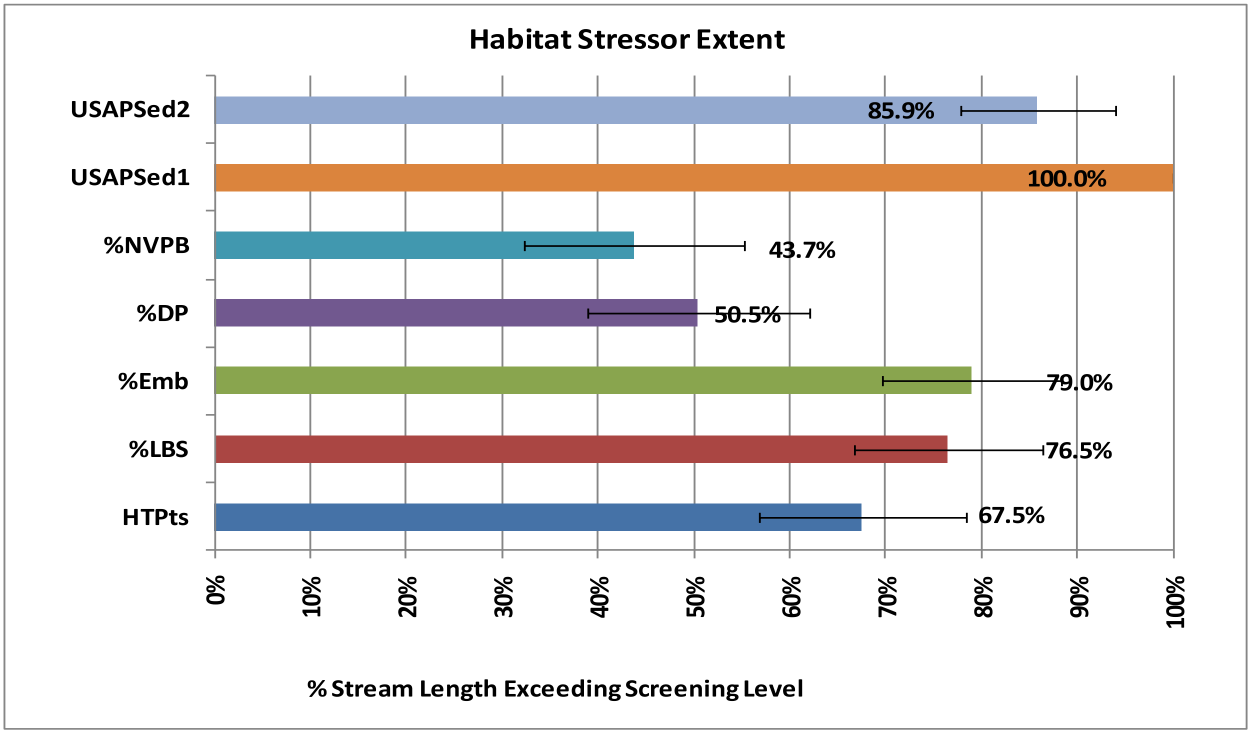
Condition Screening Limit	Condition Screening Limit Description
HTPts	Habitat total points scored from Oklahoma's Rapid Bioassessment Protocol (ORBP)
%LBS	Percent loose bed substrate metric from ORBP and used in Sediment USAP by scoring against regional reference condition
%Emb	Percent embeddedness metric from ORBP and used in Sediment USAP by scoring against regional reference condition
%DP	Percent deep pool metric from ORBP and used in Sediment USAP by scoring against regional reference condition
%NVPB	Percent non-vegetated point bar metric from ORBP and used in Sediment USAP by scoring against regional reference condition
USAPSed1	Sediment assess. prot. based on 1 of 4 metrics deviating from reference; housed in USAP
USAPSed2	Sediment assess. prot. based on 2 of 4 metrics deviating from reference; housed in USAP

Table 14. Habitat reference condition related to Strahler and high quality sites (OCC, 2004).

	by Strahler Order						
Habitat Parameter	1	2	3	4	5	6	7
Total Points	119.8	121.5	121.5	121.5	121.1	123.2	123.2
% loose bed material	3%	2%	2%	2%	2%	2%	2%
% embeddedness	12%	12%	12%	12%	12%	12%	12%
% deep pools	17%	12%	12%	12%	12%	8%	8%
% point bars	74%	65%	65%	65%	67%	57%	57%

Extent of the seven habitat stressors are illustrated by bar graphs in Figure 15. Three general patterns are noteworthy. First, generally, individual habitat parameters and total points scored are reasonable stressor extents, ranging from 44-79%. The percent loose bed sediment (77%) and embeddedness (79%) stressors may score somewhat high to be effective in determining good from poor quality sites. Second, it is expected that USAPSed1 would have a greater extent estimate than USAPSed2. However, the Sed1 extent of 100% renders it useless in distinguishing between good and poor sites. The Sed2 stressor may have some utility, however.

Figure 15. Estimated extents of stressors related to reachwide habitat. Upper and lower bounds represent a 90% confidence interval. (Refer to Table 13 for stressor descriptions.)



Relative Risk Methodology

The concept of using relative risk to develop a relationship between biological condition and stressor extent was developed initially for the USEPA's National Wadeable Streams Assessment (USEPA, 2006). Van Sickle et al. (2006) drew upon a practice commonly used in medical sciences to determine the relationship of a stressor (e.g., high cholesterol) to a medical condition (e.g., heart disease). The method calculates a ratio between the number of streams with poor biological condition/high stressor concentration and those with poor biological condition/low stressor concentration (Van Sickle, 2004). If the ratio is above 1, it indicates that biological condition is likely affected by high stressor concentrations (i.e., concentrations above a preset level). As the ratio increases beyond 1, the relative risk of the stressor increases.

The following analyses include a comparison of a variety of stressors to biological conditions for fish, macroinvertebrates, and algal biomass by using a binomial designation of good/poor for condition and high/low for stressor concentration. These binomial designations are then placed in a two-way contingency table to determine relative risk. Two initial ratios are determined. The ratio for poor condition given high stressor concentration is compared to the total number of sites having high stressor concentration, regardless of condition. Likewise, the ratio for poor condition given low stressor concentration is compared to the total number of sites having low stressor concentrations, regardless of condition. These two ratios are then used to calculate relative risk.

Relative risk results will be analyzed in several ways. First of all, significant relative risk will be determined by first determining if the resulting value is greater than one, and secondly, using a 90% confidence interval to establish significance. Although a 95% confidence level is generally more accepted, the 90% level is valid for water quality studies (Helsel an Hirsch, 1995) because data are affected by a variety of uncontrollable factors. Secondly, the magnitude of the upper confidence bound will be considered. The upper confidence bound increases as the number of sites with good condition and good water quality increase. Recognition of this is important to understanding the relationships of stressor extent to biological condition. Also, relative risks above 1 are often not significant when confidence intervals are applied. Considering the upper bound does not completely exclude certain hidden values that may exist in the analysis.

Relative Risk to Fish Biological Condition

To determine relative risk for fish biological condition, the OKFIBI and OCCFIBI were combined to produce a final fish condition classification of good or poor for all sites. For the OCCFIBI, poor condition was set at a percent of reference score of 75, which is the breakpoint between the good and fair classification. The final breakdown was 35 sites ranked as good and 16 sites ranked as poor. To determine binomial condition, the following rules were used:

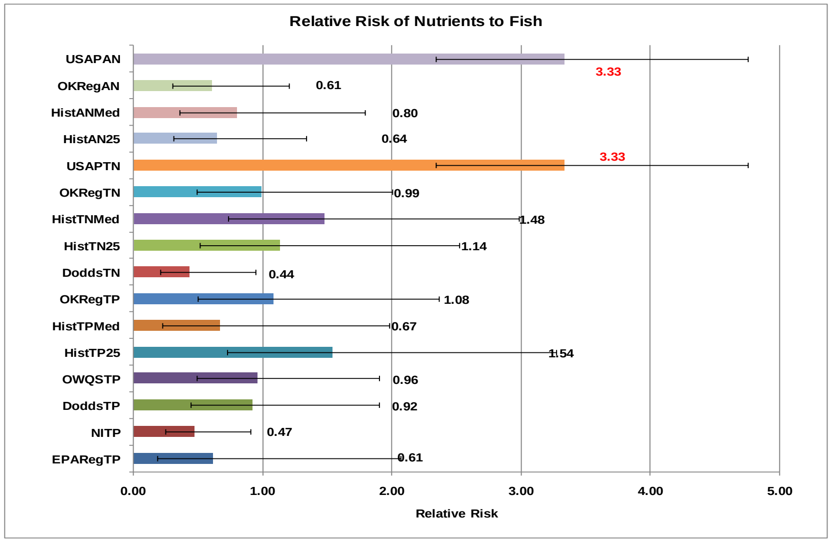
1. If the OKFIBI is supporting and the OCCFIBI final percent of reference score is greater than 74, then the site is considered "good";
2. If the OKFIBI is not supporting and the OCCFIBI final percent of reference score is less than 75, then the site is considered "poor";
3. If the OKFIBI is undetermined and the OCCFIBI final percent of reference score is greater than 74, then the site is considered "good";
4. If the OKFIBI is undetermined and the OCCFIBI final percent of reference score is less than 75, then the site is considered "poor"; and,
5. If the OKFIBI and OCCFIBI give disparate results, consideration is given to how close the numerical score was for each IBI was in relation to change of classification.

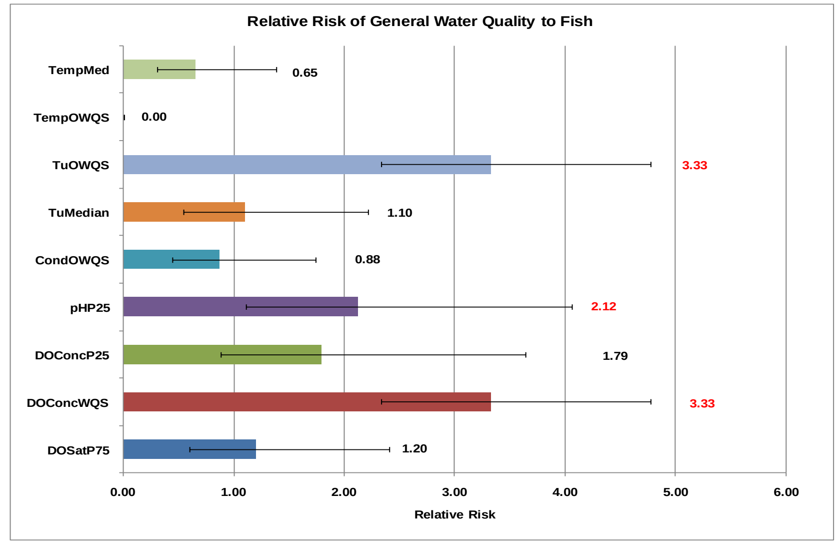
Relative risk for nutrients, general water quality, and habitat to fish condition are illustrated in Figure 16. For nutrients, the only significant risks are USAPTN and USAPAN which are likely to affect fish 3.33 times more when above the screening level. It should be noted that only one nutrient value was poor when considering the USAP screening level. Several other nutrient-related risks exceed 1.0, including HistTP25, OKRegTP, HistTN25, and the HistTNMed. However, in each case, the lower bound of the confidence interval is below a relative risk of 1.0, indicating that the risks are not significant.

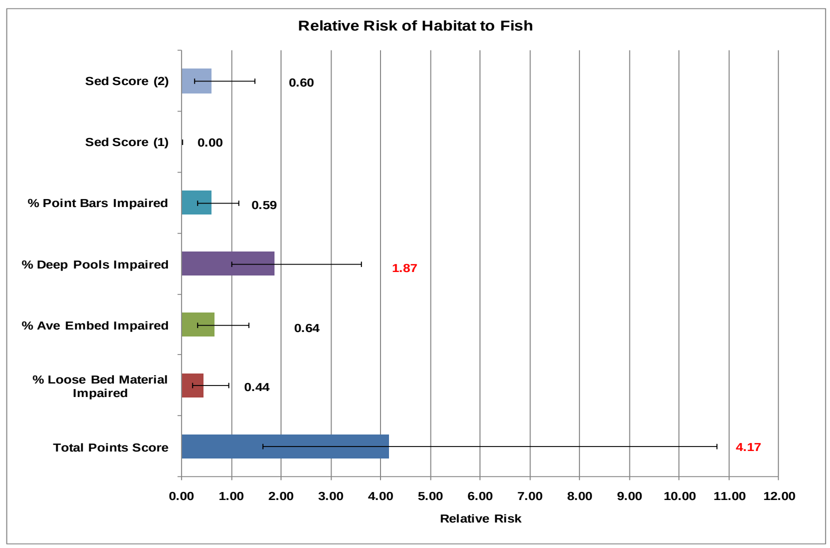
For general water quality variables, significant risks are associated with water quality standards for turbidity and dissolved oxygen (Figure 16). When site measurements are above turbidity of 10 or below a DO of 6.0 mg/L, they are likely to affect fish 3.33 times more when above the screening level. As with USAP nitrogen, it should be noted that only one site was poor when considering these criteria screening level. Likewise, when pH is below the historical 25^{th} percentile, fish condition is 2.12 times more likely to be poor. Several other nutrient-related risks exceed 1.0, including HistTuMed, HistDOCon25, and HistDOSat75. DOConcHistTP25. However, in each case, the lower bound of the confidence interval is below a relative risk of 1.0, indicating that the risks are not significant.

Several habitat-related measurements demonstrated significant relative risks including the total points score and percent deep pools (Figure 16). When total points are below the applicable reference score, fish condition is 4.14 times more likely to be poor. Similarly, fish condition is 1.87 times more likely to be poor when the percentage of deep pools is below reference. No other habitat measurement or total score for sedimentation had relative risks exceeding the 1.0 baseline.

Figure 16. Relative risk of nutrient, general water quality and habitat affect on fish condition. Red values indicate significant relative risk. Upper and lower bounds represent a 90% confidence interval. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)







Relative Risk to Macroinvertebrate Biological Condition

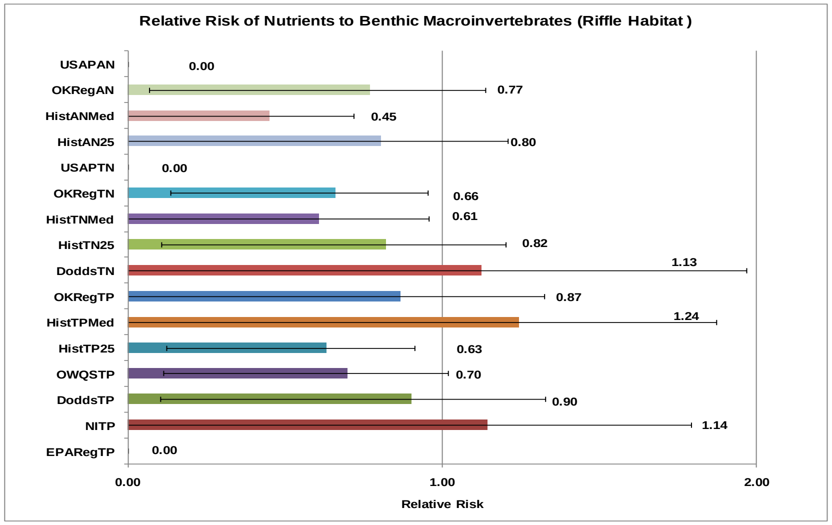
As with fish, relative risk to macroinvertebrate condition is considered for a variety of stressors. Relative risk values were developed for both riffle and combined habitat condition. To create a good/poor classification for macroinvertebrate condition, a percent of reference score of 75 was used. The final breakdown for riffle habitat was 32 sites ranked as good with 19 sites ranked as poor. The final breakdown for combined habitat was nearly equal between the two categories with 27 sites ranked as good with 24 sites ranked as poor. Relative risk for nutrients, general water quality, and habitat to benthic macroinvertebrate riffle and combined habitat condition are illustrated in Figures 17 and 18, respectively.

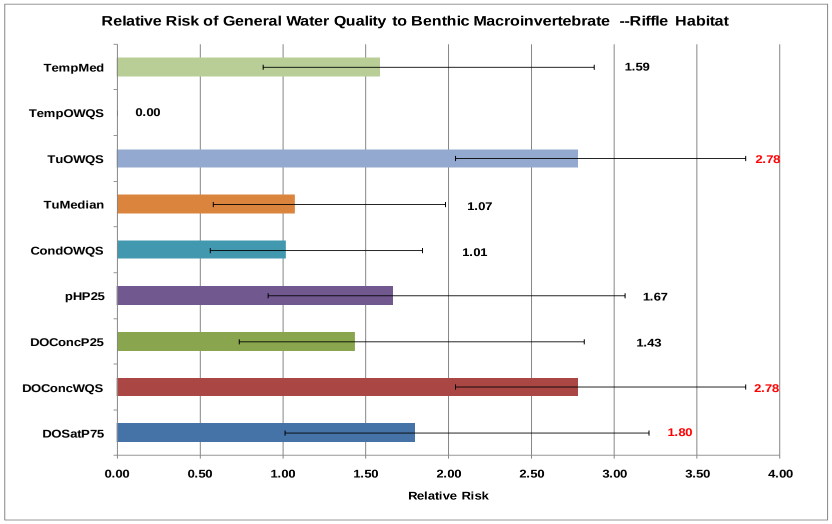
Nutrient-related relative risk to both riffle (Figure 17) and combined habitat (Figure 18) condition is non-significant for all stressors. For both representative conditions, historical TP median and NITP have relative risks above 1.0, but in each case the risk is not significant. Additionally, non-significant relative risks exceeding 1.0 were observed for DoddsTN in relation to riffle habitat and a variety of total phosphorus, total nitrogen, and available nitrogen screening levels when considering combined habitat condition.

General water quality demonstrates relative risk to macroinvertebrate condition for both turbidity and dissolved oxygen (Figures 17 and 18). When site turbidity averages are greater than 10 NTU or DO is less than 6 mg/L, riffle and combined habitat conditions are 2.78 and 2.17 times more likely to be poor. Likewise, when DO percent saturation exceeds the historical 75th percentile, riffle condition is 1.80 times more likely to be poor. When comparing riffle condition to all other stressors except the temperature standard, relative risks are greater than 1.0 but are not significant. For the combined habitat condition, screening limits related to historical DO percent saturation and concentration, pH, and turbidity as well as conductivity related criteria demonstrate relative risks greater than 1.0 but fail to be significant when lower confidence bounds are calculated.

Habitat stressors have limited significant relationship in terms of risk to macroinvertebrate condition (Figures 17 and 18). As with nutrients, no significant relative risks are related to combined habitat condition. Conversely, riffles are 1.75 times more likely to be poor when the percentage of deep pools is below the reference condition. However, no other habitat stressor demonstrates significant relative risk although each is at 1.0 or exceeding. Sediment scores show no relationship to macroinvertebrate condition.

Figure 17. Relative risk of nutrient, water quality, and habitat related to macroinvertebrate—riffle condition. Upper and lower bounds represent 90% confidence interval. Red values indicate significant relative risk. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)





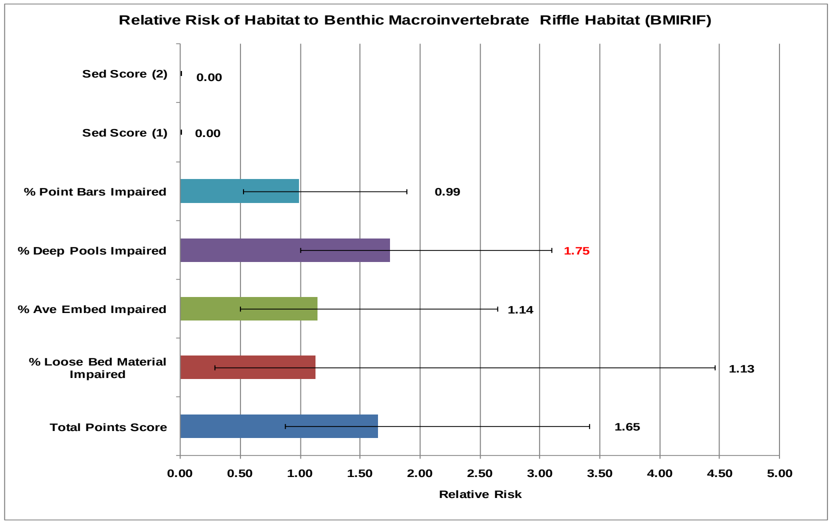
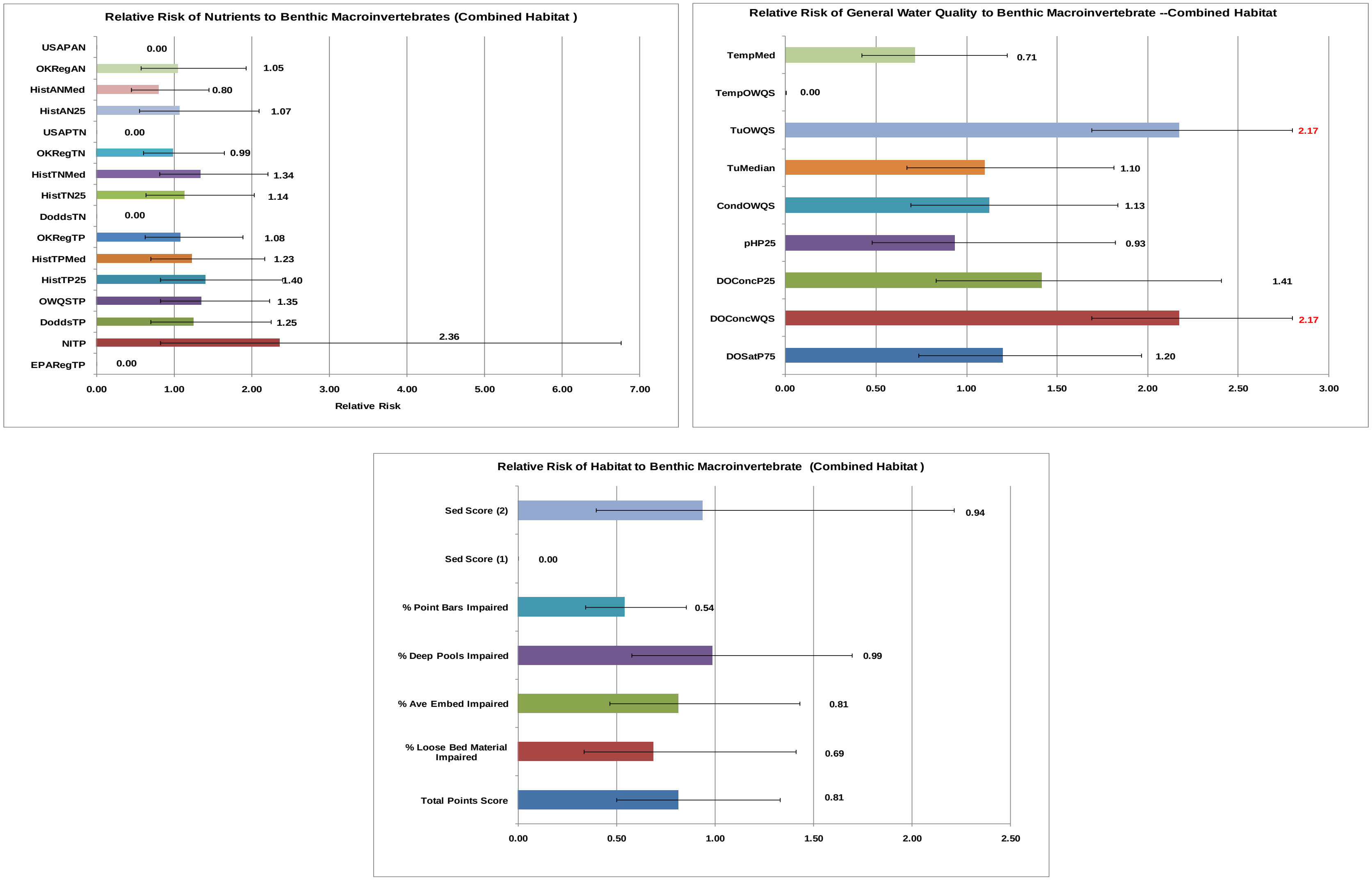


Figure 18. Relative risk of nutrient, water quality, and habitat related to macroinvertebrate—combined habitat condition. Upper and lower bounds represent 90% confidence interval. Red values indicate significant relative risk. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)



Relative Risk to Sestonic Algal Biomass

Relative risk to sestonic algal condition is considered for all nutrient, general water quality and habitat stressors. Condition for sestonic algal biomass was based upon whether a particular sample was above or below a variety of screening levels for chlorophyll-a. These include the 10 mg/m^3 sensitive water supply chlorophyll-a criterion as well as the mean, median, 75th and 25th percentiles of historical chlorophyll-a data. Risk graphs are included following the analyses and are arranged by chlorophyll-a screening level.

Stressor relative risks related to the sensitive water supply criterion are depicted in Figure 19. No nutrient stressor demonstrates significant risk to algal biomass. Several stressors including the historical total phosphorus 25th percentile, the total phosphorus and nitrogen medians, and the Oklahoma regional total phosphorus level have relative risks greater than 1.0 but are not significant. Likewise, no habitat stressor is significantly related to algal biomass at 10 mg/m^3. Total points and % deep pools have risks greater than 1.0, but like many nutrient stressors are not significant. However, when considering general water quality parameters, algal biomass condition is 25.0 times more likely to be poor when turbidity is above or dissolved oxygen is below water quality criteria standards. Similarly, condition is 10.75 times more likely to be poor when dissolved oxygen is below the historical 25th percentile. The historical 25th percentile for pH and the median temperature are above relative risks of 1.0 but are not significant.

Stressor relative risks related to the historical chlorophyll-a mean are depicted in Figure 20. Like the sensitive water supply criterion, no nutrient habitat stressor demonstrates significant risk to algal biomass. Several stressors including the historical total nitrogen 25th percentile, the Oklahoma regional total phosphorus level, and percent deep pools have risk ratios greater than 1.0 but are not significant. However, when considering general water quality parameters, algal biomass condition is 7.14 times more likely to be poor when turbidity or temperature is above or dissolved oxygen is below water quality criteria standards. All other stressors except the historical 25th percentile for pH are above relative risks of 1.0 but are not significant.

Stressor relative risks related to the historical chlorophyll-a 75th percentile are depicted in Figure 21. Like the sensitive water supply criterion, numerous total phosphorus and nitrogen nutrient stressors demonstrate non-significant risks greater than 1.0 to algal biomass, including the scenic river total phosphorus criterion. However, algal biomass condition is 2.71 times more likely to be poor when total phosphorus is greater than Oklahoma regional total phosphorus level. When considering general water quality stressors, algal biomass condition is 5.0 times more likely to be poor when turbidity or temperature is above or dissolved oxygen is below water quality criteria standards. Likewise, it is 5.1 times more likely to be poor when conductivity is above the water quality criterion. Various other water quality stressors, including historical dissolved oxygen concentration and percent saturation, turbidity and temperature are above relative risks of 1.0 but are not significant. No habitat stressor is significantly related to algal biomass at the historical 75th percentile of chlorophyll-a. Total points and % deep pools have risks greater than 1.0, but are not significant.

Stressor relative risks related to the historical chlorophyll-a median are depicted in Figure 22. Unlike other chlorophyll-a screening levels, numerous nutrient stressors demonstrate significant risks greater than 1.0 to algal biomass, including USAP total and available nitrogen with relative risks of 1.61. Similarly, total phosphorus screening levels have significant risks greater than 1.0, including the historical median (RR = 1.56), the Oklahoma regional value (RR = 1.7), the nutrient index (RR = 3.21), and the scenic river total phosphorus criterion (RR = 1.60). Even though all other nutrient stressors are not significant, each has relative risks greater than 1.0. All general water quality stressors show risk to algal biomass condition except pH, and are significant except the historical 25th percentile for dissolved oxygen concentration. Significant risks range from 1.37 for DO saturation to 1.88 for conductivity. No habitat stressor is significantly related to algal biomass at this chlorophyll-a level. Percent embeddedness and point bars as well as the USAP for excessive sedimentation have risks greater than 1.0, but are not significant.

Lastly, algal biomass at the historical 25th percentile and stressor relative risks are depicted in Figure 23. As with the median chlorophyll-a screening biomass condition, numerous nutrient stressors demonstrate significant risks greater than 1.0 to algal biomass, including USAP total and available nitrogen with relative risks of 1.19. The same total phosphorus screening levels have significant risks greater than 1.0, including the historical median (RR = 1.24), the Oklahoma regional value (RR = 1.26), the nutrient index (RR = 1.63), and the scenic river total phosphorus criterion (RR = 1.34). Similarly, even though all other nutrient stressors are not significant, each has relative risks greater than or near to 1.0, with only certain historical total and available nitrogen as well as the USEPA regional total phosphorus stressors below a 1.0 risk ratio. Also, like the median biomass condition, all general water quality stressors show risk to algal biomass condition except pH, and are significant except the historical 25th percentile for dissolved oxygen concentration. Significant risks range from 1.19 for temperature, turbidity, and dissolved oxygen criteria to 1.32 for the historical turbidity median. In keeping with all other sestonic condition levels, no habitat stressor is significantly related to algal biomass. Percent embeddedness and point bars as well as the USAP for excessive sedimentation have risks greater than 1.0, but are not significant.

Figure 19. Relative risk of nutrient, general water quality, and habitat stressors related to sestonic algal condition at the sensitive water supply criterion for chlorophyll-a. Upper and lower bounds represent 90% confidence interval. Red values represent significant relative risks. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)

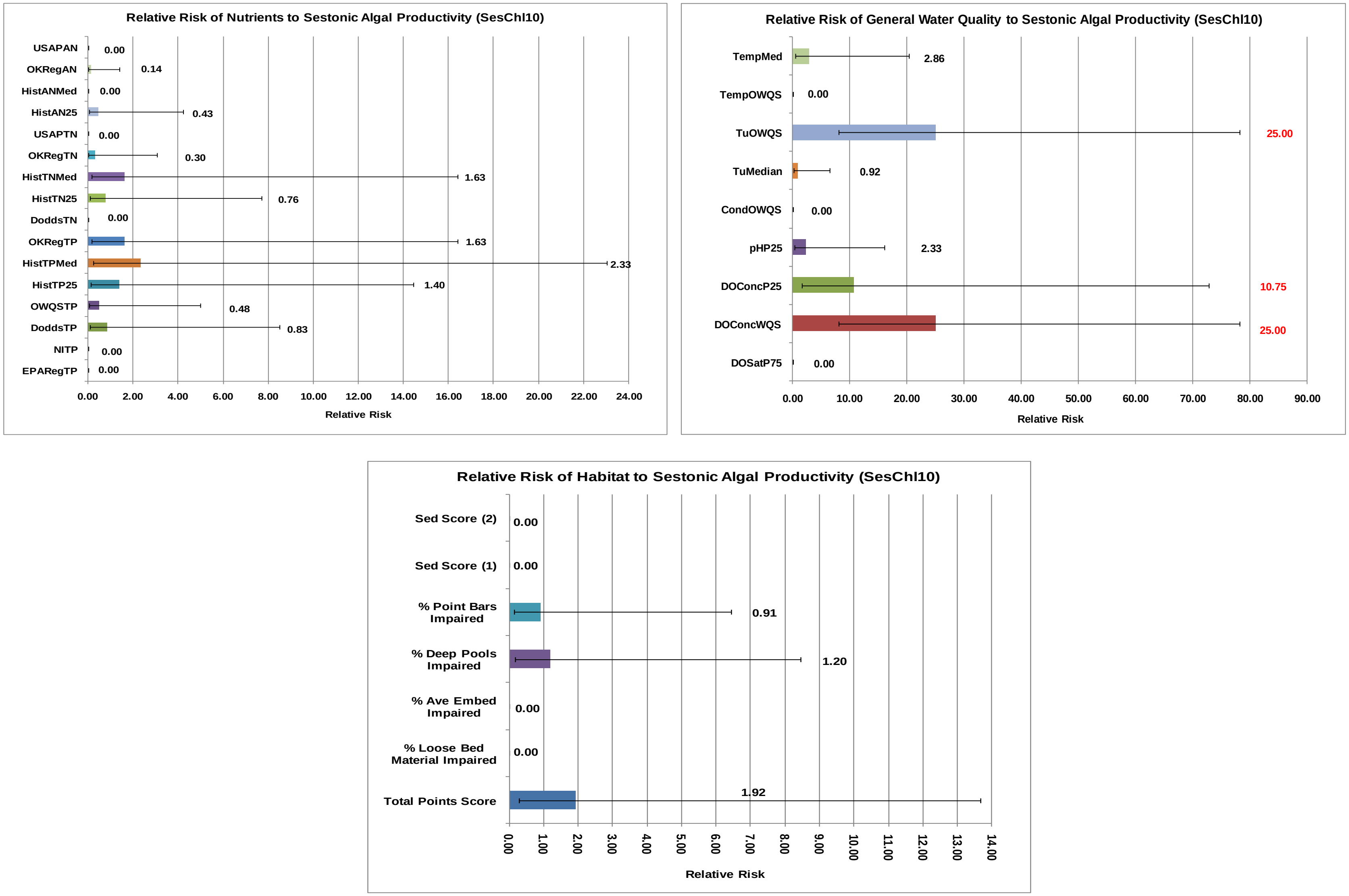
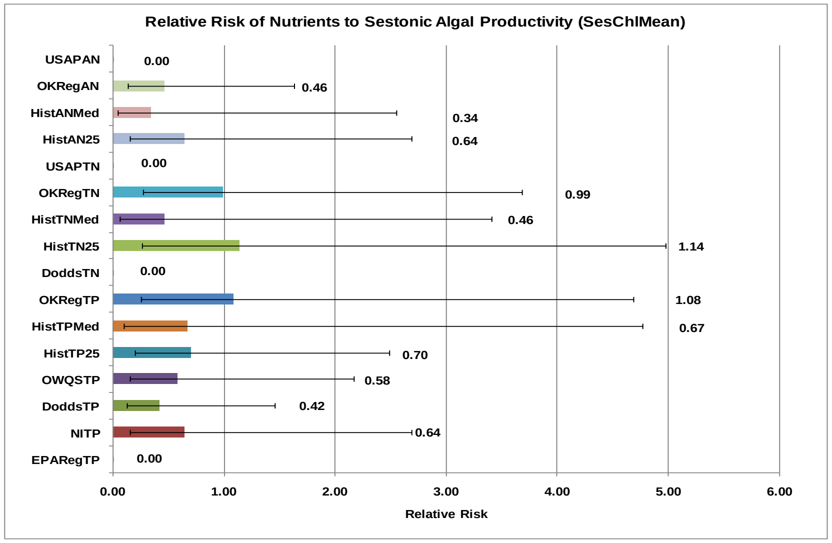
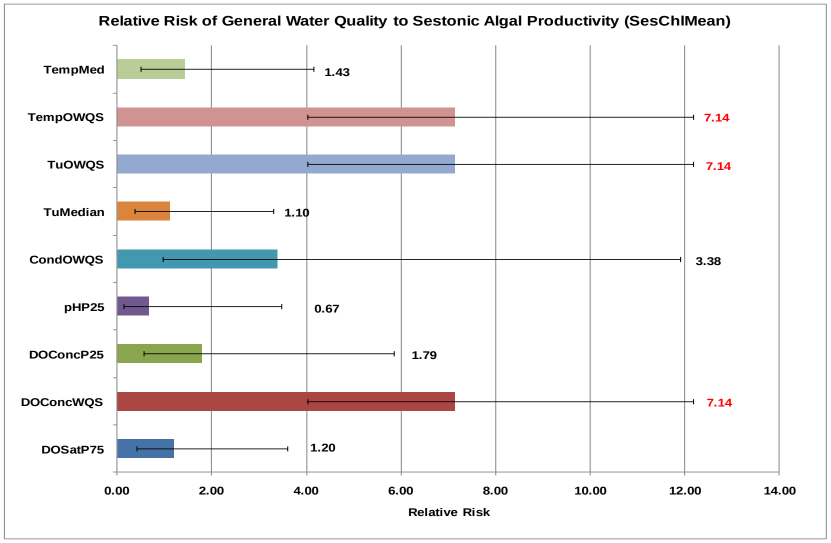


Figure 20. Relative risk of nutrient, general water quality, and habitat stressors related to sestonic algal condition at the historical mean for chlorophyll-a. Upper and lower bounds represent 90% confidence interval. Red values represent significant relative risks. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)





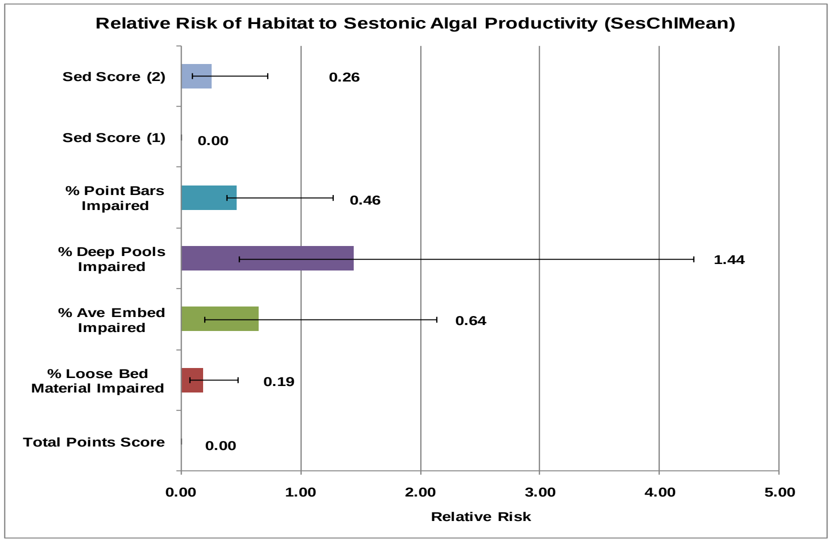
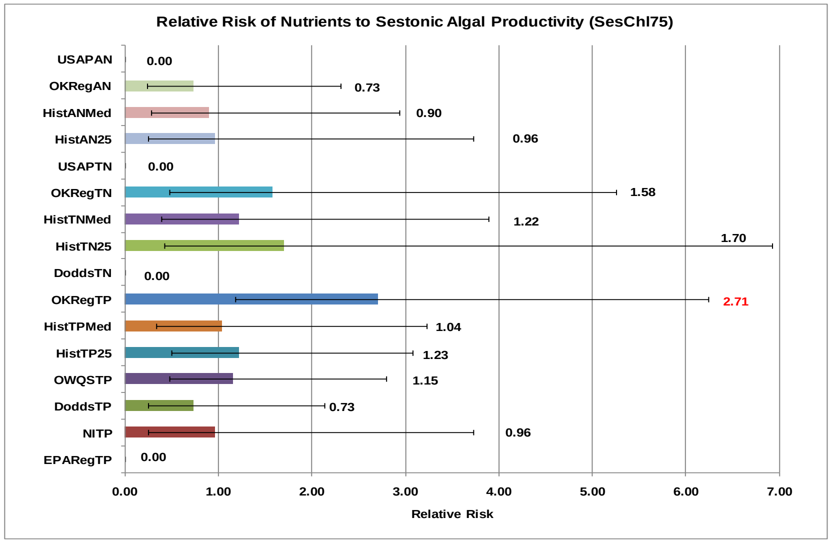
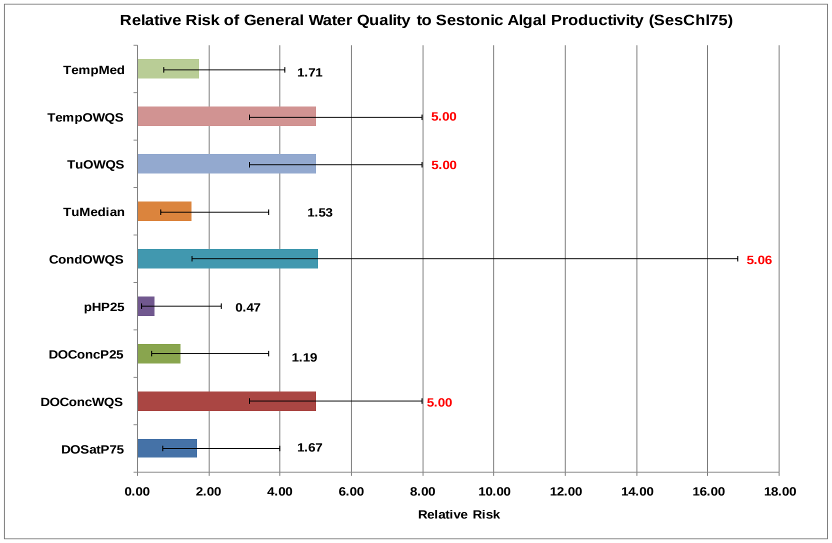


Figure 21. Relative risk of nutrient, general water quality, and habitat stressors related to sestonic algal condition at the historical 75th percentile supply criterion for chlorophyll-a. Upper and lower bounds represent 90% confidence interval. Red values represent significant relative risks. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)





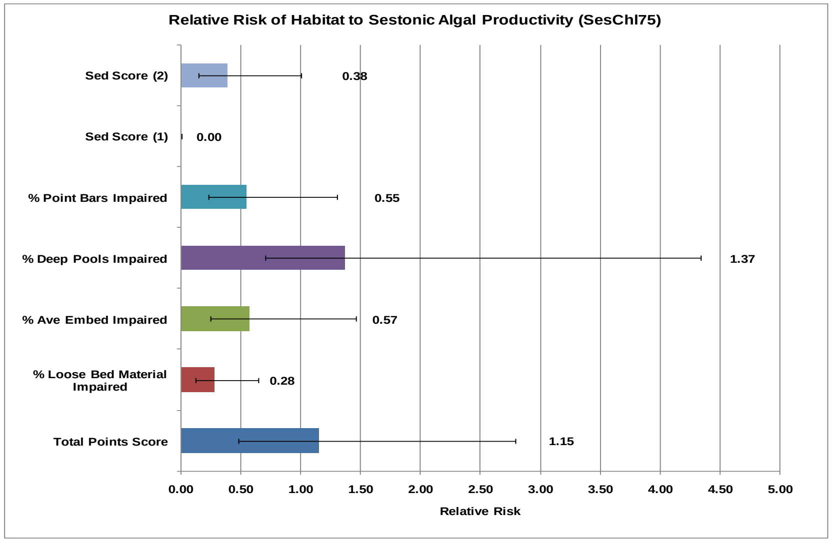
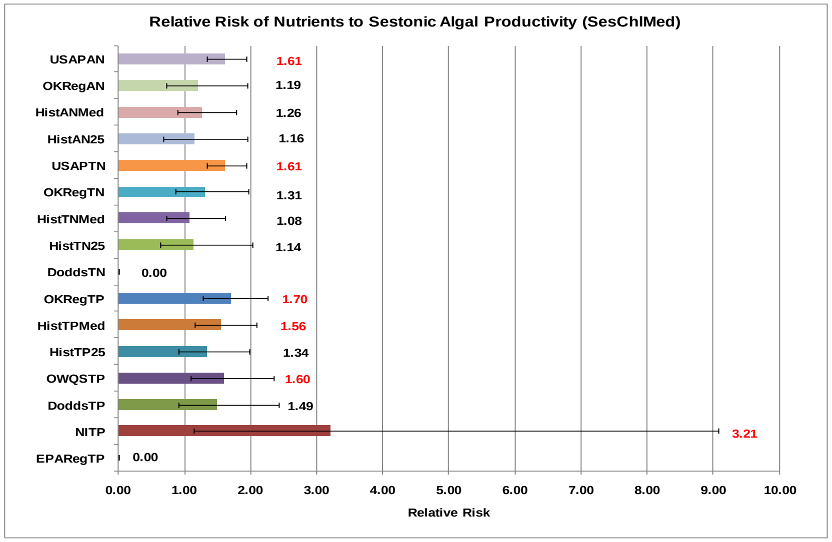
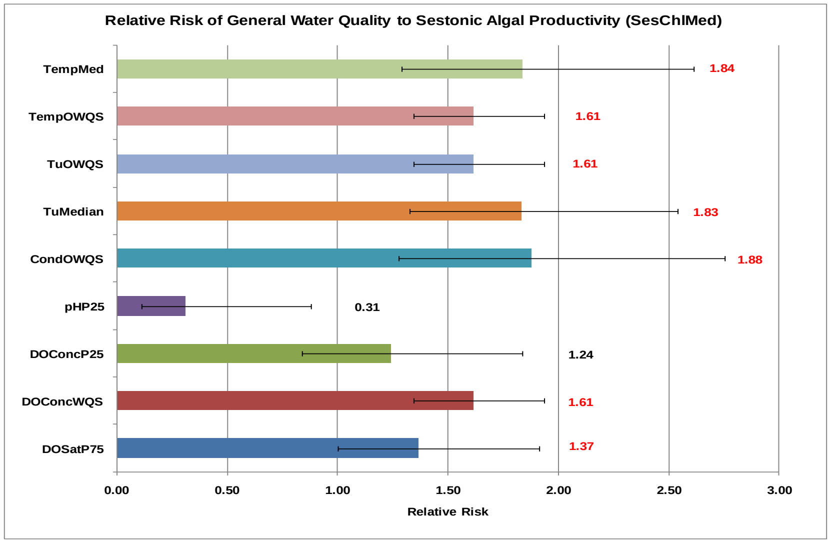


Figure 22. Relative risk of nutrient, general water quality, and habitat stressors related to sestonic algal condition at the historical median for chlorophyll-a. Upper and lower bounds represent 90% confidence interval. Red values represent significant relative risks. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)





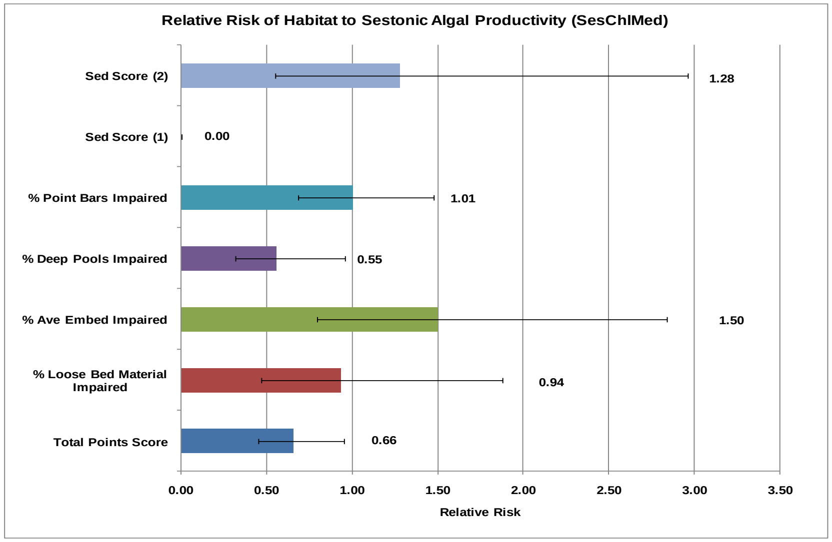
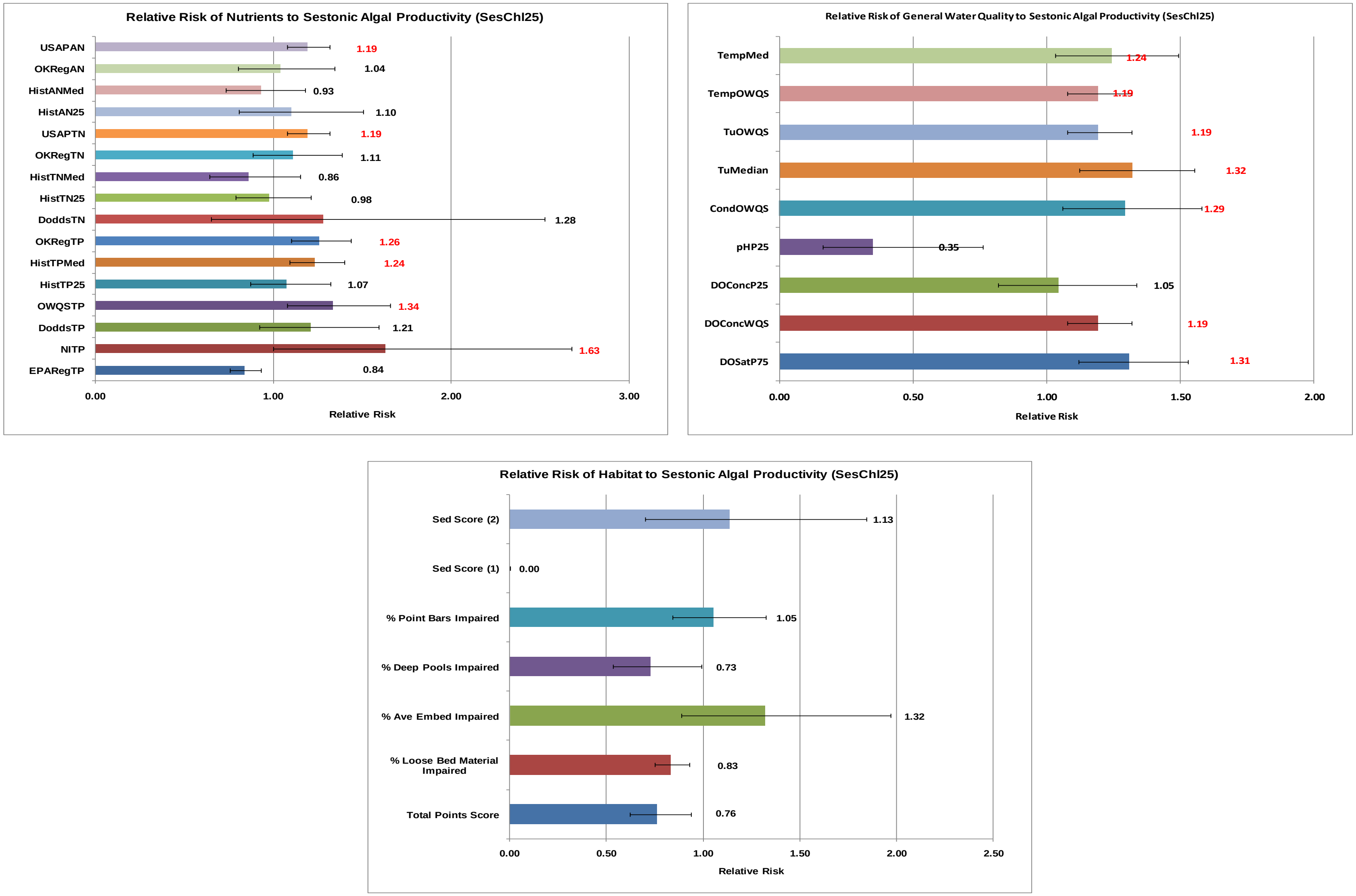


Figure 23. Relative risk of nutrient, general water quality, and habitat stressors related to sestonic algal condition at the historical 25th percentile for chlorophyll-a. Upper and lower bounds represent 90% confidence interval. Red values represent significant relative risks. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)



Relative Risk to Benthic Algal Biomass

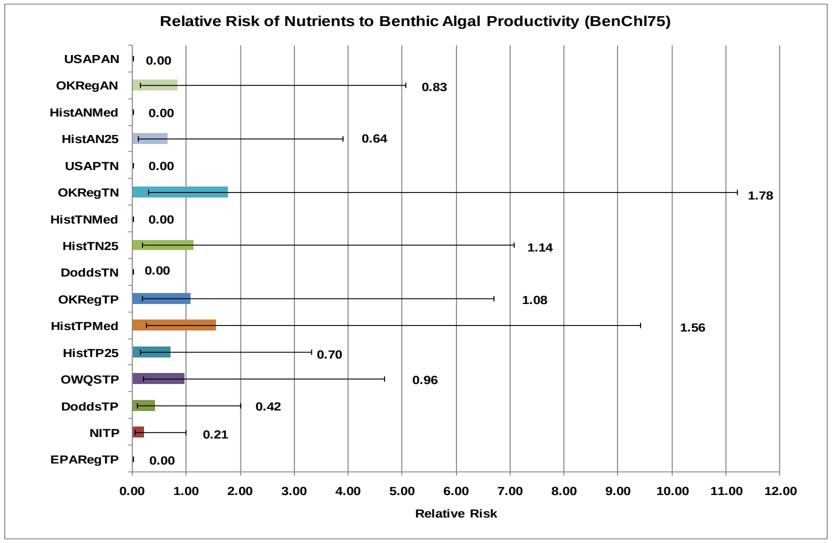
Relative risk to benthic algal condition is considered for all nutrient, general water quality and habitat stressors. Condition for benthic algal biomass was based upon whether a particular sample was above or below a variety of screening levels for chlorophyll-a. These include the 100 mg/m^2 nuisance chlorophyll-a screening level as well as the mean, median, 75th and 25th percentiles of historical benthic chlorophyll-a data. Risk graphs are included following the analyses and are arranged by chlorophyll-a screening level. Because only one site exceeded the nuisance and 75th percentile screening levels for benthic chlorophyll biomass, the calculations for relative risk were either not calculable or 0.0 because of 0.0 calculated for one or the other ratios. Therefore, the associated relative risk graphs are not presented in this report.

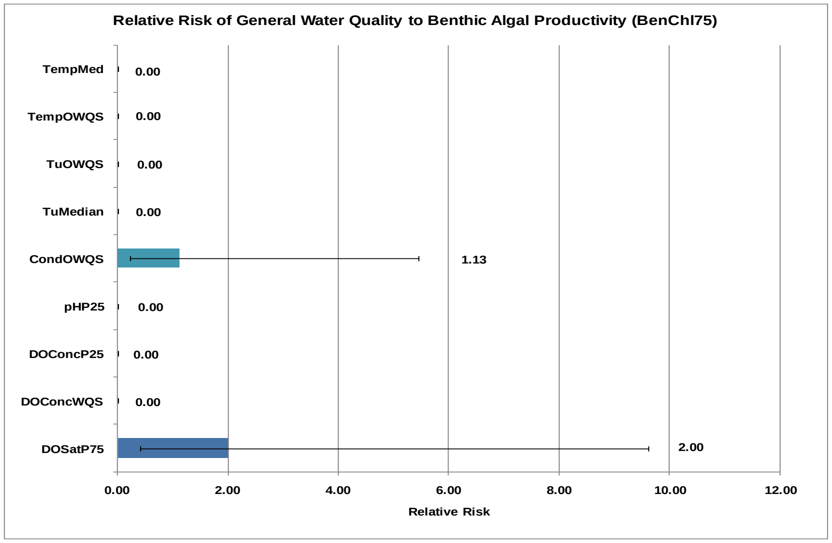
Stressor relative risks related to the benthic historical 75th percentile are depicted in Figure 24. No nutrient stressor demonstrates significant risk to algal biomass. Several stressors including the historical total phosphorus 25th percentile, the nitrogen median, and the Oklahoma regional total phosphorus and nitrogen levels have relative risks greater than 1.0 but are not significant. For habitat stressors, the total points and percent deep pools stressors show relative risks greater than 1.0, but only the ratio for percent deep pools is significant with benthic algal biomass 7.2 times more likely to be poor. However, when considering general water quality parameters, algal biomass condition is not significantly associated to any stressor. Dissolved oxygen saturation and conductivity are above relative risks of 1.0 but are not significant.

Stressor relative risks related to the benthic historical median are depicted in Figure 25. Several nutrient stressors demonstrate significant risk to algal biomass. When the USAP total and available nitrogen stressors are exceed, algal biomass is 2.08 times more likely to be poor, and when historical total phosphorus median is exceeded, algal biomass is 1.81 times more likely to be poor. All other stressors, except the nutrient index for total phosphorus and the historical median available nitrogen levels, have relative risks greater than 1.0 but are not significant. For habitat stressors, the total points, percent deep pools and point bars, and the sedimentation stressors show relative risks greater than 1.0, but are all insignificant except the percent deep pools ratio. Algal biomass is 1.89 times more likely to be poor when a site has less deep pools than applicable reference sites. For general water quality stressors, algal biomass condition is significantly associated to dissolved oxygen concentrations below the OWQS criterion (RR = 2.08). With the exception of dissolved oxygen saturation, all other stressors are below a 1.0 risk ratio.

Stressor relative risks related to the benthic historical 25th percentile are depicted in Figure 26. Only the USAP total and available nitrogen stressors have significant risk rations, with algal biomass 1.22 times more likely to be poor when these values are exceeded. All other stressors have relative risks greater than or near to 1.0 but are not significant. For habitat stressors, no stressors demonstrate risk to algal biomass condition. Although all stressors are near or exceed a risk ration of 1.0, but are not insignificant. For general water quality stressors, algal biomass condition is 1.22 times more likely to be poor when dissolved oxygen concentrations are below or water temperatures are above the OWQS criteria. Likewise, when dissolved oxygen saturations exceed the historical 75th percentile, algal biomass is 1.23 times more likely to be poor. Conductivity and the historical turbidity median have risk ratios exceeding 1.0 but are not significant.

Figure 24. Relative risk of nutrient, general water quality, and habitat stressors related to benthic algal condition at the historical 75th percentile supply criterion for chlorophyll-a. Upper and lower bounds represent 90% confidence interval. Red values represent significant relative risks. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)





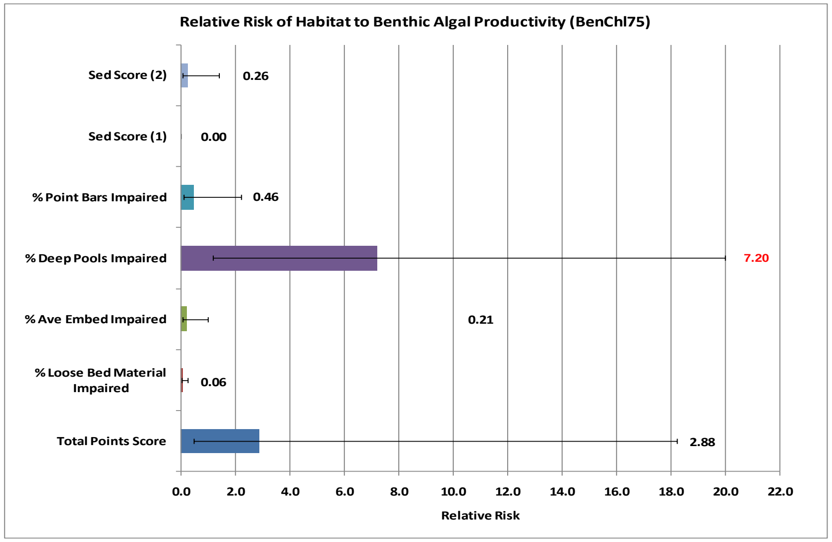


Figure 25. Relative risk of nutrient, general water quality, and habitat stressors related to benthic algal condition at the historical median for chlorophyll-a. Upper and lower bounds represent 90% confidence interval. Red values represent significant relative risks. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)

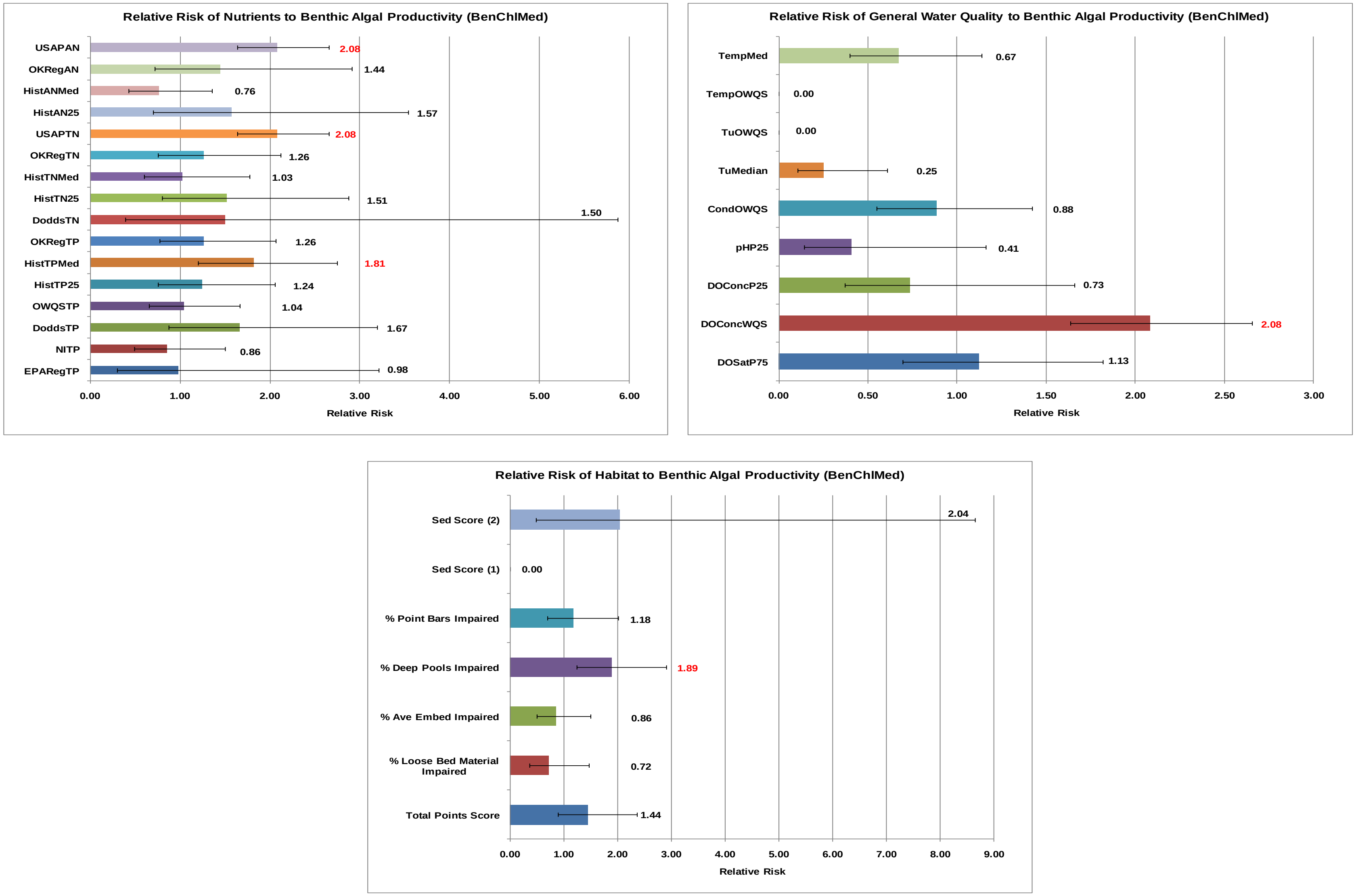
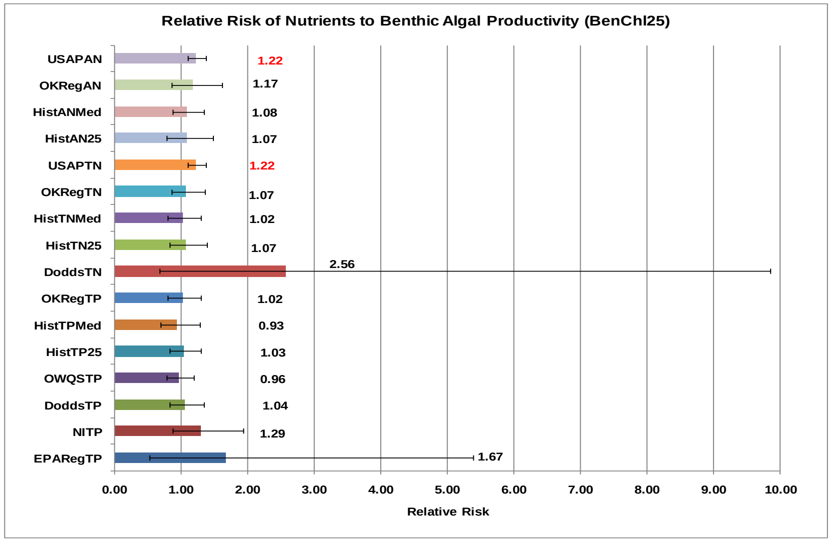
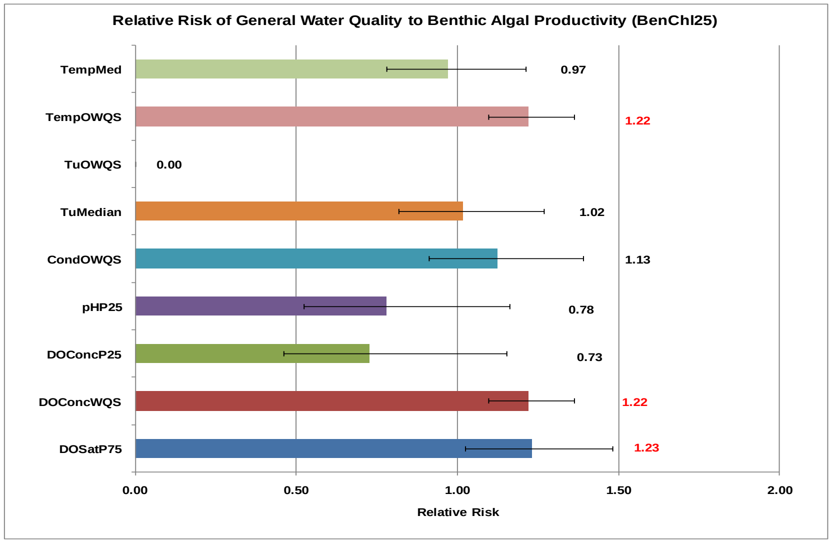
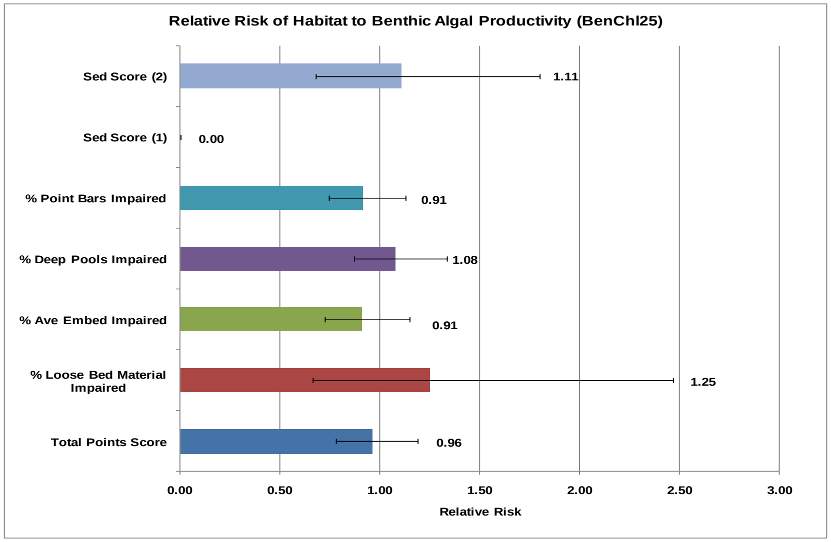


Figure 26. Relative risk of nutrient, general water quality, and habitat stressors related to benthic algal condition at the historical 25th percentile for chlorophyll-a. Upper and lower bounds represent 90% confidence interval. Red values represent significant relative risks. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)







Oklahoma's Integrated Water Quality Report

Oklahoma's environmental agencies gather and assess data across the state for a wide variety of biological, chemical, and physical water quality indicators. One purpose of these data collections is to meet federal Clean Water Act requirements to compile a list of impaired waterbodies and determine the condition of all waters of the nation. These reports are compiled to the biannual Oklahoma Water Quality Assessment Integrated Report (ODEQ, 2008b).

The current study benefits the effort in several ways. First, this report marks Oklahoma's first attempt at making a statistically based assessment of a particular watershed. The OWRB recommends that this report be adopted into the 305(b) section of the Oklahoma Water Quality Assessment Integrated Report (ODEQ, 2008b) along with the Statewide Probabilistic Assessment Report (OWRB, 2010a). Second, individual waterbodies not yet included in Oklahoma's Integrated Report (ODEQ, 2008) now have some level of assessment. The OWRB regularly submits waters for inclusion on Oklahoma's 303(d) list, and will do so again in October 2011. As a part of OWRB's submission, waterbodies assessed as part of this study will be included for consideration as not only category 5 (impaired), but as category 3 (not impaired for some uses). Because of assessment rules housed in Oklahoma's Continuing Planning Process (CPP; ODEQ, 2008a) and USAP (OWRB, 2008a), certain water quality parameters will not be included as part of the assessment. Most of Oklahoma's assessment protocols require that certain data requirements be met including the number of samples required to make an assessment determination. Protocols were developed to either assess short-term or long-term exposure. Short-term exposure protocols are written as percent exceedances, with typically a minimum of ten samples required. Long-term exposure protocols are based upon some measure of central tendency, but typically require a minimum number of samples to calculate the applicable descriptive statistic. Some exceptions to these rules include biological assessments and the application of the sediment criteria. All other parameters included in this study will not be included in assessments for the impaired waters list but will be made publicly available in the event that another entity can include the data in their assessment. A number of stations included in the study can be integrated into both OWRB and OCC segment assessments.

Relative Risk—Fish and Benthic Macroinvertebrates

The relative risk analyses produced widely variable results depending upon both biotic condition and stressor. To explore potential outcomes, matrices for the fish, benthic macroinvertebrate (BMI), and sestonic and benthic conditions and stressors were developed (Tables 15, 16, and 17). Comparisons between the two groups have implications for criteria development, not only at the stressor level, but for biological condition as well. Standards development and implementation is an ongoing process affected by growing understanding of appropriate biological metrics and index application as well as stressor levels and how they interact.

Before continuing, it is important to address certain dynamics between the ratios that produce a relative risk value, as well as the calculated confidence interval that determines whether a risk greater than 1.0 is significant (Van Sickle, 2004). As discussed in the results section, relative risk increases as the number of sites with poor condition/high stressor increases relative to the number of sites with good condition/low stressor value (i.e., matched combinations). However, the ratios are also dependant on the other two scenarios of poor condition/low stressor and good condition/high stressor value (i.e., disparate combinations). Relative risks less than 1.0 occur when either one of the disparate values are more prevalent than either one of the matched values or when the combined disparate values are greater than the combined matched values. However, why do scenarios exist that allow relative risks greater than 1.0 to be considered not significant? The most prevalent reason is when a large number of sites fit into the matched combinations, but one of these greatly outnumbers the other. And, at the same time, a close relationship exists between a disparate combination and the parent matched combination (e.g., poor condition/low stressor and good condition/low stressor), or the disparate condition greatly outnumbers the lower parent matched condition. In essence, the great number of sites fall into matched combinations, but their ratio is highly variable. Couple that with a large number of disparate sites that match the dominant matched sites, and uncertainty in the risk calculation increases. In practice, this leads to a broader confidence interval and a higher probability that the relative risk greater than 1.0 will not be significant.

For the most part, the attempt to draw relationships of stressors to fish and condition using relative risk produced mixed results depending on stressor category (Table 15). For nutrients, only the USAP screening level for total nitrogen and available nitrogen produced significant associated risk to fish condition. However, in both instances, only one site exceeded the nutrient screening level. No nutrient parameter was significantly related to poor BMI condition, regardless of the habitat assessed. The median and 25th percentile of historical total phosphorus and nitrogen data (Table 10) produced several relative risks greater than 1.0, but in each case, the risks were not significant. The reasons for this are unclear, but could be related to several things. First, although stressors represented a broad spectrum of values, many site phosphorus values were on the low end at less than 0.050 mg/L, and many nitrogen values were on the high end at greater than 1.5 mg/L. Coupled with a highly inconsistent relationship of stressor to biological condition, nutrients become a poor predictor of fish and BMI condition. Furthermore, lack of predictive capacity for nutrients and fish/BMI was also noted in the Statewide Probabilistic Assessment completed in 2009 (OWRB, 2010a). In that study, no nutrient parameter had significant associated risk with either assemblage in the Temperate Forests region.

Habitat stressors had some predictive capacity when considering fish and BMI (Table 15). Fish condition was significantly related to both the overall habitat score and percentage of deep pools, but had no other relative risk greater than 1.0. Furthermore, the BMI-Riffle habitat was significantly related to the percentage of deep pools. And, with the exception of the sedimentation USAP's, all other stressor were greater than 1.0, but showed much uncertainty with lower confidence bounds well below. Unlike nutrients, habitat does show more predictive capacity and appears to be related to overall habitat change and/or loss. Lack of deep pools likely decreases the diversity of the both assemblage populations and adversely affects sensitive benthic populations.

General water quality stressors demonstrated the greatest predictive capacity when considering fish and BMI (Table 15). Dissolved oxygen and turbidity related to water quality standards was significant for each assemblage, but it should be noted that only one site exceeded the respective criteria. However, the historical 75th percentile of DO shows promising predictive capacity. It is significant for BMI-Riffle condition, but also produced non-significant relative risks for the other two conditions. In fact, for all conditions, a number of stressors were above 1.0 but not significant.

When comparing both fish and BMI to a broad spectrum of stressors, it appears that stressor/condition relationships are difficult to pin down. In the Statewide Probabilistic Assessment this was true for the Temperate Forests region for both fish and BMI (OWRB, 2010a). That report concluded that either stressors or reference condition needed to become refined. This study looked at a very diverse set of stressors that represented a broad range of nutrient and general water quality values. Regardless of site concentrations, some notable relationship should have been formed between condition and stressor condition.

Table 15. Matrix showing results of relative risk studies for fish and benthic macroinvertebrate—riffle and combined habitat. (* = significant at alpha of 0.90) (Refer to Tables 9, 11, and 13 for stressor descriptions.) (ND = RR not calculated)

Stressor Group	Stressor	Fish	Macroinvertebrates --Riffle Habitat	Macroinvertebrates --Combined Habitat
Total Phosphorus	EPARegTP	0.61	ND	ND
	NITP	0.47	1.14	2.36
	DoddsTP	0.92	0.90	1.25
	OWQSTP	0.96	0.70	1.35
	HistTP25	1.54	0.63	1.40
	HistTPMed	0.67	1.24	1.23
	OKRegTP	1.08	0.87	1.08
	USAPTP	ND	ND	ND
Total Nitrogen	EPARegTN	ND	ND	ND
	NSATN	ND	ND	ND
	NITN	ND	ND	ND
	DoddsTN	0.44	1.13	ND
	HistTN25	1.14	0.82	1.14
	HistTNMed	1.48	0.61	1.34
	OKRegTN	0.99	0.66	0.99
	USAPTN	3.33*	0.00	0.00
Available Nitrogen	EPARegAN	ND	ND	ND
	HistAN25	0.64	0.80	1.07
	HistANMed	0.80	0.45	0.80
	OKRegAN	0.61	0.77	1.05
	USAPAN	3.33*	0.00	0.00
General Water Quality	DOSatP75	1.20	1.80*	1.20
	DOConcWQ!	3.33*	2.78*	2.17*
	DOConcP25	1.79	1.43	1.41
	pHP25	2.12*	1.67	0.93
	CondOWQS	0.88	1.01	1.13
	TuMedian	1.10	1.07	1.10
	TuOWQS	3.33*	2.78*	2.17*
	TempOWQS	0.00	0.00	0.00
	TempMed	0.65	1.59	0.71
Habitat and Sediment	HTPts	4.17*	1.65	0.81
	%LBS	0.44	1.13	0.69
	%Emb	0.64	1.14	0.81
	%DP	1.87*	1.75*	0.99
	%NVPB	0.59	0.99	0.54
	USAPSed1	ND	ND	ND
	USAPSed2	0.60	ND	0.94

Of course, the nitrogen USAP screening limit and several general water quality standards showed significant relative risk, but because in each instance only one site exceeded the stressor value, these parameters likely show only what the maximum stressor level should be. Therefore, is the lack of sensitivity due to how condition is calculated? This study used IBI's as well as reference conditions that have been widely published in studies by both the OWRB and OCC. However, either the IBI or reference may not be sensitive enough. Streams in the watershed are generally cool water communities and have exceptional habitat, including substrate and flow. In fact, habitat was likely the most relevant stressor for both BMI and fish. Because habitat is so exceptional, fish and BMI assemblages are often much more diverse and have many more sensitive species than other parts of Oklahoma. Using an IBI that is more refined to the particular characteristics of the Ozark Highlands may allow for a better defined relationship between condition and stressors.

Relative Risk—Sestonic and Benthic Algal Biomass

For sestonic algal biomass, a number of notable significant relationships exist between stressor and condition (Table 16). First, it appears that using either the historical median or 25th percentile of chlorophyll-a for algal condition produces the most significant results. At these levels greater sensitivity exists between condition and stressor levels. Each condition is highly related to total phosphorus in ranges from 0.018 mg/L to near 0.10 mg/L. However, the highest relative risks are associated with total phosphorus in the range of 0.018 mg/L to the 0.037 mg/L Oklahoma Scenic River criterion. Low level total phosphorus appears to function well as a predictor of potential degradation due to increasing algal biomass. Notably, nitrogen only becomes predictive at the high screening levels. Similarly, all general water quality stressors, with the exception of pH, are significantly related to poor sestonic algal condition. Increasing temperatures, turbidity, and DO saturation all have significant predictive capacity. Habitat has no predictive capacity.

Conversely, benthic algal biomass shows very few significant relationships to stressors (Table 17). For nutrients, the median condition is related to higher total phosphorus screening limit (HistTPMed), indicating that total phosphorus does have some relationship to poor benthic algal condition. For general water quality stressors, the stressors related to water quality standards (OWRB, 2007) are again significant, but for each stressor, only one site exceeds the criterion. Notably, the historical DO percent saturation shows some predictive capacity for poor benthic condition. The most interesting significant relationship occurs when the percentage of deep pools is acting as a stressor. When this occurs, the stream area providing a suitable photic zone for algal growth has increased.

Table 16. Matrix showing results of relative risk studies for sestonic algae. (* = significant at alpha of 0.90; NS = not significant) (Refer to Table 10 for stressor descriptions.) (ND = RR not calculated)

Stressor Group	Stressor	SesChl10	SesChlMean	SesChl75	SesChlMedian	SesChl25
Total Phosphorus	EPARegTP	ND	ND	ND	ND	0.84
	NITP	ND	0.64	0.96	3.21*	1.63*
	DoddsTP	0.83	0.42	0.73	1.49	1.21
	OWQSTP	0.48	0.58	1.15	1.60*	1.34*
	HistTP25	1.40	0.70	1.23	1.34	1.07
	HistTPMed	2.33	0.67	1.04	1.56*	1.24*
	OKRegTP	1.63	1.08	2.71*	1.70*	1.26*
	USAPTP	ND	ND	ND	ND	ND
Total Nitrogen	EPARegTN	ND	ND	ND	ND	ND
	NSATN	ND	ND	ND	ND	ND
	NITN	ND	ND	ND	ND	ND
	DoddsTN	ND	ND	ND	ND	1.28
	HistTN25	0.76	1.14	1.70	1.14	0.98
	HistTNMed	1.63	0.46	1.22	1.08	0.86
	OKRegTN	0.30	0.99	1.58	1.31	1.11
	USAPTN	0.00	0.00	0.00	1.61*	1.19*
Available Nitrogen	EPARegAN	ND	ND	ND	ND	ND
	HistAN25	0.43	0.64	0.96	1.16	1.10
	HistANMed	0.00	0.34	0.90	1.26	0.93
	OKRegAN	0.14	0.46	0.73	1.19	1.04
	USAPAN	0.00	0.00	0.00	1.61*	1.19*
General Water Quality	DOSatP75	0.00	1.20	1.67	1.37*	1.31*
	DOConcWQ	25.00*	7.14*	5.00*	1.61*	1.19*
	DOConcP25	10.75*	1.79	1.19	1.24	1.05
	pHP25	2.33	0.67	0.47	0.31	0.35
	CondOWQS	ND	3.38	5.06*	1.88*	1.29*
	TuMedian	0.92	1.10	1.53	1.83*	1.32*
	TuOWQS	25.00*	7.14*	5.00*	1.61*	1.19*
	TempOWQS	ND	7.14*	5.00*	1.61*	1.19*
	TempMed	2.86	1.43	1.71	1.84*	1.24*
Habitat and Sediment	HTPts	1.92	ND	1.15	0.66	0.76
	%LBS	ND	0.19	0.28	0.94	0.83
	%Emb	ND	0.64	0.57	1.50	1.32
	%DP	1.20	1.44	1.37	0.55	0.73
	%NVPB	0.91	0.46	0.55	1.01	1.05
	USAPSed1	ND	ND	ND	ND	ND
	USAPSed2	ND	0.26	0.38	1.28	1.13

Table 17. Matrix showing results of relative risk studies for benthic algae. (* = significant at alpha of 0.90; NS = not significant) (Refer to Table 10 for stressor descriptions.) (ND = RR not calculated)

Stressor Group	Stressor	BenChl75	BenChlMedian	BenChl25
Total Phosphorus	EPARegTP	ND	0.98	1.67
	NITP	0.21	0.86	1.29
	DoddsTP	0.42	1.67	1.04
	OWQSTP	0.96	1.04	0.96
	HistTP25	0.70	1.24	1.03
	HistTPMed	1.56	1.81*	0.93
	OKRegTP	1.08	1.26	1.02
	USAPTP	ND	ND	ND
Total Nitrogen	EPARegTN	ND	ND	ND
	NSATN	ND	ND	ND
	NITN	ND	ND	ND
	DoddsTN	ND	1.50	2.56
	HistTN25	1.14	1.51	1.07
	HistTNMed	0.00	1.03	1.02
	OKRegTN	1.78	1.26	1.07
	USAPTN	ND	2.08*	1.22*
Available Nitrogen	EPARegAN	ND	ND	ND
	HistAN25	0.64	1.57	1.07
	HistANMed	ND	0.76	1.08
	OKRegAN	0.83	1.44	1.17
	USAPAN	ND	2.08*	1.22*
General Water Quality	DOSatP75	2.00	1.13	1.23*
	DOConcWQ!	0.00	2.08*	1.22*
	DOConcP25	0.00	0.73	0.73
	pHP25	0.00	0.41	0.78
	CondOWQS	1.13	0.88	1.13
	TuMedian	0.00	0.25	1.02
	TuOWQS	0.00	0.00	0.00
	TempOWQS	0.00	0.00	1.22*
	TempMed	0.00	0.67	0.97
Habitat and Sediment	HTPts	2.88	1.44	0.96
	%LBS	0.06	0.72	1.25
	%Emb	0.21	0.86	0.91
	%DP	7.20*	1.89*	1.08
	%NVPB	0.46	1.18	0.91
	USAPSed1	ND	ND	ND
	USAPSed2	0.26	2.04	1.11

Recommendations
Further development of regional IBI's and reference condition should be funded through the Clean Water Act to develop more sensitive tools for determining biotic condition. Biological monitoring is becoming more prevalent in all state and local programs and provides an excellent assessment tool to determine waterbody integrity. However, IBI's in Oklahoma to date have been developed with a one-size fits all approach in terms of metrics and scoring. Due to Oklahoma's vast ecological diversity, this approach may not be appropriate for the long-term. In the past, funding and limited data have been the driving forces in development. Although funding is still limited, the volume of data has increased exponentially in the last five years. For the Ozark Highlands Ecoregion, other IBI's have been developed, which explored other taxonomic, functional, or trophic metrics (Dauwalter, et al., 2003; Radwell and Kwak, 2005; Justus et al., 2010). These IBI's were not incorporated in this study because published reference condition did not exist for Oklahoma. However, future work exploring the incorporation of a more diverse group of metrics may provide a more sensitive IBI.

Second, data exists to support the further development of nutrient and habitat-based criteria to protect waterbodies from future and increased eutrophication. Studies such as this one, when coupled with fixed station network data, provide a valuable dataset from which to begin setting these criteria. Although relative risk showed varying relationships between condition and stressors, correlation, discriminant, and regression analyses may demonstrate that a moderate to large portion of biotic condition variance can be explained by the nutrients, general water quality, and habitat (Lohman and Jones, 1999; Radwell and Kwak, 2005; Wang, et al., 2007; Maret, et al., 2010). To further explore relationships between condition and chemical physical parameters included in this study, a preliminary regression analysis was performed. First, all data were log-transformed and graphically compared to non-transformed data, and the data with a more normal distribution were used for subsequent analyses. Second, screening analyses were completed between each condition and stressor data to filter variables for use in formal regression analyses. The screening analyses included a best subset analysis for each condition to determine the potential explanatory variables that could be included in multiple regressions (Appendix D), and stepwise analyses to pinpoint which explanatory variables were significant ($p < 0.20$). From these preliminary analyses, several multiple regressions were performed for each condition based on the best explanatory candidates. The preliminary best fit models are in Table 18.

Table 18. Preliminary best fit regression models developed for fish, BMI, and algal biomass. (* = significant at $p < 0.05$)

Model Equation	R^2	ANOVA F-value
OKFIBI = - 20.6 + 0.312 TPts + 12.1 NVPB + 1.17 DO	56.7	15.09*
OCCFIBI = - 26.4 + 0.532 TPts + 29.6 NVPB + 3.33 DO	39.9	10.40*
BIBIRIF = - 16.6 + 17.8 LogAN + 0.591 TPts - 11.0 LogLBS + 35.5 NVPB	29.1	4.71*
LogBenChlA = - 1.11 + 0.171 logTP + 0.478 pH - 0.0501 Temp	30.0	4.92*
LogSesChlA = - 7.50 - 0.523 logTP - 12.8 LogAN + 13.9 logTN + 0.804 NVPB	58.5	10.35*

For both fish IBI's, total habitat points, non-vegetated point bars, and DO concentration produce the best model. The R^2 values are somewhat different, but appear to be good preliminary models. For BMI, only the BIBIRIF produced a useable model. Predictive relationships were again tied to measures of habitat (total points, loose bed sediments, and point bars), but instead of dissolved oxygen, available nitrogen was a significant predictor of BMI condition. For algal biomass, there is a vast difference between the most explanatory variables. Total phosphorus (TP), available nitrogen (AN), and total nitrogen (TN) are significant explanatory variables for sestonic algal condition, and have been commonly verified in other studies (Lohman and Jones, 1999; Maret, et al., 2010). In each study, R^2 values ranged from 0.32 – 0.94 for TP and from 0.21 to 0.84 for TN. Additionally, non-vegetated point bars are included in the model. Maret, et al. (2010) also explored the relationship between TP and TN to benthic chlorophyll and found poor predictive relationships. In this preliminary analysis, each variable individually showed little predictive capacity for benthic chlorophyll, but when coupled with pH and water temperature in multiple regression analysis, TP was significant. From this preliminary analysis, there is ample information to support future model development for stressor condition relationships in the Ozarks.

Last, watershed characterizations utilizing probabilistic designs should continue to be funded and utilized throughout the state. These studies allow for relatively little data collection to characterize a broad multi-assemblage population and begin to explore how stressor relationships affect them. These studies can be useful for human health condition as well. The current study should be repeated in two to four years to determine how implementation work in the watershed has affected condition and stressor extent.

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Table 19. Appendix A—Nutrient Data for All Sites.

Sample ID	Station ID	Station Description	Sample Date	Sample Time	Nitrogen, Total Kjeldahl (mg/L)	Nitrogen, Nitrate/Nitrite as N (mg/L)	Nitrogen, Total (mg/L)	Phosphorous, Total (mg/L)
459449	OKI06594-002	Illinois River	03/03/2009	16:45	0.200	2.330	2.530	0.047
466986	OKI06594-002	Illinois River	07/14/2009	10:45	0.170	1.220	1.390	0.070
450421	OKI06594-002	Illinois River	08/26/2008	17:40	0.230	1.640	1.870	0.060
459180	OKI06594-005	Illinois River	02/24/2009	13:30	0.160	2.860	3.020	0.067
466982	OKI06594-005	Illinois River	07/13/2009	14:35	0.240	1.470	1.710	0.078
447838	OKI06594-005	Illinois River	08/05/2008	21:04	0.250	1.720	1.970	0.084
457853	OKI06594-008	Flint Creek	02/04/2009	10:35	0.140	2.680	2.820	0.008
434463	OKI06594-008	Flint Creek	01/02/2008	14:40	0.150	3.330	3.480	0.020
424710	OKI06594-008	Flint Creek	08/28/2007	12:00	0.160	0.270	0.430	0.035
423678	OKI06594-008	Flint Creek	08/14/2007	15:30	0.220	0.240	0.460	0.038
459178	OKI06594-009	Illinois River	02/25/2009	10:45	0.220	2.990	3.210	0.054
466980	OKI06594-009	Illinois River	07/13/2009	11:45	0.220	1.830	2.050	0.073
468955	OKI06594-009	Illinois River	08/11/2009	13:30	0.230	1.530	1.760	0.089
452730	OKI06594-009	Illinois River	10/14/2008	12:00	0.270	2.440	2.710	0.062
466051	OKI06594-009	Illinois River	06/29/2009	13:10	0.340	1.950	2.290	0.074

Sample ID	Station ID	Station Description	Sample Date	Sample Time	Nitrogen, Total Kjeldahl (mg/L)	Nitrogen, Nitrate/Nitrite as N (mg/L)	Nitrogen, Total (mg/L)	Phosphorous, Total (mg/L)
464712	OKI06594-009	Illinois River	06/01/2009	14:00	0.460	2.210	2.670	0.061
423161	OKI06594-011	Tyner creek	08/07/2007	10:00	0.050	1.240	1.290	0.010
424713	OKI06594-011	Tyner creek	08/29/2007	10:30	0.050	2.020	2.070	0.013
436886	OKI06594-011	Tyner creek	02/11/2008	16:22	0.100	2.940	3.040	0.007
457374	OKI06594-011	Tyner creek	01/21/2009	16:22	0.100	2.180	2.280	0.007
424074	OKI06594-012	Barren Fork	08/21/2007	13:30	0.050	1.150	1.200	0.063
457123	OKI06594-012	Barren Fork	01/14/2009	08:02	0.100	2.150	2.250	0.034
434464	OKI06594-012	Barren Fork	01/04/2008	11:42	0.130	2.080	2.210	0.044
423154	OKI06594-012	Barren Fork	08/07/2007	14:00	0.190	1.410	1.600	0.066
436890	OKI06594-018	Steely Hollow	02/13/2008	09:54	0.100	0.520	0.620	0.005
426400	OKI06594-018	Steely Hollow	09/18/2007	08:02	0.050	0.270	0.320	0.006
423682	OKI06594-018	Steely Hollow	08/15/2007	13:00	0.080	0.240	0.320	0.014
457850	OKI06594-018	Steely Hollow	02/03/2009	17:35	0.170	0.730	0.900	0.005
457369	OKI06594-019	Bidding Creek	01/20/2009	13:51	0.100	1.180	1.280	0.019
446645	OKI06594-019	Bidding Creek	07/22/2008	18:00	0.110	1.470	1.580	0.030
466064	OKI06594-019	Bidding Creek	07/01/2009	12:00	0.120	1.070	1.190	0.034
453140	OKI06594-020	Barren Fork	10/20/2008	13:30	0.150	1.890	2.040	0.017

Sample ID	Station ID	Station Description	Sample Date	Sample Time	Nitrogen, Total Kjeldahl (mg/L)	Nitrogen, Nitrate/Nitrite as N (mg/L)	Nitrogen, Total (mg/L)	Phosphorous, Total (mg/L)
459181	OKI06594-020	Barren Fork	02/23/2009	17:30	0.110	1.900	2.010	0.030
466974	OKI06594-020	Barren Fork	07/14/2009	13:25	0.110	1.040	1.150	0.041
468458	OKI06594-020	Barren Fork	08/03/2009	12:00	0.130	0.670	0.800	0.043
466978	OKI06594-021	Illinois River	07/15/2009	09:05	0.180	1.610	1.790	0.087
459179	OKI06594-021	Illinois River	02/24/2009	09:20	0.220	2.880	3.100	0.071
447839	OKI06594-021	Illinois River	08/05/2008	12:02	0.250	1.790	2.040	0.086
434465	OKI06594-024	Flint Creek	01/02/2008	13:01	0.160	3.070	3.230	0.023
424708	OKI06594-024	Flint Creek	08/27/2007	14:30	0.270	0.310	0.580	0.058
457854	OKI06594-024	Flint Creek	02/04/2009	08:55	0.270	2.840	3.110	0.012
423675	OKI06594-024	Flint Creek	08/13/2007	16:30	0.660	0.240	0.900	0.106
423676	OKI06594-025	Dripping Springs Branch	08/14/2007	11:30	0.050	1.080	1.130	0.024
424709	OKI06594-025	Dripping Springs Branch	08/28/2007	09:15	0.070	1.460	1.530	0.031
435940	OKI06594-025	Dripping Springs Branch	01/29/2008	14:20	0.100	3.200	3.300	0.022
457847	OKI06594-025	Dripping Springs Branch	02/03/2009	14:53	0.260	1.920	2.180	0.028
457370	OKI06594-026	Trib to Waltrip Branch	01/21/2009	14:49	0.100	1.820	1.920	0.027
466056	OKI06594-026	Trib to Waltrip Branch	06/30/2009	09:50	0.200	1.340	1.540	0.038
449651	OKI06594-026	Trib to Waltrip Branch	08/27/2008	17:03	0.220	1.770	1.990	0.041

Sample ID	Station ID	Station Description	Sample Date	Sample Time	Nitrogen, Total Kjeldahl (mg/L)	Nitrogen, Nitrate/Nitrite as N (mg/L)	Nitrogen, Total (mg/L)	Phosphorous, Total (mg/L)
437517	OKI06594-028	Evansville Creek	02/26/2008	11:15	0.130	2.100	2.230	0.019
424073	OKI06594-028	Evansville Creek	08/21/2007	11:30	0.050	0.260	0.310	0.022
426403	OKI06594-028	Evansville Creek	09/19/2007	08:01	0.070	0.340	0.410	0.017
434466	OKI06594-028	Evansville Creek	01/03/2008	12:40	0.100	1.070	1.170	0.015
458151	OKI06594-028	Evansville Creek	02/09/2009	13:50	0.100	1.080	1.180	0.018
457133	OKI06594-028	Evansville Creek	01/13/2009	15:32	0.140	0.790	0.930	0.017
427074	OKI06594-028	Evansville Creek	09/26/2007	12:05	0.150	0.210	0.360	0.019
423158	OKI06594-028	Evansville Creek	08/07/2007	11:20	0.160	0.400	0.560	0.021
425030	OKI06594-029	Tyner Creek	09/04/2007	13:00	0.240	6.660	6.900	0.128
457366	OKI06594-029	Tyner Creek	01/22/2009	09:03	0.250	6.380	6.630	0.093
423680	OKI06594-029	Tyner Creek	08/15/2007	09:00	0.400	4.600	5.000	0.131
436888	OKI06594-029	Tyner Creek	02/12/2008	11:03	0.890	7.470	8.360	0.396
449652	OKI06594-030	Tailholt Creek	08/28/2008	08:08	0.200	0.720	0.920	0.047
457367	OKI06594-030	Tailholt Creek	01/20/2009	17:02	0.130	0.690	0.820	0.036
466065	OKI06594-030	Tailholt Creek	07/01/2009	13:35	0.250	0.610	0.860	0.066
458160	OKI06594-031	Barren Fork	02/10/2009	14:25	0.130	1.800	1.930	0.033
424712	OKI06594-031	Barren Fork	08/28/2007	09:00	0.070	0.500	0.570	0.034

Sample ID	Station ID	Station Description	Sample Date	Sample Time	Nitrogen, Total Kjeldahl (mg/L)	Nitrogen, Nitrate/Nitrite as N (mg/L)	Nitrogen, Total (mg/L)	Phosphorous, Total (mg/L)
434467	OKI06594-031	Barren Fork	01/04/2008	14:32	0.100	1.760	1.860	0.028
423159	OKI06594-031	Barren Fork	08/07/2007	08:30	0.120	0.870	0.990	0.040
424071	OKI06594-032	Evansville Creek	08/20/2007	17:00	0.050	0.840	0.890	0.030
434468	OKI06594-032	Evansville Creek	01/03/2008	10:32	0.100	1.300	1.400	0.013
457135	OKI06594-032	Evansville Creek	01/13/2009	10:33	0.130	0.970	1.100	0.008
423151	OKI06594-032	Evansville Creek	08/07/2007	09:00	0.190	1.050	1.240	0.028
424711	OKI06594-033	Flint Creek	08/28/2007	14:00	0.150	1.810	1.960	0.429
435939	OKI06594-033	Flint Creek	01/29/2008	11:15	0.190	4.950	5.140	0.243
457851	OKI06594-033	Flint Creek	02/04/2009	15:12	0.230	2.990	3.220	0.157
423677	OKI06594-033	Flint Creek	08/14/2007	12:30	0.240	1.270	1.510	0.395
424072	OKI06594-035	Tributary to Smith Hollow	08/21/2007	08:30	0.050	1.210	1.260	0.035
423150	OKI06594-035	Tributary to Smith Hollow	08/06/2007	15:00	0.090	1.190	1.280	0.029
436889	OKI06594-035	Tributary to Smith Hollow	02/12/2008	08:19	0.100	1.170	1.270	0.017
457368	OKI06594-035	Tributary to Smith Hollow	01/20/2009	11:09	0.120	1.090	1.210	0.020
423162	OKI06594-038	Tributary to Barren Fork	08/08/2007	11:00	0.090	1.360	1.450	0.023

Sample ID	Station ID	Station Description	Sample Date	Sample Time	Nitrogen, Total Kjeldahl (mg/L)	Nitrogen, Nitrate/Nitrite as N (mg/L)	Nitrogen, Total (mg/L)	Phosphorous, Total (mg/L)
425031	OKI06594-038	Tributary to Barren Fork	09/04/2007	16:30	0.090	1.540	1.630	0.016
434469	OKI06594-038	Tributary to Barren Fork	01/03/2008	14:43	0.100	1.820	1.920	0.016
457129	OKI06594-038	Tributary to Barren Fork	01/12/2009	14:54	0.110	1.770	1.880	0.008
466052	OKI06594-041	Flint Creek	06/29/2009	11:10	0.230	1.580	1.810	0.187
468954	OKI06594-041	Flint Creek	08/11/2009	11:52	0.250	1.590	1.840	0.292
457855	OKI06594-041	Flint Creek	02/04/2009	17:00	0.280	2.700	2.980	0.125
426398	OKI06594-042	Barren Fork	09/17/2007	12:01	0.050	0.630	0.680	0.018
423679	OKI06594-042	Barren Fork	08/14/2007	17:20	0.050	0.610	0.660	0.028
435941	OKI06594-042	Barren Fork	01/30/2008	09:15	0.100	1.530	1.630	0.010
457371	OKI06594-042	Barren Fork	01/21/2009	10:32	0.100	1.370	1.470	0.013
424077	OKI06594-043	Peacheater Creek	08/22/2007	11:30	0.050	2.820	2.870	0.044
423157	OKI06594-043	Peacheater Creek	08/07/2007	17:00	0.090	3.130	3.220	0.038
436887	OKI06594-043	Peacheater Creek	02/12/2008	13:50	0.180	4.210	4.390	0.034
457843	OKI06594-043	Peacheater Creek	02/02/2009	14:51	0.210	4.550	4.760	0.032
423155	OKI06594-044	Peavine Creek	08/07/2007	15:25	0.100	0.600	0.700	0.023
424076	OKI06594-044	Peavine Creek	08/22/2007	10:15	0.050	0.700	0.750	0.029
434470	OKI06594-044	Peavine Creek	01/04/2008	09:45	0.100	1.000	1.100	0.012

Sample ID	Station ID	Station Description	Sample Date	Sample Time	Nitrogen, Total Kjeldahl (mg/L)	Nitrogen, Nitrate/Nitrite as N (mg/L)	Nitrogen, Total (mg/L)	Phosphorous, Total (mg/L)
457124	OKI06594-044	Peavine Creek	01/14/2009	12:10	0.100	0.970	1.070	0.006
434471	OKI06594-046	Tahlequah Creek	01/03/2008	16:14	0.330	2.130	2.460	0.111
423681	OKI06594-046	Tahlequah Creek	08/15/2007	11:25	0.370	1.190	1.560	0.279
457132	OKI06594-046	Tahlequah Creek	01/12/2009	13:03	0.480	1.300	1.780	0.156
425032	OKI06594-046	Tahlequah Creek	09/05/2007	08:00	0.570	2.440	3.010	0.353
424075	OKI06594-047	Barren Fork	08/21/2007	17:00	0.050	0.690	0.740	0.051
423674	OKI06594-047	Barren Fork	08/13/2007	14:00	0.090	0.870	0.960	0.049
458158	OKI06594-047	Barren Fork	02/10/2009	11:20	0.100	1.750	1.850	0.035
436885	OKI06594-047	Barren Fork	02/11/2008	12:25	0.180	1.760	1.940	0.027
426401	OKI06594-048	Evansville Creek	09/18/2007	12:30	0.150	0.490	0.640	0.019
458155	OKI06594-048	Evansville Creek	02/09/2009	11:27	0.190	1.130	1.320	0.020
423152	OKI06594-048	Evansville Creek	08/07/2007	10:30	0.280	0.620	0.900	0.022
434472	OKI06594-048	Evansville Creek	01/03/2008	09:52	0.100	1.160	1.260	0.015
437516	OKI06594-048	Evansville Creek	02/26/2008	08:00	0.100	2.100	2.200	0.018
457134	OKI06594-048	Evansville Creek	01/13/2009	11:42	0.100	0.840	0.940	0.005
427073	OKI06594-048	Evansville Creek	09/24/2007	16:00	0.120	0.190	0.310	0.011
424070	OKI06594-048	Evansville Creek	08/20/2007	14:30	0.150	0.320	0.470	0.033

Sample ID	Station ID	Station Description	Sample Date	Sample Time	Nitrogen, Total Kjeldahl (mg/L)	Nitrogen, Nitrate/Nitrite as N (mg/L)	Nitrogen, Total (mg/L)	Phosphorous, Total (mg/L)
466983	OKI06594-049	Black Fox Hollow	07/13/2009	13:52	0.100	0.580	0.680	0.016
450422	OKI06594-049	Black Fox Hollow	08/26/2008	11:35	0.110	0.520	0.630	0.018
458619	OKI06594-049	Black Fox Hollow	02/17/2009	15:17	0.150	1.350	1.500	0.011
459447	OKI06594-053	Illinois River	03/03/2009	10:30	0.190	2.640	2.830	0.054
466973	OKI06594-053	Illinois River	07/15/2009	12:20	0.200	1.610	1.810	0.084
468956	OKI06594-053	Illinois River	08/11/2009	17:01	0.250	1.470	1.720	0.127
464713	OKI06594-053	Illinois River	06/01/2009	11:00	0.420	2.220	2.640	0.061
457375	OKI06594-056	Ballard Creek	01/22/2009	08:05	0.160	2.320	2.480	0.032
452401	OKI06594-056	Ballard Creek	10/08/2008	14:00	0.200	3.380	3.580	0.056
449187	OKI06594-056	Ballard Creek	08/22/2008	08:57	0.250	2.410	2.660	0.094
466053	OKI06594-056	Ballard Creek	06/29/2009	15:08	0.310	1.510	1.820	0.090
459448	OKI06594-057	Illinois River	03/03/2009	13:10	0.200	2.600	2.800	0.052
466979	OKI06594-057	Illinois River	07/15/2009	10:53	0.210	1.650	1.860	0.085
468957	OKI06594-057	Illinois River	08/11/2009	18:05	0.260	1.430	1.690	0.125
464714	OKI06594-057	Illinois River	06/01/2009	15:00	0.350	2.110	2.460	0.069
457125	OKI06594-060	Barren Fork	01/14/2009	10:07	0.100	1.310	1.410	0.019
466976	OKI06594-060	Barren Fork	07/14/2009	15:53	0.110	0.700	0.810	0.048

Sample ID	Station ID	Station Description	Sample Date	Sample Time	Nitrogen, Total Kjeldahl (mg/L)	Nitrogen, Nitrate/Nitrite as N (mg/L)	Nitrogen, Total (mg/L)	Phosphorous, Total (mg/L)
449185	OKI06594-060	Barren Fork	08/21/2008	15:34	0.140	1.660	1.800	0.054
452729	OKI06594-060	Barren Fork	10/13/2008	16:45	0.150	1.580	1.730	0.041
466985	OKI06594-061	Illinois River	07/14/2009	09:35	0.150	1.390	1.540	0.074
449650	OKI06594-061	Illinois River	08/27/2008	13:00	0.220	1.570	1.790	0.074
459454	OKI06594-061	Illinois River	03/02/2009	15:00	0.230	2.510	2.740	0.052
457373	OKI06594-062	Barren Fork	01/21/2009	08:00	0.100	1.340	1.440	0.014
458152	OKI06594-062	Barren Fork	02/09/2009	15:50	0.100	1.740	1.840	0.025
466981	OKI06594-062	Barren Fork	07/13/2009	16:20	0.100	0.940	1.040	0.029
468459	OKI06594-062	Barren Fork	08/05/2009	08:35	0.100	0.680	0.780	0.027
444955	OKI06594-062	Barren Fork	06/25/2008	10:00	0.150	1.400	1.550	0.029
466057	OKI06594-062	Barren Fork	06/30/2009	08:57	0.160	1.130	1.290	0.029
464715	OKI06594-062	Barren Fork	06/01/2009	09:12	0.170	1.250	1.420	0.028
470569	OKI06594-062	Barren Fork	08/31/2009	15:01	0.180	0.500	0.680	0.025
447297	OKI06594-063	Tyner Creek	07/28/2008	12:42	0.110	1.780	1.890	0.014
457849	OKI06594-063	Tyner Creek	02/03/2009	09:02	0.110	2.240	2.350	0.005
466059	OKI06594-063	Tyner Creek	06/30/2009	12:30	0.120	2.150	2.270	0.017
458157	OKI06594-064	Barren Fork	02/10/2009	08:02	0.110	1.770	1.880	0.033

Sample ID	Station ID	Station Description	Sample Date	Sample Time	Nitrogen, Total Kjeldahl (mg/L)	Nitrogen, Nitrate/Nitrite as N (mg/L)	Nitrogen, Total (mg/L)	Phosphorous, Total (mg/L)
466060	OKI06594-064	Barren Fork	06/30/2009	14:10	0.170	0.940	1.110	0.058
449183	OKI06594-064	Barren Fork	08/21/2008	12:12	0.190	1.570	1.760	0.055
452400	OKI06594-064	Barren Fork	10/07/2008	17:00	0.200	1.990	2.190	0.018
466984	OKI06594-066	Illinois River	07/14/2009	08:20	0.160	1.230	1.390	0.075
452016	OKI06594-066	Illinois River	09/29/2008	17:22	0.200	2.180	2.380	0.043
468455	OKI06594-066	Illinois River	08/05/2009	14:16	0.200	1.070	1.270	0.068
459453	OKI06594-066	Illinois River	03/03/2009	12:45	0.210	2.540	2.750	0.053
457844	OKI06594-067	England Hollow	02/02/2009	11:30	0.370	2.030	2.400	0.034
447296	OKI06594-067	England Hollow	07/29/2008	14:48	0.160	1.910	2.070	0.038
466054	OKI06594-067	England Hollow	06/29/2009	16:50	0.460	1.120	1.580	0.089
447293	OKI06594-071	Barren Fork	07/29/2008	13:08	0.170	1.580	1.750	0.044
458156	OKI06594-071	Barren Fork	02/10/2009	16:12	0.100	1.940	2.040	0.033
444954	OKI06594-071	Barren Fork	06/24/2008	18:34	0.250	1.440	1.690	0.049
457127	OKI06594-072	Evansville Creek	01/13/2009	09:02	0.120	1.050	1.170	0.005
443504	OKI06594-072	Evansville Creek	06/04/2008	10:00	0.150	1.420	1.570	0.026
447840	OKI06594-072	Evansville Creek	08/06/2008	15:02	0.200	2.070	2.270	0.025
466062	OKI06594-072	Evansville Creek	07/01/2009	09:10	0.250	1.480	1.730	0.032

Sample ID	Station ID	Station Description	Sample Date	Sample Time	Nitrogen, Total Kjeldahl (mg/L)	Nitrogen, Nitrate/Nitrite as N (mg/L)	Nitrogen, Total (mg/L)	Phosphorous, Total (mg/L)
457848	OKI06594-076	Beaver Creek	02/03/2009	11:11	0.110	2.200	2.310	0.005
447837	OKI06594-076	Beaver Creek	08/04/2008	15:40	0.290	0.940	1.230	0.030
442270	OKI06594-076	Beaver Creek	05/13/2008	13:43	0.480	1.840	2.320	0.071
458159	OKI06594-079	Barren Fork	02/10/2009	10:17	0.120	1.780	1.900	0.037
452399	OKI06594-079	Barren Fork	10/07/2008	13:00	0.170	2.100	2.270	0.032
449184	OKI06594-079	Barren Fork	08/21/2008	09:54	0.190	1.610	1.800	0.055
466058	OKI06594-079	Barren Fork	06/30/2009	15:52	0.190	0.920	1.110	0.056
457128	OKI06594-080	Evansville Creek	01/13/2009	13:59	0.110	0.920	1.030	0.005
447295	OKI06594-080	Evansville Creek	07/30/2008	14:09	0.170	1.740	1.910	0.033
466063	OKI06594-080	Evansville Creek	07/01/2009	08:10	0.170	0.860	1.030	0.023
449182	OKI06594-081	Flint Creek	08/22/2008	12:55	0.100	3.420	3.520	0.280
443086	OKI06594-081	Flint Creek	05/27/2008	16:59	0.300	2.840	3.140	0.262
457852	OKI06594-081	Flint Creek	02/04/2009	12:50	0.330	3.160	3.490	0.162
459182	OKI06594-086	Barren Fork	02/23/2009	11:37	0.100	1.850	1.950	0.024
468457	OKI06594-086	Barren Fork	08/03/2009	13:31	0.110	0.720	0.830	0.030
470568	OKI06594-086	Barren Fork	08/31/2009	11:30	0.140	0.630	0.770	0.029
466061	OKI06594-086	Barren Fork	06/30/2009	10:50	0.150	1.160	1.310	0.033

Sample ID	Station ID	Station Description	Sample Date	Sample Time	Nitrogen, Total Kjeldahl (mg/L)	Nitrogen, Nitrate/Nitrite as N (mg/L)	Nitrogen, Total (mg/L)	Phosphorous, Total (mg/L)
452017	OKI06594-086	Barren Fork	10/01/2008	14:00	0.190	1.740	1.930	0.013
457372	OKI06594-090	Barren Fork	01/21/2009	13:02	0.100	1.360	1.460	0.014
468456	OKI06594-090	Barren Fork	08/05/2009	11:04	0.110	0.640	0.750	0.026
445242	OKI06594-090	Barren Fork	07/01/2008	14:15	0.150	1.290	1.440	0.028
452728	OKI06594-092	Peavine Creek	10/13/2008	14:30	0.100	0.540	0.640	0.005
457122	OKI06594-092	Peavine Creek	01/14/2009	13:33	0.100	0.840	0.940	0.005
466975	OKI06594-092	Peavine Creek	07/14/2009	17:58	0.100	0.620	0.720	0.007
449186	OKI06594-092	Peavine Creek	08/21/2008	17:50	0.160	0.480	0.640	0.015
457130	OKI06594-093	Park Hill Branch	01/12/2009	11:18	0.270	1.030	1.300	0.022
443503	OKI06594-093	Park Hill Branch	06/03/2008	11:30	0.510	1.070	1.580	0.078
466055	OKI06594-093	Park Hill Branch	06/29/2009	07:20	0.510	0.690	1.200	0.070
464729	OKI06594-093	Park Hill Branch	06/02/2009	09:12	0.520	0.760	1.280	0.071
458618	OKI06594-093	Park Hill Branch	02/17/2009	11:01	0.540	1.430	1.970	0.035
470570	OKI06594-093	Park Hill Branch	08/31/2009	16:22	0.540	1.170	1.710	0.068
466977	OKI06594-093	Park Hill Branch	07/14/2009	07:15	0.730	0.170	0.900	0.110
468952	OKI06594-093	Park Hill Branch	08/10/2009	12:00	0.830	0.320	1.150	0.162
443087	OKI06594-094	Town Branch	05/28/2008	09:22	0.210	0.630	0.840	0.021

Sample ID	Station ID	Station Description	Sample Date	Sample Time	Nitrogen, Total Kjeldahl (mg/L)	Nitrogen, Nitrate/Nitrite as N (mg/L)	Nitrogen, Total (mg/L)	Phosphorous, Total (mg/L)
468953	OKI06594-094	Town Branch	08/10/2009	13:30	0.360	0.780	1.140	0.018
457131	OKI06594-094	Town Branch	01/12/2009	15:28	0.390	0.450	0.840	0.005
449181	OKI06594-100	Crazy Creek	08/22/2008	15:28	0.100	2.550	2.650	0.069
458620	OKI06594-100	Crazy Creek	02/17/2009	17:10	0.230	3.740	3.970	0.078
442703	OKI06594-100	Crazy Creek	05/20/2008	10:50	0.330	3.240	3.570	0.067

Table 20. Appendix B—General Water Quality Data for All Sites.

Sample ID	Station ID	Station Description	Sample Date	Sample Time	DO (%sat)	DO (mg/L)	pH (units)	Specific Conducivity (us/Cm)	Turbidity (NTU)	Water Temperature (°C)
459449	OKI06594-002	Illinois River	03/03/2009	16:45	106.5	12.4	8.49	252.0	2.8	8.7
466986	OKI06594-002	Illinois River	07/14/2009	10:45	95.9	7.4	7.83	293.0	2.1	28.9
450421	OKI06594-002	Illinois River	08/26/2008	17:40	129.1	10.3	7.72	294.0	1.8	26.7
459180	OKI06594-005	Illinois River	02/24/2009	13:30	103.7	12.1	8.27	237.0	2.3	8.8
466982	OKI06594-005	Illinois River	07/13/2009	14:35	151.5	11.4	8.20	307.0	1.7	30.3
447838	OKI06594-005	Illinois River	08/05/2008	21:04	113.2	8.5	7.98	298.0	2.9	30.4
457853	OKI06594-008	Flint Creek	02/04/2009	10:35	104.8	13.2	8.10	282.0	1.2	5.5
434463	OKI06594-008	Flint Creek	01/02/2008	14:40	136.6	17.1	7.84	285.0	2.0	5.7
424710	OKI06594-008	Flint Creek	08/28/2007	12:00	72.6	5.7	7.32	298.5	4.0	25.0
423678	OKI06594-008	Flint Creek	08/14/2007	15:30	106.5	7.9	7.11	286.5	3.0	28.8
464712	OKI06594-009	Illinois River	06/01/2009	14:00	164.6	13.8	8.55	258.0	9.0	24.1
466051	OKI06594-009	Illinois River	06/29/2009	13:10	139.9	10.8	8.23	324.0	2.3	28.8
466980	OKI06594-009	Illinois River	07/13/2009	11:45	96.4	7.7	8.16	320.0	2.1	29.7
459178	OKI06594-009	Illinois River	02/25/2009	10:45	94.6	11.2	8.14	251.0	2.2	7.9
468955	OKI06594-009	Illinois River	08/11/2009	13:30	110.9	8.7	8.02	315.0	3.0	27.8

Sample ID	Station ID	Station Description	Sample Date	Sample Time	DO (%sat)	DO (mg/L)	pH (units)	Specific Conducivity (us/Cm)	Turbidity (NTU)	Water Temperature (^oC)
452730	OKI06594-009	Illinois River	10/14/2008	12:00	90.3	8.3	7.89	260.0	1.6	19.2
436886	OKI06594-011	Tyner creek	02/11/2008	16:22	100.4	11.6	8.23	187.0	1.0	8.9
457374	OKI06594-011	Tyner creek	01/21/2009	16:22	99.3	11.5	7.88	192.0	0.0	8.8
423161	OKI06594-011	Tyner creek	08/07/2007	10:00	75.3	6.4	7.01	204.0	1.0	21.7
424713	OKI06594-011	Tyner creek	08/29/2007	10:30	42.1	3.4	6.91	231.0	1.0	21.6
434464	OKI06594-012	Barren Fork	01/04/2008	11:42	113.4	13.8	8.15	293.0	1.0	6.9
457123	OKI06594-012	Barren Fork	01/14/2009	08:02	87.6	11.1	8.02	288.0	0.3	5.4
423154	OKI06594-012	Barren Fork	08/07/2007	14:00	104.8	8.0	7.19	300.1	3.0	26.9
424074	OKI06594-012	Barren Fork	08/21/2007	13:30	72.5	5.6	7.13	299.0	1.0	26.1
457850	OKI06594-018	Steely Hollow	02/03/2009	17:35	94.9	11.7	8.22	145.0	1.9	6.5
426400	OKI06594-018	Steely Hollow	09/18/2007	08:02	106.6	9.3	8.04	218.6	0.0	21.1
436890	OKI06594-018	Steely Hollow	02/13/2008	09:54	114.5	14.8	7.94	187.0	1.0	4.6
423682	OKI06594-018	Steely Hollow	08/15/2007	13:00	111.7	8.6	7.88	205.4	0.0	26.8
457369	OKI06594-019	Bidding Creek	01/20/2009	13:51	116.5	14.7	8.11	266.0	0.1	5.5
466064	OKI06594-019	Bidding Creek	07/01/2009	12:00	93.6	8.1	7.64	227.0	0.5	22.5
446645	OKI06594-019	Bidding Creek	07/22/2008	18:00	102.7	9.1	7.45	193.0	0.9	21.2
459181	OKI06594-020	Barren Fork	02/23/2009	17:30	119.7	13.6	8.40	171.0	0.3	9.9
468458	OKI06594-020	Barren Fork	08/03/2009	12:00	125.7	9.7	8.19	217.0	3.7	28.8

Sample ID	Station ID	Station Description	Sample Date	Sample Time	DO (%sat)	DO (mg/L)	pH (units)	Specific Conducivity (us/Cm)	Turbidity (NTU)	Water Temperature (°C)
453140	OKI06594-020	Barren Fork	10/20/2008	13:30	121.2	11.3	7.65	211.0	0.3	18.9
459179	OKI06594-021	Illinois River	02/24/2009	09:20	96.4	11.4	8.17	238.0	2.2	8.2
447839	OKI06594-021	Illinois River	08/05/2008	12:02	98.4	7.6	7.79	303.0	2.3	28.7
466978	OKI06594-021	Illinois River	07/15/2009	09:05	79.4	6.2	7.69	321.0	2.2	27.9
457854	OKI06594-024	Flint Creek	02/04/2009	08:55	92.4	11.8	7.81	289.0	1.4	5.0
434465	OKI06594-024	Flint Creek	01/02/2008	13:01	127.8	16.8	7.69	260.0	2.0	3.9
424708	OKI06594-024	Flint Creek	08/27/2007	14:30	99.0	7.2	7.48	281.0	4.3	26.9
423675	OKI06594-024	Flint Creek	08/13/2007	16:30	104.8	7.8	7.40	280.1	9.3	28.6
435940	OKI06594-025	Dripping Springs Branch	01/29/2008	14:20	88.0	10.5	8.07	176.0	1.0	7.6
457847	OKI06594-025	Dripping Springs Branch	02/03/2009	14:53	91.2	11.0	7.44	128.0	5.1	7.5
424709	OKI06594-025	Dripping Springs Branch	08/28/2007	09:15	56.8	4.9	6.77	217.1	1.0	20.4
423676	OKI06594-025	Dripping Springs Branch	08/14/2007	11:30	59.5	5.2	6.51	210.3	0.0	20.3
466056	OKI06594-026	Trib to Waltrip Branch	06/30/2009	09:50	90.6	8.1	7.82	222.0	1.1	20.7
449651	OKI06594-026	Trib to Waltrip Branch	08/27/2008	17:03	94.4	8.3	7.45	193.0	7.5	21.9
457133	OKI06594-028	Evansville Creek	01/13/2009	15:32	135.5	16.9	8.28	208.0	0.9	5.8
434466	OKI06594-028	Evansville Creek	01/03/2008	12:40	131.6	17.1	8.13	225.0	1.0	4.3

Sample ID	Station ID	Station Description	Sample Date	Sample Time	DO (%sat)	DO (mg/L)	pH (units)	Specific Conducivity (us/Cm)	Turbidity (NTU)	Water Temperature (°C)
437517	OKI06594-028	Evansville Creek	02/26/2008	11:15	130.0	15.3	8.06	220.0	3.0	8.1
458151	OKI06594-028	Evansville Creek	02/09/2009	13:50	106.2	11.6	7.98	215.0	2.1	11.6
426403	OKI06594-028	Evansville Creek	09/19/2007	08:01	114.8	9.5	7.52	209.5	1.1	22.8
427074	OKI06594-028	Evansville Creek	09/26/2007	12:05	72.5	6.0	7.45	242.0	3.0	22.1
423158	OKI06594-028	Evansville Creek	08/07/2007	11:20	114.4	8.7	7.37	233.0	2.0	27.4
424073	OKI06594-028	Evansville Creek	08/21/2007	11:30	66.4	5.3	7.33	232.0	3.0	25.1
436888	OKI06594-029	Tyner Creek	02/12/2008	11:03	98.5	11.6	7.80	278.0	1.0	8.3
457366	OKI06594-029	Tyner Creek	01/22/2009	09:03	87.6	10.3	7.65	273.0	0.6	8.2
425030	OKI06594-029	Tyner Creek	09/04/2007	13:00	88.9	7.8	7.39	289.0	1.0	19.9
423680	OKI06594-029	Tyner Creek	08/15/2007	09:00	91.1	8.1	7.11	265.7	6.0	19.1
457367	OKI06594-030	Tailholt Creek	01/20/2009	17:02	128.0	16.1	8.29	283.0	2.0	5.7
466065	OKI06594-030	Tailholt Creek	07/01/2009	13:35	99.1	8.3	7.90	247.0	3.7	24.4
449652	OKI06594-030	Tailholt Creek	08/28/2008	08:08	100.5	8.9	7.39	220.0	5.0	21.3
434467	OKI06594-031	Barren Fork	01/04/2008	14:32	131.6	15.9	8.65	216.0	1.0	7.2
458160	OKI06594-031	Barren Fork	02/10/2009	14:25	112.5	12.2	8.32	221.0	0.6	11.9
423159	OKI06594-031	Barren Fork	08/07/2007	08:30	114.1	8.8	7.52	245.0	1.0	26.6
424712	OKI06594-031	Barren Fork	08/28/2007	09:00	89.6	6.9	7.46	246.0	1.0	26.2
434468	OKI06594-032	Evansville Creek	01/03/2008	10:32	113.5	16.1	8.11	246.0	2.0	1.2

Sample ID	Station ID	Station Description	Sample Date	Sample Time	DO (%sat)	DO (mg/L)	pH (units)	Specific Conducivity (us/Cm)	Turbidity (NTU)	Water Temperature (°C)
423151	OKI06594-032	Evansville Creek	08/07/2007	09:00	98.3	7.3	7.44	277.0	5.0	28.7
424071	OKI06594-032	Evansville Creek	08/20/2007	17:00	65.6	5.0	7.36	273.0	3.3	29.2
457135	OKI06594-032	Evansville Creek	01/13/2009	10:33	ND	ND	ND	ND	1.0	ND
457851	OKI06594-033	Flint Creek	02/04/2009	15:12	135.8	16.5	8.29	292.0	1.3	6.9
423677	OKI06594-033	Flint Creek	08/14/2007	12:30	121.0	9.1	7.59	378.0	1.5	27.6
435939	OKI06594-033	Flint Creek	01/29/2008	11:15	100.5	11.2	7.59	336.0	1.0	10.6
424711	OKI06594-033	Flint Creek	08/28/2007	14:00	97.0	7.3	7.58	385.1	2.0	27.9
436889	OKI06594-035	Tributary to Smith Hollow	02/12/2008	08:19	80.0	9.0	7.65	367.0	1.0	10.4
457368	OKI06594-035	Tributary to Smith Hollow	01/20/2009	11:09	100.7	11.5	7.57	388.0	0.2	9.6
423150	OKI06594-035	Tributary to Smith Hollow	08/06/2007	15:00	96.3	8.5	6.92	382.0	1.0	19.6
424072	OKI06594-035	Tributary to Smith Hollow	08/21/2007	08:30	51.8	4.8	6.82	371.0	1.0	18.0
457129	OKI06594-038	Tributary to Barren Fork	01/12/2009	14:54	111.0	13.5	8.35	208.0	0.7	7.0
434469	OKI06594-038	Tributary to Barren Fork	01/03/2008	14:43	121.4	16.4	8.18	213.0	1.0	2.8
423162	OKI06594-038	Tributary to Barren Fork	08/08/2007	11:00	120.8	9.6	7.82	224.0	1.0	24.6
425031	OKI06594-038	Tributary to Barren Fork	09/04/2007	16:30	97.3	8.3	7.80	244.9	0.7	21.8
457855	OKI06594-041	Flint Creek	02/04/2009	17:00	130.2	15.9	8.44	263.0	1.6	6.7

Sample ID	Station ID	Station Description	Sample Date	Sample Time	DO (%sat)	DO (mg/L)	pH (units)	Specific Conducivity (us/Cm)	Turbidity (NTU)	Water Temperature (°C)
466052	OKI06594-041	Flint Creek	06/29/2009	11:10	119.5	9.8	8.13	306.0	0.4	25.5
468954	OKI06594-041	Flint Creek	08/11/2009	11:52	98.8	8.2	7.84	298.0	4.0	24.7
457371	OKI06594-042	Barren Fork	01/21/2009	10:32	99.3	12.4	7.89	214.0	0.1	5.9
426398	OKI06594-042	Barren Fork	09/17/2007	12:01	127.4	10.2	7.70	220.2	0.4	24.5
435941	OKI06594-042	Barren Fork	01/30/2008	09:15	91.0	11.2	7.65	220.0	1.0	6.6
423679	OKI06594-042	Barren Fork	08/14/2007	17:20	105.9	7.8	7.23	214.5	3.5	28.9
436887	OKI06594-043	Peacheater Creek	02/12/2008	13:50	102.9	11.5	7.94	221.0	1.0	10.6
457843	OKI06594-043	Peacheater Creek	02/02/2009	14:51	91.9	10.1	7.55	159.0	3.0	11.0
424077	OKI06594-043	Peacheater Creek	08/22/2007	11:30	64.4	5.7	6.82	218.0	ND	19.1
423157	OKI06594-043	Peacheater Creek	08/07/2007	17:00	73.7	6.7	6.74	221.0	1.0	18.5
434470	OKI06594-044	Peavine Creek	01/04/2008	09:45	104.4	13.2	8.27	239.0	1.0	5.4
457124	OKI06594-044	Peavine Creek	01/14/2009	12:10	101.8	12.0	7.85	223.0	0.0	8.3
424076	OKI06594-044	Peavine Creek	08/22/2007	10:15	85.3	7.1	7.59	272.0	ND	22.4
423155	OKI06594-044	Peavine Creek	08/07/2007	15:25	ND	ND	ND	ND	1.0	ND
457132	OKI06594-046	Tahlequah Creek	01/12/2009	13:03	121.1	13.9	8.33	317.0	0.7	9.4
434471	OKI06594-046	Tahlequah Creek	01/03/2008	16:14	130.3	15.9	8.14	336.0	1.0	6.8
423681	OKI06594-046	Tahlequah Creek	08/15/2007	11:25	105.1	8.1	7.55	363.9	1.5	26.5
425032	OKI06594-046	Tahlequah Creek	09/05/2007	08:00	78.5	6.3	7.52	417.0	1.0	24.5

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458158	OKI06594-047	Barren Fork	02/10/2009	11:20	100.9	11.4	8.10	230.0	0.6	10.0
436885	OKI06594-047	Barren Fork	02/11/2008	12:25	110.5	13.3	8.07	222.0	1.0	7.3
423674	OKI06594-047	Barren Fork	08/13/2007	14:00	106.0	7.8	7.15	244.1	2.0	28.9
424075	OKI06594-047	Barren Fork	08/21/2007	17:00	ND	ND	ND	ND	1.0	ND
434472	OKI06594-048	Evansville Creek	01/03/2008	09:52	113.5	16.1	8.11	264.0	2.0	1.2
437516	OKI06594-048	Evansville Creek	02/26/2008	08:00	122.1	14.9	8.10	233.0	4.0	6.8
457134	OKI06594-048	Evansville Creek	01/13/2009	11:42	112.6	14.9	7.95	223.0	1.0	3.6
458155	OKI06594-048	Evansville Creek	02/09/2009	11:27	91.3	9.9	7.72	227.0	2.9	11.6
427073	OKI06594-048	Evansville Creek	09/24/2007	16:00	123.0	9.5	7.61	278.5	3.4	26.5
423152	OKI06594-048	Evansville Creek	08/07/2007	10:30	98.3	7.3	7.44	277.0	5.0	28.7
426401	OKI06594-048	Evansville Creek	09/18/2007	12:30	ND	ND	ND	ND	5.1	ND
458619	OKI06594-049	Black Fox Hollow	02/17/2009	15:17	105.9	11.7	7.77	125.0	3.6	11.0
466983	OKI06594-049	Black Fox Hollow	07/13/2009	13:52	101.2	8.4	7.49	228.0	0.2	24.6
450422	OKI06594-049	Black Fox Hollow	08/26/2008	11:35	91.3	8.3	6.79	212.0	0.2	20.0
466973	OKI06594-053	Illinois River	07/15/2009	12:20	148.6	11.2	8.30	307.0	2.7	30.3
468956	OKI06594-053	Illinois River	08/11/2009	17:01	126.0	9.8	8.22	309.0	4.0	28.4
459447	OKI06594-053	Illinois River	03/03/2009	10:30	101.9	12.2	8.20	271.0	4.5	7.6
464713	OKI06594-053	Illinois River	06/01/2009	11:00	97.7	8.7	7.77	273.0	7.3	21.0

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466053	OKI06594-056	Ballard Creek	06/29/2009	15:08	129.2	10.2	8.23	278.0	1.7	27.4
457375	OKI06594-056	Ballard Creek	01/22/2009	08:05	84.7	11.6	8.02	306.0	0.5	2.3
452401	OKI06594-056	Ballard Creek	10/08/2008	14:00	91.1	9.0	7.93	312.0	2.0	15.9
449187	OKI06594-056	Ballard Creek	08/22/2008	08:57	86.3	7.6	7.69	276.0	1.8	21.6
459448	OKI06594-057	Illinois River	03/03/2009	13:10	102.9	12.2	8.29	269.0	3.8	7.9
466979	OKI06594-057	Illinois River	07/15/2009	10:53	113.0	7.8	7.98	322.0	3.9	27.8
468957	OKI06594-057	Illinois River	08/11/2009	18:05	114.6	8.9	7.92	297.0	3.0	27.7
464714	OKI06594-057	Illinois River	06/01/2009	15:00	157.6	13.6	ND	262.0	4.5	22.7
457125	OKI06594-060	Barren Fork	01/14/2009	10:07	115.8	14.2	8.09	224.0	0.0	6.6
449185	OKI06594-060	Barren Fork	08/21/2008	15:34	125.4	10.5	7.97	224.0	0.1	24.3
466976	OKI06594-060	Barren Fork	07/14/2009	15:53	130.9	10.1	7.77	222.0	0.1	29.0
452729	OKI06594-060	Barren Fork	10/13/2008	16:45	121.2	10.9	7.77	197.0	0.0	20.7
459454	OKI06594-061	Illinois River	03/02/2009	15:00	122.3	14.2	8.42	256.0	3.7	8.8
466985	OKI06594-061	Illinois River	07/14/2009	09:35	78.7	6.2	7.69	304.0	1.7	28.0
449650	OKI06594-061	Illinois River	08/27/2008	13:00	123.3	10.0	7.56	286.0	2.5	26.1
464715	OKI06594-062	Barren Fork	06/01/2009	09:12	132.0	11.5	8.32	192.0	2.0	22.0
457373	OKI06594-062	Barren Fork	01/21/2009	08:00	88.9	11.2	8.16	214.0	0.2	5.4
458152	OKI06594-062	Barren Fork	02/09/2009	15:50	112.1	12.3	8.07	195.0	1.1	11.3

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470569	OKI06594-062	Barren Fork	08/31/2009	15:01	119.7	10.0	7.89	203.0	3.6	24.7
444955	OKI06594-062	Barren Fork	06/25/2008	10:00	102.4	8.8	7.70	188.0	1.8	23.2
466981	OKI06594-062	Barren Fork	07/13/2009	16:20	127.7	9.9	7.68	208.0	0.8	28.9
466057	OKI06594-062	Barren Fork	06/30/2009	08:57	87.4	7.4	7.53	221.0	0.6	23.9
468459	OKI06594-062	Barren Fork	08/05/2009	08:35	86.8	7.2	7.32	213.0	3.1	24.6
457849	OKI06594-063	Tyner Creek	02/03/2009	09:02	89.1	10.6	7.54	169.0	0.8	8.0
466059	OKI06594-063	Tyner Creek	06/30/2009	12:30	103.6	9.1	7.48	196.0	0.2	21.8
447297	OKI06594-063	Tyner Creek	07/28/2008	12:42	101.7	8.8	7.35	199.0	0.1	22.6
466060	OKI06594-064	Barren Fork	06/30/2009	14:10	148.6	11.6	8.08	252.0	0.3	27.9
452400	OKI06594-064	Barren Fork	10/07/2008	17:00	104.8	9.6	7.89	254.0	0.5	19.4
449183	OKI06594-064	Barren Fork	08/21/2008	12:12	113.4	9.6	7.75	226.0	0.2	23.6
452016	OKI06594-066	Illinois River	09/29/2008	17:22	13.5	1.6	8.27	273.0	0.8	22.9
459453	OKI06594-066	Illinois River	03/03/2009	12:45	108.9	13.0	8.18	259.0	1.5	7.6
466984	OKI06594-066	Illinois River	07/14/2009	08:20	70.9	5.5	7.68	298.0	1.7	28.6
468455	OKI06594-066	Illinois River	08/05/2009	14:16	114.0	8.8	7.54	293.0	3.6	28.7
457844	OKI06594-067	England Hollow	02/02/2009	11:30	99.3	11.9	7.79	275.0	3.6	7.7
466054	OKI06594-067	England Hollow	06/29/2009	16:50	86.1	7.3	7.78	417.0	1.9	23.6
447296	OKI06594-067	England Hollow	07/29/2008	14:48	88.5	7.5	7.66	392.0	0.6	23.4

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458156	OKI06594-071	Barren Fork	02/10/2009	16:12	99.2	11.0	8.22	160.0	1.1	10.9
444954	OKI06594-071	Barren Fork	06/24/2008	18:34	116.7	9.5	8.11	155.0	1.3	25.6
447293	OKI06594-071	Barren Fork	07/29/2008	13:08	128.1	10.0	7.93	218.0	0.6	28.2
457127	OKI06594-072	Evansville Creek	01/13/2009	09:02	104.0	13.6	8.03	226.0	0.9	3.8
443504	OKI06594-072	Evansville Creek	06/04/2008	10:00	93.8	7.9	7.71	290.0	1.2	23.8
466062	OKI06594-072	Evansville Creek	07/01/2009	09:10	90.0	7.4	7.69	337.0	2.2	24.7
447840	OKI06594-072	Evansville Creek	08/06/2008	15:02	115.6	8.8	7.63	344.0	3.0	29.4
457848	OKI06594-076	Beaver Creek	02/03/2009	11:11	83.0	10.0	7.89	250.0	2.7	7.4
447837	OKI06594-076	Beaver Creek	08/04/2008	15:40	56.6	5.0	7.15	404.0	0.6	21.3
442270	OKI06594-076	Beaver Creek	05/13/2008	13:43	44.7	4.6	6.97	ND	0.3	14.6
466058	OKI06594-079	Barren Fork	06/30/2009	15:52	141.8	10.9	8.04	247.0	0.2	29.1
458159	OKI06594-079	Barren Fork	02/10/2009	10:17	99.0	11.2	8.03	229.0	0.6	9.8
452399	OKI06594-079	Barren Fork	10/07/2008	13:00	104.8	9.6	7.89	254.0	0.5	19.4
449184	OKI06594-079	Barren Fork	08/21/2008	09:54	98.2	8.5	7.48	225.0	0.4	22.6
457128	OKI06594-080	Evansville Creek	01/13/2009	13:59	125.1	16.0	8.26	226.0	0.8	5.1
447295	OKI06594-080	Evansville Creek	07/30/2008	14:09	115.2	9.1	7.64	284.0	0.7	26.6
466063	OKI06594-080	Evansville Creek	07/01/2009	08:10	54.6	4.4	7.44	294.0	1.9	24.9
457852	OKI06594-081	Flint Creek	02/04/2009	12:50	102.4	12.4	7.92	297.0	1.1	7.2

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443086	OKI06594-081	Flint Creek	05/27/2008	16:59	98.5	8.7	7.65	274.0	2.3	21.5
449182	OKI06594-081	Flint Creek	08/22/2008	12:55	98.3	8.3	7.58	333.0	1.2	23.5
459182	OKI06594-086	Barren Fork	02/23/2009	11:37	116.3	13.6	8.05	165.0	0.6	8.7
468457	OKI06594-086	Barren Fork	08/03/2009	13:31	118.1	9.4	7.97	210.0	3.7	26.8
470568	OKI06594-086	Barren Fork	08/31/2009	11:30	111.0	9.2	7.82	210.0	5.2	24.5
466061	OKI06594-086	Barren Fork	06/30/2009	10:50	112.1	9.2	7.81	221.0	0.9	25.3
452017	OKI06594-086	Barren Fork	10/01/2008	14:00	113.4	10.1	7.55	207.0	1.0	21.2
457372	OKI06594-090	Barren Fork	01/21/2009	13:02	109.7	13.2	7.97	213.0	0.2	7.4
445242	OKI06594-090	Barren Fork	07/01/2008	14:15	92.7	8.0	7.76	193.0	1.4	22.4
468456	OKI06594-090	Barren Fork	08/05/2009	11:04	106.8	8.7	7.34	209.0	3.1	25.7
457122	OKI06594-092	Peavine Creek	01/14/2009	13:33	93.1	10.5	7.54	219.0	1.6	10.2
452728	OKI06594-092	Peavine Creek	10/13/2008	14:30	50.2	4.8	7.02	167.0	1.1	17.6
466975	OKI06594-092	Peavine Creek	07/14/2009	17:58	82.8	7.8	6.80	245.0	0.7	18.4
449186	OKI06594-092	Peavine Creek	08/21/2008	17:50	60.5	5.7	6.80	212.0	1.3	18.6
457130	OKI06594-093	Park Hill Branch	01/12/2009	11:18	84.5	10.9	8.12	281.0	3.8	4.5
470570	OKI06594-093	Park Hill Branch	08/31/2009	16:22	120.9	10.1	8.01	236.0	27.0	24.2
468952	OKI06594-093	Park Hill Branch	08/10/2009	12:00	104.0	8.0	7.98	266.0	41.0	27.4
458618	OKI06594-093	Park Hill Branch	02/17/2009	11:01	104.3	12.0	7.69	228.0	6.0	9.2

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443503	OKI06594-093	Park Hill Branch	06/03/2008	11:30	95.3	7.9	7.61	256.0	6.0	24.6
464729	OKI06594-093	Park Hill Branch	06/02/2009	09:12	69.2	6.2	7.56	256.0	18.0	20.7
466977	OKI06594-093	Park Hill Branch	07/14/2009	07:15	33.0	2.6	7.41	267.0	8.1	28.1
466055	OKI06594-093	Park Hill Branch	06/29/2009	07:20	50.6	4.2	ND	286.0	7.7	24.7
457131	OKI06594-094	Town Branch	01/12/2009	15:28	148.4	16.3	9.52	194.0	0.6	11.3
468953	OKI06594-094	Town Branch	08/10/2009	13:30	152.8	10.9	8.81	257.0	2.0	33.3
443087	OKI06594-094	Town Branch	05/28/2008	09:22	149.6	13.3	8.64	279.0	0.4	21.5
458620	OKI06594-100	Crazy Creek	02/17/2009	17:10	103.3	11.8	7.79	193.0	1.7	9.4
442703	OKI06594-100	Crazy Creek	05/20/2008	10:50	113.3	10.8	7.69	231.0	0.0	17.6
449181	OKI06594-100	Crazy Creek	08/22/2008	15:28	107.4	9.1	7.59	248.0	0.5	23.8

Table 21. Appendix C—Habitat Data for All Sites.

Station ID	Station Description	Total Points	sand	silt	clay	Loose Bed Material	Average Embeddedness	Deep Pools (> 0.5 meters)	Point Bars
OKI06594-038	Trib to Barren Fork	64.90	2.0%	0.0%	0.0%	2.0%	2.7%	4.0%	83.0%
OKI06594-056	Ballard Creek	109.10	2.0%	2.0%	0.0%	4.0%	29.2%	32.0%	87.0%
OKI06594-076	Indian Grave Hollow	82.80	10.0%	0.0%	0.0%	10.0%	44.5%	4.0%	70.0%
OKI06594-094	Town Branch	72.70	1.0%	0.0%	0.0%	1.0%	100.0%	0.0%	0.0%
OKI06594-026	Trib to Waltrip Branch	64.60	12.0%	4.0%	0.0%	16.0%	10.4%	0.0%	87.0%
OKI06594-035	Tributary to Smith Hollow	70.70	4.0%	17.0%	0.0%	21.0%	51.3%	0.0%	87.0%
OKI06594-067	England Hollow	86.40	13.0%	8.0%	0.0%	21.0%	51.7%	12.0%	87.0%
OKI06594-092	Peavine Creek	89.90	9.0%	9.0%	0.0%	18.0%	28.3%	16.0%	87.0%
OKI06594-100	Crazy Creek	92.30	24.0%	11.0%	0.0%	35.0%	33.8%	20.0%	87.0%
OKI06594-018	Steely Hollow	81.10	3.0%	2.0%	0.0%	5.0%	38.5%	0.0%	87.0%
OKI06594-025	Dripping Springs Branch	74.30	18.0%	1.0%	0.0%	19.0%	23.5%	0.0%	57.0%
OKI06594-030	Tailholt Creek	93.40	7.0%	1.0%	0.0%	8.0%	27.4%	16.0%	87.0%
OKI06594-043	Peacheater Creek	87.40	5.0%	13.0%	0.0%	18.0%	10.8%	20.0%	70.0%
OKI06594-044	Peavine Creek	79.50	3.0%	1.0%	0.0%	4.0%	4.3%	4.0%	87.0%

Station ID	Station Description	Total Points	sand	silt	clay	Loose Bed Material	Average Embeddedness	Deep Pools (> 0.5 meters)	Point Bars
OKI06594-049	Black Fox Hollow	85.50	5.0%	15.0%	0.0%	20.0%	15.0%	4.0%	22.0%
OKI06594-093	Park Hill Branch	90.00	26.0%	16.0%	0.0%	42.0%	27.9%	20.0%	87.0%
OKI06594-008	Flint Creek	101.60	7.0%	27.0%	0.0%	34.0%	15.3%	28.0%	52.0%
OKI06594-012	Barren Fork	103.40	9.0%	8.0%	0.0%	17.0%	33.8%	36.0%	87.0%
OKI06594-019	Bidding Creek	100.50	1.0%	0.0%	0.0%	1.0%	15.8%	12.0%	65.0%
OKI06594-024	Flint Creek	100.10	5.0%	26.0%	0.0%	31.0%	10.5%	16.0%	65.0%
OKI06594-028	Evansville Creek	100.50	13.0%	6.0%	0.0%	19.0%	17.9%	28.0%	78.5%
OKI06594-029	Tyner Creek	79.20	6.0%	47.0%	0.0%	53.0%	23.5%	20.0%	83.0%
OKI06594-032	Evansville Creek	102.90	27.0%	29.0%	0.0%	56.0%	39.3%	24.0%	65.0%
OKI06594-033	Flint Creek	96.70	30.0%	10.0%	0.0%	40.0%	50.0%	36.0%	83.0%
OKI06594-041	Flint Creek	87.90	12.0%	5.0%	0.0%	17.0%	32.3%	4.0%	87.0%
OKI06594-046	Tahlequah Creek	83.60	9.0%	5.0%	0.0%	14.0%	7.4%	4.0%	87.0%
OKI06594-048	Evansville Creek	93.20	5.0%	37.5%	0.0%	42.5%	45.7%	52.0%	54.5%
OKI06594-072	Evansville Creek	94.50	18.0%	10.0%	0.0%	28.0%	44.3%	16.0%	87.0%
OKI06594-080	Evansville Creek	97.40	19.0%	8.0%	0.0%	27.0%	45.0%	64.0%	87.0%
OKI06594-081	Flint Creek	97.80	39.0%	8.0%	0.0%	47.0%	19.3%	16.0%	87.0%
OKI06594-011	Tyner Creek	78.60	13.0%	11.0%	0.0%	24.0%	41.0%	4.0%	87.0%

Station ID	Station Description	Total Points	sand	silt	clay	Loose Bed Material	Average Embeddedness	Deep Pools (> 0.5 meters)	Point Bars
OKI06594-020	Barren Fork	102.40	8.0%	13.0%	0.0%	21.0%	22.3%	32.0%	87.0%
OKI06594-031	Barren Fork	83.10	21.0%	5.0%	0.0%	26.0%	14.3%	4.0%	87.0%
OKI06594-047	Barren Fork	88.30	20.0%	1.0%	0.0%	21.0%	13.3%	12.0%	87.0%
OKI06594-060	Barren Fork	79.70	2.0%	1.0%	0.0%	3.0%	27.3%	4.0%	87.0%
OKI06594-063	Tyner Creek	92.60	38.0%	10.0%	0.0%	48.0%	47.1%	20.0%	87.0%
OKI06594-064	Barren Fork	94.90	1.0%	4.0%	0.0%	5.0%	18.6%	32.0%	87.0%
OKI06594-071	Barren Fork	97.80	34.5%	11.5%	0.0%	46.0%	44.8%	36.0%	87.0%
OKI06594-079	Barren Fork	95.30	7.0%	4.0%	0.0%	11.0%	25.0%	40.0%	87.0%
OKI06594-005	Illinois River	95.30	5.0%	0.0%	0.0%	5.0%	35.5%	32.0%	87.0%
OKI06594-021	Illinois River	100.80	4.0%	3.0%	0.0%	7.0%	39.0%	20.0%	87.0%
OKI06594-042	Barren Fork	81.50	24.0%	8.0%	0.0%	32.0%	31.5%	8.0%	87.0%
OKI06594-053	Illinois River	103.20	5.0%	3.0%	0.0%	8.0%	15.0%	16.0%	87.0%
OKI06594-057	Illinois River	91.70	8.0%	0.0%	0.0%	8.0%	29.3%	20.0%	52.0%
OKI06594-061	Illinois River	89.70	27.0%	11.0%	0.0%	38.0%	34.3%	16.0%	87.0%
OKI06594-062	Barren Fork	92.70	20.0%	9.0%	0.0%	29.0%	48.4%	4.0%	87.0%
OKI06594-086	Barren Fork	90.10	22.0%	2.0%	0.0%	24.0%	13.7%	8.0%	87.0%
OKI06594-090	Barren Fork	95.10	31.0%	14.0%	0.0%	45.0%	42.5%	16.0%	87.0%

Station ID	Station Description	Total Points	sand	silt	clay	Loose Bed Material	Average Embeddedness	Deep Pools (> 0.5 meters)	Point Bars
OKI06594-002	Illinois River	91.30	6.0%	2.0%	0.0%	8.0%	33.8%	20.0%	87.0%
OKI06594-009	Illinois River	97.80	22.0%	6.0%	0.0%	28.0%	24.0%	16.0%	87.0%
OKI06594-066	Illinois River	80.70	5.0%	1.0%	0.0%	6.0%	37.0%	8.0%	87.0%

Table 22. Appendix C—Fish and Macroinvertebrate Scores and Classifications for All Sites.

Station ID	Station Descriptions	OKFIBI Score	OKFIBI Category	OCCFIBI Score	OCCFIBI Category
OKI06594-002	Illinois River	41	Supporting	77	Good
OKI06594-005	Illinois River	41	Supporting	100	Reference
OKI06594-008	Flint Creek	43	Supporting	83	Good
OKI06594-009	Illinois River	41	Supporting	77	Good
OKI06594-011	Tyner Creek	33	Undetermined	77	Good
OKI06594-012	Barren Fork	39	Supporting	89	Good
OKI06594-018	Steely Hollow	35	Undetermined	83	Good
OKI06594-019	Bidding Creek	41	Supporting	83	Good
OKI06594-020	Barren Fork	41	Supporting	77	Good
OKI06594-021	Illinois River	41	Supporting	94	Excellent
OKI06594-024	Flint Creek	41	Supporting	89	Good
OKI06594-025	Dripping Springs Branch	33	Undetermined	76	Fair
OKI06594-026	Trib to Waltrip Branch	26	Undetermined	64	Fair
OKI06594-028	Evansville Creek	37	Supporting	83	Good
OKI06594-029	Tyner Creek	33	Undetermined	71	Fair
OKI06594-030	Tailholt Creek	39	Supporting	83	Good
OKI06594-031	Barren Fork	41	Supporting	89	Good

Station ID	Station Descriptions	OKFIBI Score	OKFIBI Category	OCCFIBI Score	OCCFIBI Category
OKI06594-032	Evansville Creek	38	Supporting	77	Good
OKI06594-033	Flint Creek	41	Supporting	83	Good
OKI06594-035	Tributary to Smith Hollow	33	Supporting	64	Fair
OKI06594-038	Tributary to Barren Fork	27	Undetermined	52	Poor
OKI06594-041	Flint Creek	37	Supporting	77	Good
OKI06594-042	Barren Fork	39	Supporting	89	Good
OKI06594-043	Peacheater Creek	29	Not Supporting	60	Poor
OKI06594-044	Peavine Creek	27	Not Supporting	60	Poor
OKI06594-046	Tahlequah Creek	39	Supporting	94	Excellent
OKI06594-047	Barren Fork	39	Supporting	89	Good
OKI06594-048	Evansville Creek	39	Supporting	77	Good
OKI06594-049	Black Fox Hollow	27	Undetermined	54	Poor
OKI06594-053	Illinois River	41	Supporting	71	Fair
OKI06594-056	Ballard Creek	41	Supporting	94	Excellent
OKI06594-057	Illinois River	41	Supporting	71	Good
OKI06594-060	Barren Fork	41	Supporting	89	Good
OKI06594-061	Illinois River	43	Supporting	89	Good
OKI06594-062	Barren Fork	39	Supporting	89	Good

Station ID	Station Descriptions	OKFIBI Score	OKFIBI Category	OCCFIBI Score	OCCFIBI Category
OKI06594-063	Tyner Creek	41	Supporting	89	Good
OKI06594-064	Barren Fork	39	Supporting	71	Fair
OKI06594-066	Illinois River	43	Supporting	83	Good
OKI06594-067	England Hollow	29	Not Supporting	66	Fair
OKI06594-071	Barren Fork	39	Supporting	77	Good
OKI06594-072	Evansville Creek	41	Supporting	89	Good
OKI06594-076	Beaver Creek	13	Not Supporting	21	Very Poor
OKI06594-079	Barren Fork	39	Supporting	71	Fair
OKI06594-080	Evansville Creek	41	Supporting	77	Good
OKI06594-081	Flint Creek	41	Supporting	77	Good
OKI06594-086	Barren Fork	39	Supporting	94	Excellent
OKI06594-090	Barren Fork	39	Supporting	77	Good
OKI06594-092	Peavine Creek	29	Not Supporting	54	Poor
OKI06594-093	Park Hill Branch	37	Supporting	70	Fair
OKI06594-094	Town Branch	21	Not Supporting	54	Poor
OKI06594-100	Crazy Creek	31	Supporting	76	Fair

Table 23. Appendix C—Benthic Macroinvertebrate Scores and Classifications for All Sites.

Station ID	Station Description	OKBIBI_RIF Score	OKBIBI_RIF Category	OKBIBI_CMB Score	OKBIBI_CMB Category
OKI06594-002	Illinois River	73	Slightly Impaired	75	Slightly Impaired
OKI06594-005	Illinois River	100	Non-Impaired	93	Non-Impaired
OKI06594-008	Flint Creek	86	Non-Impaired	79	Slightly Impaired
OKI06594-009	Illinois River	55	Slightly Impaired	55	Slightly Impaired
OKI06594-011	Tyner Creek	29	Moderately Impaired	45	Moderately Impaired
OKI06594-012	Barren Fork	97	Non-Impaired	97	Non-Impaired
OKI06594-018	Steely Hollow	80	Slightly Impaired	91	Non-Impaired
OKI06594-019	Bidding Creek	87	Non-Impaired	65	Slightly Impaired
OKI06594-020	Barren Fork	92	Non-Impaired	97	Non-Impaired
OKI06594-021	Illinois River	100	Non-Impaired	87	Non-Impaired
OKI06594-024	Flint Creek	88	Non-Impaired	65	Slightly Impaired
OKI06594-025	Dripping Springs Branch	40	Moderately Impaired	43	Moderately Impaired
OKI06594-026	Trib to Waltrip Branch	76	Slightly Impaired	64	Slightly Impaired
OKI06594-028	Evansville Creek	84	Non-Impaired	60	Slightly Impaired
OKI06594-029	Tyner Creek	86	Non-Impaired	82	Slightly Impaired
OKI06594-030	Tailholt Creek	82	Slightly Impaired	83	Slightly Impaired
OKI06594-031	Barren Fork	68	Slightly Impaired	67	Slightly Impaired
OKI06594-032	Evansville Creek	61	Slightly Impaired	60	Slightly Impaired
OKI06594-033	Flint Creek	90	Non-Impaired	66	Slightly Impaired
OKI06594-035	Tributary to Smith Hollow	80	Slightly Impaired	82	Slightly Impaired
OKI06594-038	Tributary to Barren Fork	89	Non-Impaired	83	Non-Impaired
OKI06594-041	Flint Creek	67	Slightly Impaired	75	Slightly Impaired

Station ID	Station Description	OKBIBI_RIF Score	OKBIBI_RIF Category	OKBIBI_CMB Score	OKBIBI_CMB Category
OKI06594-042	Barren Fork	91	Non-Impaired	94	Non-Impaired
OKI06594-043	Peacheater Creek	97	Non-Impaired	79	Slightly Impaired
OKI06594-044	Peavine Creek	81	Slightly Impaired	88	Non-Impaired
OKI06594-046	Tahlequah Creek	36	Moderately Impaired	39	Moderately Impaired
OKI06594-047	Barren Fork	82	Slightly Impaired	54	Slightly Impaired
OKI06594-048	Evansville Creek	58	Slightly Impaired	52	Moderately Impaired
OKI06594-049	Black Fox Hollow	51	Moderately Impaired	80	Slightly Impaired
OKI06594-053	Illinois River	96	Non-Impaired	96	Non-Impaired
OKI06594-056	Ballard Creek	79	Slightly Impaired	70	Slightly Impaired
OKI06594-057	Illinois River	100	Non-Impaired	70	Slightly Impaired
OKI06594-060	Barren Fork	82	Slightly Impaired	80	Slightly Impaired
OKI06594-061	Illinois River	71	Slightly Impaired	78	Slightly Impaired
OKI06594-062	Barren Fork	79	Slightly Impaired	75	Slightly Impaired
OKI06594-063	Tyner Creek	86	Non-Impaired	91	Non-Impaired
OKI06594-064	Barren Fork	100	Non-Impaired	63	Slightly Impaired
OKI06594-066	Illinois River	90	Non-Impaired	85	Non-Impaired
OKI06594-067	England Hollow	83	Slightly Impaired	67	Slightly Impaired
OKI06594-071	Barren Fork	71	Slightly Impaired	58	Slightly Impaired
OKI06594-072	Evansville Creek	87	Non-Impaired	83	Slightly Impaired
OKI06594-076	Beaver Creek	37	Moderately Impaired	48	Moderately Impaired
OKI06594-079	Barren Fork	73	Moderately Impaired	50	Moderately Impaired
OKI06594-080	Evansville Creek	47	Moderately Impaired	53	Moderately Impaired
OKI06594-081	Flint Creek	93	Non-Impaired	70	Slightly Impaired

Station ID	Station Description	OKBIBI_RIF Score	OKBIBI_RIF Category	OKBIBI_CMB Score	OKBIBI_CMB Category
OKI06594-086	Barren Fork	68	Slightly Impaired	80	Slightly Impaired
OKI06594-090	Barren Fork	66	Slightly Impaired	88	Non-Impaired
OKI06594-092	Peavine Creek	82	Slightly Impaired	75	Slightly Impaired
OKI06594-093	Park Hill Branch	70	Slightly Impaired	69	Slightly Impaired
OKI06594-094	Town Branch	31	Moderately Impaired	42	Moderately Impaired
OKI06594-100	Crazy Creek	101	Reference	102	Reference

Table 24. Appendix C—Benthic and Sestonic Algal Data for All Sites.

Station ID	Station Description	Sample Date	Sample Time	Sestonic Sample ID	Sestonic Chlorophyl A (mg/m^3)	Benthic Sample ID	Benthic Chlorophyl A (mg/m^2)
OKI06594-002	Illinois River	03/03/2009	17:30	460813	0.530	460004	12.9167
OKI06594-002	Illinois River	08/26/2008	14:01	451674	1.490	451715	15.2083
OKI06594-002	Illinois River	07/14/2009	10:43	467075	2.600	467098	25.6250
OKI06594-005	Illinois River	02/24/2009	13:28	460821	0.490	460010	6.8229
OKI06594-005	Illinois River	07/13/2009	14:36	467083	2.820	451702	10.5208
OKI06594-005	Illinois River	08/05/2008	19:00	451660	4.410	467104	34.7917
OKI06594-008	Flint Creek	08/14/2007	21:45	431597	0.520	458821	7.5521
OKI06594-008	Flint Creek	02/04/2009	10:30	460838	0.540	425910	15.4167
OKI06594-008	Flint Creek	08/28/2007	12:01	431595	1.340	425894	56.1458
OKI06594-009	Illinois River	08/11/2009	13:31	471286	0.100	467106	12.8125
OKI06594-009	Illinois River	02/25/2009	10:50	460809	0.640	460005	20.1042
OKI06594-009	Illinois River	06/29/2009	13:12	467061	2.670	469765	20.2083
OKI06594-009	Illinois River	07/13/2009	11:48	467082	2.770	467102	21.8750
OKI06594-011	Tyner creek	08/29/2007	10:31	431589	0.100	457605	15.3125
OKI06594-011	Tyner creek	08/08/2007	10:00	431600	0.250	425904	25.0000
OKI06594-011	Tyner creek	01/21/2009	16:20	460792	0.320	425893	36.7708

Station ID	Station Description	Sample Date	Sample Time	Sestonic Sample ID	Sestonic Chlorophyl A (mg/m^3)	Benthic Sample ID	Benthic Chlorophyl A (mg/m^2)
OKI06594-012	Barren Fork	08/21/2007	13:31	431591	0.100	425919	36.6667
OKI06594-012	Barren Fork	01/14/2009	08:01	460771	0.720	425900	49.8958
OKI06594-012	Barren Fork	08/07/2077	14:00	431617	0.770	457623	208.3333
OKI06594-018	Steely Hollow	02/03/2009	17:30	460834	0.350	458828	33.0208
OKI06594-018	Steely Hollow	09/18/2007	08:00	431624	0.590	425915	35.3125
OKI06594-018	Steely Hollow	08/14/2007	13:01	431599	1.170	433241	57.7083
OKI06594-019	Bidding Creek	07/22/2008	17:30	451654	0.390	467119	3.4271
OKI06594-019	Bidding Creek	07/01/2009	12:03	467073	0.430	451694	9.2917
OKI06594-019	Bidding Creek	01/20/2009	13:50	460794	0.720	457610	24.3750
OKI06594-020	Barren Fork	02/23/2009	15:00	460808	0.400	460006	19.1667
OKI06594-020	Barren Fork	08/03/2009	17:31	471280	1.370	467097	21.6667
OKI06594-020	Barren Fork	07/14/2009	13:30	467081	1.550	469763	78.8542
OKI06594-021	Illinois River	07/15/2009	09:00	467087	0.290	460011	12.5000
OKI06594-021	Illinois River	02/24/2009	09:21	460820	0.700	467121	25.1042
OKI06594-021	Illinois River	08/05/2008	12:01	451662	3.260	451700	31.2500
OKI06594-024	Flint Creek	02/04/2009	08:50	460840	0.670	425911	8.1042
OKI06594-024	Flint Creek	08/27/2007	14:31	431584	1.000	425897	20.6250

Station ID	Station Description	Sample Date	Sample Time	Sestonic Sample ID	Sestonic Chlorophyl A (mg/m^3)	Benthic Sample ID	Benthic Chlorophyl A (mg/m^2)
OKI06594-024	Flint Creek	08/13/2007	16:35	431607	7.040	458822	43.3333
OKI06594-025	Dripping Springs Branch	08/28/2007	09:16	431594	0.100	458826	4.2292
OKI06594-025	Dripping Springs Branch	02/03/2009	14:50	460835	0.120	425909	40.5208
OKI06594-025	Dripping Springs Branch	08/14/2007	11:31	431609	0.280	425895	59.6875
OKI06594-026	Trib to Waltrip Branch	06/30/2009	09:55	467067	0.420	451711	3.9688
OKI06594-026	Trib to Waltrip Branch	08/27/2008	17:01	451672	0.520	467112	6.6146
OKI06594-026	Trib to Waltrip Branch	01/21/2009	14:47	460789	0.560	457609	23.3333
OKI06594-028	Evansville Creek	02/09/2009	13:55	460824	0.100	433246	2.0417
OKI06594-028	Evansville Creek	08/21/2007	11:31	431592	0.150	425901	8.1042
OKI06594-028	Evansville Creek	01/13/2009	15:31	460763	0.760	458808	9.2813
OKI06594-028	Evansville Creek	09/19/2007	08:00	431625	0.900	457615	41.0417
OKI06594-028	Evansville Creek	08/20/2007	14:30	431585	1.780	433239	66.1458
OKI06594-028	Evansville Creek	09/26/2007	12:00	431627	8.500	ND	ND
OKI06594-029	Tyner Creek	09/04/2007	13:02	429264	0.650	425888	13.1250

Station ID	Station Description	Sample Date	Sample Time	Sestonic Sample ID	Sestonic Chlorophyl A (mg/m^3)	Benthic Sample ID	Benthic Chlorophyl A (mg/m^2)
OKI06594-029	Tyner Creek	01/22/2009	09:31	460785	0.810	425906	19.3750
OKI06594-029	Tyner Creek	08/15/2007	09:01	431611	3.340	457604	61.1458
OKI06594-030	Tailholt Creek	08/28/2008	08:12	451675	1.140	451714	2.9479
OKI06594-030	Tailholt Creek	01/20/2009	17:08	460795	0.610	467120	11.0417
OKI06594-030	Tailholt Creek	07/01/2009	13:35	467074	3.680	457612	52.2917
OKI06594-031	Barren Fork	02/10/2009	14:27	460798	0.920	458814	15.2083
OKI06594-031	Barren Fork	08/29/2007	09:00	431588	0.440	425913	28.6458
OKI06594-031	Barren Fork	08/08/2007	08:30	431602	0.750	425892	102.9167
OKI06594-032	Evansville Creek	01/13/2009	10:32	460762	0.270	425916	1.7604
OKI06594-032	Evansville Creek	08/20/2007	17:01	431590	0.920	457614	18.1250
OKI06594-032	Evansville Creek	08/07/2007	09:00	431612	2.790	425899	32.8125
OKI06594-033	Flint Creek	08/28/2007	14:01	431605	0.750	458823	24.0625
OKI06594-033	Flint Creek	08/14/2007	12:31	431608	0.780	425907	62.2917
OKI06594-033	Flint Creek	02/04/2009	15:20	460839	0.940	425896	143.7500
OKI06594-035	Tributary to Smith Hollow	08/21/2007	08:31	431593	0.100	425902	15.2083
OKI06594-035	Tributary to Smith Hollow	08/06/2007	15:00	431613	0.410	425923	18.9583

Station ID	Station Description	Sample Date	Sample Time	Sestonic Sample ID	Sestonic Chlorophyl A (mg/m^3)	Benthic Sample ID	Benthic Chlorophyl A (mg/m^2)
OKI06594-035	Tributary to Smith Hollow	01/20/2009	11:10	460790	0.630	457611	24.7917
OKI06594-038	Tributary to Barren Fork	08/06/2007	11:00	431614	0.440	425914	30.2083
OKI06594-038	Tributary to Barren Fork	01/12/2009	14:53	460767	14.900	425889	77.2917
OKI06594-038	Tributary to Barren Fork	09/04/2007	12:00	429265	1.530	457619	170.8333
OKI06594-041	Flint Creek	06/29/2009	11:16	467060	1.150	469769	15.6250
OKI06594-041	Flint Creek	08/11/2009	11:01	471285	1.370	467107	26.4583
OKI06594-041	Flint Creek	02/04/2009	17:05	460841	2.620	458820	64.7917
OKI06594-042	Barren Fork	09/17/2007	12:00	431620	1.400	433245	25.8333
OKI06594-042	Barren Fork	08/14/2007	17:20	431598	0.100	425908	38.6458
OKI06594-042	Barren Fork	01/21/2009	10:31	460788	0.480	457608	69.8958
OKI06594-043	Peacheater Creek	08/22/2007	11:35	431587	0.100	458832	5.7188
OKI06594-043	Peacheater Creek	08/07/2077	21:35	431619	0.150	425922	19.6875
OKI06594-043	Peacheater Creek	02/02/2009	14:50	460829	0.190	425891	31.4583
OKI06594-044	Peavine Creek	08/07/2077	15:25	431618	0.380	425920	60.0000
OKI06594-044	Peavine Creek	08/22/2007	10:16	431586	0.100	457622	7.5417

Station ID	Station Description	Sample Date	Sample Time	Sestonic Sample ID	Sestonic Chlorophyl A (mg/m^3)	Benthic Sample ID	Benthic Chlorophyl A (mg/m^2)
OKI06594-044	Peavine Creek	01/14/2009	12:05	460772	0.480	425890	55.1042
OKI06594-046	Tahlequah Creek	08/15/2007	11:26	431610	1.590	425887	51.6667
OKI06594-046	Tahlequah Creek	09/05/2007	08:06	429267	2.410	425905	84.2708
OKI06594-046	Tahlequah Creek	01/12/2009	13:01	460764	3.440	457616	177.0833
OKI06594-047	Barren Fork	08/21/2007	17:01	431596	0.100	458816	6.1042
OKI06594-047	Barren Fork	02/10/2009	11:28	460805	0.100	425912	35.8333
OKI06594-047	Barren Fork	08/13/2007	13:59	431606	0.760	425903	115.6250
OKI06594-048	Evansville Creek	09/18/2007	12:31	431623	0.990	433242	6.4167
OKI06594-048	Evansville Creek	02/09/2009	11:35	460826	2.080	425917	6.5417
OKI06594-048	Evansville Creek	08/07/2007	11:21	431603	2.730	458810	22.9167
OKI06594-048	Evansville Creek	01/13/2009	11:41	460768	0.770	457620	2.1667
OKI06594-048	Evansville Creek	08/07/2007	11:25	431616	1.540	433240	4.1667
OKI06594-048	Evansville Creek	09/24/2007	16:15	431626	4.460	425898	12.6042
OKI06594-049	Evansville Creek	08/07/2007	11:20	ND	ND	425885	72.2917
OKI06594-049	Black Fox Hollow	08/26/2008	11:40	451673	0.100	458806	4.3021
OKI06594-049	Black Fox Hollow	07/13/2009	13:40	467086	0.170	467105	5.2917
OKI06594-049	Black Fox Hollow	02/17/2009	15:16	460803	0.200	451713	11.4583

Station ID	Station Description	Sample Date	Sample Time	Sestonic Sample ID	Sestonic Chlorophyl A (mg/m^3)	Benthic Sample ID	Benthic Chlorophyl A (mg/m^2)
OKI06594-053	Illinois River	03/03/2009	10:31	460815	0.750	469766	21.1458
OKI06594-053	Illinois River	08/11/2009	17:00	471287	1.850	467122	40.3125
OKI06594-053	Illinois River	07/15/2009	12:25	467088	4.270	460002	59.4792
OKI06594-056	Ballard Creek	01/22/2009	08:10	460786	0.590	451706	19.4792
OKI06594-056	Ballard Creek	06/29/2009	15:05	467062	0.770	467108	36.4583
OKI06594-056	Ballard Creek	08/22/2008	08:56	451668	1.370	457603	50.3125
OKI06594-057	Illinois River	03/03/2009	13:13	460814	0.790	460003	11.1458
OKI06594-057	Illinois River	08/11/2009	18:00	471288	2.070	469767	23.2292
OKI06594-057	Illinois River	07/15/2009	10:50	467085	3.580	467123	27.6042
OKI06594-060	Barren Fork	08/21/2008	15:30	451665	0.650	451708	21.6667
OKI06594-060	Barren Fork	01/14/2009	10:10	460773	0.650	467096	40.2083
OKI06594-060	Barren Fork	07/14/2009	15:55	467080	0.980	457624	55.8333
OKI06594-061	Illinois River	03/02/2009	15:02	460817	0.420	460000	18.0208
OKI06594-061	Illinois River	08/27/2008	13:01	451671	1.530	467099	22.2917
OKI06594-061	Illinois River	07/14/2009	09:30	467076	2.260	451712	54.6875
OKI06594-062	Barren Fork	01/21/2009	08:05	460787	0.730	471293	17.1875
OKI06594-062	Barren Fork	02/09/2009	15:50	460825	0.800	451688	24.8958

Station ID	Station Description	Sample Date	Sample Time	Sestonic Sample ID	Sestonic Chlorophyl A (mg/m^3)	Benthic Sample ID	Benthic Chlorophyl A (mg/m^2)
OKI06594-062	Barren Fork	08/31/2009	15:03	471292	1.130	458809	25.1042
OKI06594-062	Barren Fork	07/13/2009	16:20	467084	1.180	467103	26.7708
OKI06594-062	Barren Fork	08/05/2009	08:40	471279	1.380	467113	35.6250
OKI06594-062	Barren Fork	06/30/2009	08:45	467066	1.600	469764	59.0625
OKI06594-062	Barren Fork	06/25/2008	13:00	451648	2.120	457606	67.0833
OKI06594-063	Tyner Creek	07/28/2008	16:10	451655	0.310	451695	1.5000
OKI06594-063	Tyner Creek	02/03/2009	09:01	460836	0.320	458827	11.1458
OKI06594-063	Tyner Creek	06/30/2009	12:35	467068	0.360	467111	12.1875
OKI06594-064	Barren Fork	02/10/2009	08:00	460801	0.580	467114	7.5521
OKI06594-064	Barren Fork	08/21/2008	12:11	451666	0.770	451707	11.4583
OKI06594-064	Barren Fork	06/30/2009	14:10	467064	1.150	458819	25.4167
OKI06594-066	Illinois River	03/02/2009	12:45	460818	0.450	460001	18.1250
OKI06594-066	Illinois River	08/05/2009	14:15	471283	1.730	467100	44.8958
OKI06594-066	Illinois River	07/14/2009	08:50	467077	2.260	469760	46.0417
OKI06594-067	England Hollow	02/02/2009	11:33	460830	1.890	458831	11.6667
OKI06594-067	England Hollow	07/29/2008	14:25	451658	0.310	451698	6.5521
OKI06594-067	England Hollow	06/29/2009	16:53	467063	0.760	467109	8.9271

Station ID	Station Description	Sample Date	Sample Time	Sestonic Sample ID	Sestonic Chlorophyl A (mg/m^3)	Benthic Sample ID	Benthic Chlorophyl A (mg/m^2)
OKI06594-071	Barren Fork	07/29/2008	12:00	451656	1.450	451696	15.6250
OKI06594-071	Barren Fork	02/10/2009	16:14	460804	0.800	451689	4.9167
OKI06594-071	Barren Fork	06/25/2008	16:35	451649	0.830	458817	16.0417
OKI06594-072	Evansville Creek	01/13/2009	09:05	460769	0.720	451687	8.5521
OKI06594-072	Evansville Creek	06/04/2008	10:05	451647	0.790	467117	33.6458
OKI06594-072	Evansville Creek	08/06/2008	15:15	451663	2.940	451703	34.5833
OKI06594-072	Evansville Creek	07/01/2009	09:10	467071	15.000	457621	107.2917
OKI06594-076	Beaver Creek	02/03/2009	11:10	460833	0.100	458825	5.1667
OKI06594-076	Beaver Creek	08/04/2008	15:35	451661	0.500	451701	7.1875
OKI06594-076	Beaver Creek	05/13/2008	13:40	451639	76.900	451679	119.7917
OKI06594-079	Barren Fork	08/21/2008	09:51	451664	0.670	451710	5.3542
OKI06594-079	Barren Fork	02/10/2009	10:16	460806	0.720	467116	35.6250
OKI06594-079	Barren Fork	06/30/2009	15:55	467065	1.350	458818	78.2292
OKI06594-080	Evansville Creek	01/13/2009	14:05	460761	0.520	457613	3.5521
OKI06594-080	Evansville Creek	07/30/2008	12:00	451659	1.110	467118	6.2083
OKI06594-080	Evansville Creek	07/01/2009	08:15	467072	29.100	451699	40.7292
OKI06594-081	Flint Creek	08/22/2008	12:54	451669	0.620	451684	4.5729

Station ID	Station Description	Sample Date	Sample Time	Sestonic Sample ID	Sestonic Chlorophyl A (mg/m^3)	Benthic Sample ID	Benthic Chlorophyl A (mg/m^2)
OKI06594-081	Flint Creek	02/04/2009	12:55	460796	0.650	451705	4.8125
OKI06594-081	Flint Creek	05/27/2008	18:00	451644	1.880	458824	24.4792
OKI06594-086	Barren Fork	02/23/2009	11:50	460822	0.270	460007	20.2083
OKI06594-086	Barren Fork	08/03/2009	13:33	471281	1.290	467115	26.4583
OKI06594-086	Barren Fork	08/31/2009	11:30	471290	1.490	469762	27.1875
OKI06594-086	Barren Fork	06/30/2009	10:51	467070	2.040	ND	ND
OKI06594-090	Barren Fork	01/21/2009	13:01	460793	0.830	469761	26.8750
OKI06594-090	Barren Fork	08/05/2009	11:01	471282	1.690	451693	44.2708
OKI06594-090	Barren Fork	07/01/2008	14:22	451653	2.970	457607	119.7917
OKI06594-092	Peavine Creek	01/14/2009	13:35	460774	0.230	451709	4.3646
OKI06594-092	Peavine Creek	08/21/2008	15:53	451667	0.660	467095	10.9375
OKI06594-092	Peavine Creek	07/14/2009	18:05	467079	1.100	457625	12.8125
OKI06594-093	Park Hill Branch	06/03/2008	11:42	451646	2.650	467101	0.0000
OKI06594-093	Park Hill Branch	01/12/2009	11:20	460766	4.440	458807	0.4531
OKI06594-093	Park Hill Branch	02/17/2009	11:02	460797	6.270	467110	1.7708
OKI06594-093	Park Hill Branch	06/30/2009	07:20	467069	6.760	457618	2.1250
OKI06594-093	Park Hill Branch	08/31/2009	15:36	471291	8.550	451685	2.3750

Station ID	Station Description	Sample Date	Sample Time	Sestonic Sample ID	Sestonic Chlorophyl A (mg/m^3)	Benthic Sample ID	Benthic Chlorophyl A (mg/m^2)
OKI06594-093	Park Hill Branch	07/14/2009	07:10	467078	12.060	471295	10.0833
OKI06594-093	Park Hill Branch	08/10/2009	12:01	471289	31.000	ND	ND
OKI06594-094	Town Branch	05/28/2008	11:15	451643	3.090	469770	16.7708
OKI06594-094	Town Branch	01/12/2009	15:45	460765	5.320	451683	98.9583
OKI06594-094	Town Branch	08/10/2009	13:31	471284	7.520	457617	151.0417
OKI06594-100	Crazy Creek	08/22/2008	15:27	451670	0.240	451704	9.8958
OKI06594-100	Crazy Creek	02/17/2009	17:00	460802	0.400	458805	45.8333
OKI06594-100	Crazy Creek	05/20/2008	10:30	451641	4.670	451681	75.1042

Table 25. Appendix C—Condition Binomials for all Sites.

SITE_ID	Station Description	Fish Binomial	BMI_RIF Binomial	BMI_CMB Binomial	BenChl 100	BenChl Mean	BenChl75	BenChlMed	BenChl25	SesChl10	SesChlMean	SesChl75	SesChlMed	SesChl25
OKI06594-002	Illinois River	GOOD	POOR	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-005	Illinois River	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-008	Flint Creek	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-009	Illinois River	GOOD	POOR	POOR	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-011	Tyner Creek	GOOD	POOR	POOR	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-012	Barren Fork	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-018	Steely Hollow	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-019	Bidding Creek	GOOD	GOOD	POOR	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR
OKI06594-020	Barren Fork	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-021	Illinois River	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-024	Flint Creek	GOOD	GOOD	POOR	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-025	Dripping Springs Branch	GOOD	POOR	POOR	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR

SITE_ID	Station Description	Fish Binomial	BMI_RIF Binomial	BMI_CMB Binomial	BenChl 100	BenChl Mean	BenChl75	BenChlMed	BenChl25	SesChl10	SesChlMean	SesChl75	SesChlMed	SesChl25
OKI06594-026	Trib to Waltrip Branch	POOR	GOOD	POOR	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR
OKI06594-028	Evansville Creek	GOOD	GOOD	POOR	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-029	Tyner Creek	POOR	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-030	Tailholt Creek	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-031	Barren Fork	GOOD	POOR	POOR	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-032	Evansville Creek	GOOD	POOR	POOR	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-033	Flint Creek	GOOD	GOOD	POOR	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-035	Tributary to Smith Hollow	POOR	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-038	Tributary to Barren Fork	POOR	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-041	Flint Creek	GOOD	POOR	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-042	Barren Fork	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-043	Peacheater Creek	POOR	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR

SITE_ID	Station Description	Fish Binomial	BMI_RIF Binomial	BMI_CMB Binomial	BenChl 100	BenChl Mean	BenChl75	BenChlMed	BenChl25	SesChl10	SesChlMean	SesChl75	SesChlMed	SesChl25
OKI06594-044	Peavine Creek	POOR	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-046	Tahlequah Creek	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-047	Barren Fork	GOOD	GOOD	POOR	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-048	Evansville Creek	GOOD	POOR	POOR	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-049	Black Fox Hollow	POOR	POOR	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR
OKI06594-053	Illinois River	POOR	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-056	Ballard Creek	GOOD	GOOD	POOR	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-057	Illinois River	POOR	GOOD	POOR	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-060	Barren Fork	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-061	Illinois River	GOOD	POOR	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-062	Barren Fork	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-063	Tyner Creek	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR

SITE_ID	Station Description	Fish Binomial	BMI_RIF Binomial	BMI_CMB Binomial	BenChl 100	BenChl Mean	BenChl75	BenChlMed	BenChl25	SesChl10	SesChlMean	SesChl75	SesChlMed	SesChl25
OKI06594-064	Barren Fork	POOR	GOOD	POOR	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-066	Illinois River	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-067	England Hollow	POOR	GOOD	POOR	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR
OKI06594-071	Barren Fork	GOOD	POOR	POOR	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR
OKI06594-072	Evansville Creek	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-076	Beaver Creek	POOR	POOR	POOR	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-079	Barren Fork	POOR	POOR	POOR	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-080	Evansville Creek	GOOD	POOR	POOR	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-081	Flint Creek	GOOD	GOOD	POOR	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR
OKI06594-086	Barren Fork	GOOD	POOR	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-090	Barren Fork	GOOD	POOR	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-092	Peavine Creek	POOR	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR
OKI06594-093	Park Hill	POOR	POOR	POOR	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR

SITE_ID	Station Description	Fish Binomial	BMI_RIF Binomial	BMI_CMB Binomial	BenChl 100	BenChl Mean	BenChl75	BenChlMed	BenChl25	SesChl10	SesChlMean	SesChl75	SesChlMed	SesChl25
	Branch													
OKI06594-094	Town Branch	POOR	POOR	POOR	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
OKI06594-100	Crazy Creek	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR

Table 26. Appendix D—Comparison of OKFIBI to various nutrient, general water quality, and habitat parameters.

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
1	36	34.7	20.1	5.075				X										
1	13.3	11.5	44	5.9074								X						
1	13.1	11.3	44.2	5.9144														X
1	12.1	10.4	45.2	5.9456	X													
1	10.4	8.6	47	6.0042									X					
2	44.4	42.1	13.3	4.7789				X				X						
2	41.3	38.9	16.6	4.9094				X						X				
2	40.9	38.4	17	4.9285				X					X					
2	40.5	38.1	17.4	4.9419				X										X
2	39.8	37.3	18.1	4.9711	X			X										
3	53.3	50.3	6	4.4284				X				X	X					
3	52.3	49.3	7	4.4725				X				X		X				
3	48.8	45.5	10.7	4.6345				X				X						X
3	48.8	45.5	10.8	4.6367				X				X			X			
3	46.4	43	13.2	4.7418	X			X				X						
4	56.7	53	4.4	4.3057				X				X		X				X
4	54.9	50.9	6.3	4.3981				X	X			X	X					
4	54	50	7.2	4.4392				X				X	X					X
4	54	50	7.3	4.4405				X				X	X				X	
4	53.9	49.9	7.4	4.4465	X			X				X	X					
5	59.1	54.6	3.9	4.2308				X				X		X	X			X
5	58.5	53.9	4.5	4.2623				X	X			X		X				X
5	57.2	52.4	5.9	4.3316				X				X	X	X				X

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
5	57.2	52.4	5.9	4.3324	X			X				X		X				X
5	57	52.2	6.1	4.3408				X				X		X			X	X
6	59.8	54.3	5.2	4.2449				X	X			X		X	X			X
6	59.8	54.3	5.2	4.2462	X			X				X		X	X			X
6	59.6	54.1	5.4	4.2551				X				X		X	X		X	X
6	59.2	53.7	5.8	4.2741				X		X		X		X	X			X
6	59.2	53.7	5.8	4.2746				X				X	X	X	X			X
7	61.1	54.7	5.9	4.2259	X	X	X	X				X		X				X
7	60.9	54.6	6	4.2323	X	X		X				X		X	X			X
7	60.6	54.2	6.3	4.2507		X	X	X	X			X		X				X
7	60.5	54.1	6.4	4.2555	X		X	X				X		X	X			X
7	60.3	53.8	6.7	4.2688	X			X	X			X		X	X			X
8	63.6	56.6	5.2	4.1355	X	X	X	X	X			X		X				X
8	63.3	56.3	5.5	4.1515	X	X	X	X				X		X	X			X
8	62.2	55.1	6.6	4.2099	X	X	X	X				X		X			X	X
8	62.1	54.9	6.7	4.216	X	X	X	X				X	X	X				X
8	61.7	54.4	7.2	4.2411	X	X	X	X	X				X	X				X
9	64.5	56.7	6.3	4.1337	X	X	X	X				X		X	X		X	X
9	64.4	56.6	6.3	4.1359	X	X	X	X	X			X		X	X			X
9	64.3	56.5	6.4	4.143	X	X	X	X	X			X	X	X				X
9	64.2	56.4	6.5	4.1487	X	X	X	X	X			X		X			X	X
9	63.8	55.8	7	4.1743	X	X	X	X				X	X	X	X			X
10	65.2	56.5	7.5	4.1413	X	X	X	X	X			X		X	X		X	X
10	64.9	56.1	7.8	4.1607	X	X	X	X	X			X	X	X	X			X
10	64.8	56	7.9	4.165	X	X	X	X		X		X		X	X		X	X
10	64.7	55.8	8.1	4.1725	X	X	X	X				X		X	X	X	X	X
10	64.6	55.8	8.1	4.1771	X	X	X	X	X			X	X	X			X	X

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
11	65.3	55.6	9.4	4.1855	X	X	X	X	X			X	X	X	X		X	X
11	65.3	55.5	9.4	4.1868	X	X	X	X	X	X		X		X	X		X	X
11	65.3	55.5	9.4	4.1891	X	X	X	X	X			X		X	X	X	X	X
11	65.2	55.4	9.5	4.1939	X	X	X	X	X	X		X		X	X		X	X
11	65.2	55.4	9.5	4.1949	X	X	X	X		X		X		X	X	X	X	X
12	65.5	54.6	11.2	4.2305	X	X	X	X	X	X		X		X	X	X	X	X
12	65.4	54.5	11.3	4.2344	X	X	X	X	X	X		X	X	X	X		X	X
12	65.4	54.5	11.3	4.235	X	X	X	X	X			X	X	X	X	X	X	X
12	65.4	54.4	11.3	4.2385	X	X	X	X	X	X	x	X		X	X		X	X
12	65.4	54.4	11.3	4.2399	X	X	X	X	X	X		X	X	X	X		X	X
13	65.6	53.5	13.1	4.2805	X	X	X	X	X	X		X	X	X	X	X	X	X
13	65.6	53.5	13.1	4.2828	X	X	X	X	X	X	x	X		X	X	X	X	X
13	65.5	53.4	13.2	4.2883	X	X	X	X	X	X	x	X	X	X	X		X	X
13	65.4	53.3	13.3	4.2916	X	X	X	X	X	X		X	X	X	X	X	X	X
13	65.4	53.2	13.3	4.2947	X	X	X	X		X	x	X	X	X	X	X	X	X
14	65.7	52.3	15	4.3352	X	X	X	X	X	X	x	X	X	X	X	X	X	X

Table 27. Appendix D—Comparison of OCCFIBI to various nutrient, general water quality, and habitat parameters.

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
1	18	16.3	11.9	12.932				X										
1	12.6	10.8	15.7	13.35							X							
1	9.8	7.9	17.7	13.564									X					
1	8.9	7	18.4	13.633										X				
1	6.9	5	19.8	13.775	X													
2	28.2	25.2	6.5	12.225							X		X					
2	27.2	24.1	7.3	12.312				X			X							
2	27.2	24.1	7.3	12.312				X						X				
2	25.5	22.4	8.4	12.45							X			X				
2	23.8	20.7	9.6	12.591				X					X					
3	39.9	36.1	0.1	11.303				X			X			X				
3	37.6	33.6	1.8	11.519				X			X		X					
3	33	28.7	5.1	11.938				X			X				X			
3	31.8	27.4	6	12.045					X		X		X					
3	30.5	26.1	6.9	12.153							X			X				X
4	41.6	36.5	0.9	11.262				X			X			X				X
4	41.5	36.4	1	11.27				X		X	X			X				
4	40.7	35.6	1.5	11.348				X	X		X			X				
4	40.4	35.2	1.8	11.379	X			X			X			X				
4	40.2	35	1.9	11.396				X			X		X	X				
5	43	36.7	1.9	11.247				X			X			X	X			X
5	42.9	36.6	2	11.259				X	X		X			X				X
5	42.5	36.2	2.2	11.295				X		X	X			X				X
5	42.1	35.7	2.6	11.339	X			X		X	X			X				
5	42.1	35.6	2.6	11.34				X			X		X	X				X
6	44.1	36.5	3.1	11.268				X		X	X			X	X			X

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
6	43.6	35.9	3.5	11.32				X	X		X			X	X			X
6	43.5	35.8	3.6	11.33				X	X	X	X			X				X
6	43.4	35.7	3.6	11.339	X			X		X	X			X		X		
6	43.3	35.6	3.7	11.348	X	X	X	X			X			X				
7	45.1	36.2	4.4	11.294	X	X	X	X		X	X			X				
7	44.7	35.6	4.7	11.34	X	X	X	X	X		X			X				
7	44.5	35.5	4.8	11.357		X	X	X	X		X			X				X
7	44.5	35.4	4.8	11.359	X	X	X	X			X			X				X
7	44.4	35.4	4.9	11.362	X			X		X	X			X	X			X
8	46.4	36.1	5.5	11.296	X	X	X	X	X		X			X				X
8	46.3	36.1	5.5	11.304	X	X	X	X		X	X			X		X		
8	46	35.8	5.7	11.33	X	X	X	X	X	X	X			X				
8	45.9	35.6	5.8	11.342	X	X	X	X		X	X			X			X	
8	45.8	35.5	5.9	11.355	X	X	X	X			X			X	X			X
9	47.6	36.1	6.6	11.298	X	X	X	X		X	X			X		X	X	
9	47.1	35.5	6.9	11.352	X	X	X	X		X	X			X	X			X
9	47.1	35.5	7	11.357	X	X	X	X	X		X		X	X				X
9	47	35.4	7	11.364	X	X	X	X	X	X	X			X				X
9	46.9	35.3	7.1	11.372	X	X	X	X	X	X	X			X		X		
10	48.1	35.1	8.3	11.389	X	X	X	X		X	X			X	X	X	X	
10	48	35	8.3	11.399	X	X	X	X		X	X			X	X	X		X
10	47.9	34.9	8.4	11.404	X	X	X	X		X	X			X	X		X	X
10	47.9	34.9	8.4	11.408	X	X	X	X	X	X	X			X		X	X	
10	47.9	34.8	8.4	11.411	X	X	X	X		X	X	X		X		X	X	
11	49.3	34.9	9.4	11.403	X	X	X	X		X	X			X	X	X	X	X
11	48.6	34.1	9.9	11.478	X	X	X	X		X	X		X	X	X	X		X
11	48.4	33.9	10	11.495	X	X	X	X		X	X	X		X	X	X	X	

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
11	48.4	33.8	10	11.5	X	X	X	X	X	X	X		X	X		X		X
11	48.3	33.8	10.1	11.506	X	X	X	X		X	X		X	X		X	X	X
12	49.7	33.8	11.1	11.504	X	X	X	X		X	X	X		X	X	X	X	X
12	49.4	33.4	11.3	11.534	X	X	X	X		X	X		X	X	X	X	X	X
12	49.3	33.3	11.4	11.549	X	X	X	X	X	X	X			X	X	X	X	X
12	48.8	32.7	11.7	11.601	X	X	X	X	X	X	X		X	X	X	X		X
12	48.8	32.6	11.8	11.607	X	X	X	X	X	X	X		X	X		X	X	X
13	49.8	32.2	13	11.641	X	X	X	X		X	X	X	X	X	X	X	X	X
13	49.7	32	13.1	11.658	X	X	X	X	X	X	X	X		X	X	X	X	X
13	49.4	31.7	13.3	11.684	X	X	X	X	X	X	X		X	X	X	X	X	X
13	49	31.1	13.6	11.738	X	X	X	X	X	X	X	X	X	X		X	X	X
13	48.9	31	13.6	11.742	X	X	X	X	X	X	X	X	X	X	X	X		X
14	49.8	30.3	15	11.8	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 28. Appendix D—Comparison of BIBIRIF to various nutrient, general water quality, and habitat parameters.

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
1	13.6	11.8	7.3	17.875							X							
1	9.9	8.1	9.6	18.246				X										
1	7.2	5.3	11.3	18.521			X											
1	5.7	3.8	12.3	18.67		X												
1	5.4	3.5	12.4	18.696	X													
2	20.9	17.6	4.7	17.281				X				X						
2	18.2	14.8	6.4	17.572								X	X					
2	16.4	12.9	7.5	17.757			X					X						
2	16.1	12.6	7.8	17.795			X	X										
2	15.9	12.4	7.8	17.809	X							X						
3	25.2	20.5	4	16.971				X	X			X						
3	24.7	19.9	4.3	17.033				X		X		X						
3	24.4	19.5	4.5	17.073		X	X	X										
3	23.5	18.6	5.1	17.171				X				X	X					
3	23.4	18.6	5.1	17.175			X	X				X						
4	29.1	22.9	3.6	16.71			X	X	X			X						
4	28.3	22.1	4	16.799		X	X	X				X						
4	28.2	21.9	4.2	16.819		X		X	X			X						
4	28	21.8	4.2	16.831				X		X	X	X						
4	27.8	21.5	4.4	16.861				X	X	X		X						
5	33.1	25.7	3	16.407		X	X	X	X			X						
5	31.2	23.6	4.2	16.635		X	X	X				X	X					
5	31.2	23.6	4.2	16.638		X	X	X		X		X						
5	31.1	23.5	4.3	16.651		X	X	X	X								X	
5	31.1	23.4	4.3	16.652			X	X	X	X		X						
6	35.3	26.5	3.6	16.313		X	X	X	X			X					X	

Variables Considered	R-Sq	R-Sq(adj)	Mallow’s CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
6	34.8	25.9	4	16.382		X	X	X	X	X		X						
6	34.6	25.7	4.1	16.405		X	X	X	X		X	X						
6	34.6	25.7	4.1	16.407			X	X	X	X	X	X						
6	34.4	25.5	4.2	16.428			X	X	X			X	X		X			
7	37.9	27.7	4.1	16.178		X	X	X	X	X	X	X						
7	37.1	26.8	4.5	16.28		X	X	X	X			X	X				X	
7	36.6	26.2	4.9	16.346		X	X	X	X	X		X					X	
7	36.5	26.2	4.9	16.348		X	X	X	X			X	X		X			
7	36.5	26.1	4.9	16.359		X	X	X		X	X	X	X					
8	41	29.8	4.1	15.945		X	X	X	X			X	X		X		X	
8	38.8	27.2	5.4	16.242		X	X	X	X	X	X	X	X					
8	38.7	27	5.5	16.263		X	X	X	X	X	X	X					X	
8	38.4	26.6	5.7	16.3			X	X	X	X	X	X	X		X			
8	38.4	26.6	5.7	16.301	X	X	X	X	X	X	X	X						
9	41.6	28.8	5.7	16.056		X	X	X	X		X	X	X		X		X	
9	41.4	28.5	5.8	16.089		X	X	X	X	X		X	X		X		X	
9	41.1	28.1	6	16.134		X	X	X	X			X	X		X		X	X
9	41.1	28.1	6	16.135	X	X	X	X	X			X	X		X		X	
9	41.1	28.1	6	16.136		X	X	X	X			X	X		X	X	X	
10	42.6	28.3	7.1	16.12		X	X	X	X	X	X	X	X		X		X	
10	41.7	27.1	7.6	16.247		X	X	X	X		X	X	X		X		X	X
10	41.7	27.1	7.7	16.249	X	X	X	X	X		X	X	X		X		X	
10	41.7	27.1	7.7	16.252		X	X	X	X		X	X	X		X	X	X	
10	41.6	27.1	7.7	16.254		X	X	X	X		X	X	X	X	X		X	
11	42.7	26.5	9	16.315		X	X	X	X	X	X	X	X	X	X		X	
11	42.7	26.5	9	16.319	X	X	X	X	X	X	X	X	X		X		X	
11	42.6	26.4	9.1	16.322		X	X	X	X	X	X	X	X		X	X	X	

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
11	42.6	26.4	9.1	16.323		X	X	X	X	X	X	X	X		X		X	X
11	41.7	25.3	9.6	16.447	X	X	X	X	X		X	X	X		X	X	X	
12	42.7	24.6	11	16.524	X	X	X	X	X	X	X	X	X	X	X		X	
12	42.7	24.6	11	16.526		X	X	X	X	X	X	X	X	X	X	X	X	
12	42.7	24.6	11	16.527		X	X	X	X	X	X	X	X	X	X		X	X
12	42.7	24.6	11	16.531	X	X	X	X	X	X	X	X	X		X		X	X
12	42.7	24.5	11	16.532	X	X	X	X	X	X	X	X	X		X	X	X	
13	42.7	22.6	13	16.745	X	X	X	X	X	X	X	X	X	X	X		X	X
13	42.7	22.6	13	16.745	X	X	X	X	X	X	X	X	X	X	X	X	X	
13	42.7	22.6	13	16.747		X	X	X	X	X	X	X	X	X	X	X	X	X
13	42.7	22.5	13	16.752	X	X	X	X	X	X	X	X	X		X	X	X	X
13	41.8	21.4	13.6	16.873	X	X	X	X	X		X	X	X	X	X	X	X	X
14	42.7	20.4	15	16.975	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 29. Appendix D—Comparison of BIBICMB to various nutrient, general water quality, and habitat parameters.

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
1	10.3	8.4	-7.1	15.41								X						
1	1.7	0	-3.3	16.127				X										
1	0.8	0	-2.9	16.198							X							
1	0.7	0	-2.8	16.212													X	
1	0.6	0	-2.8	16.22			X											
2	11.9	8.2	-5.8	15.428								X	X					
2	11.5	7.8	-5.6	15.463								X		X				
2	11.3	7.7	-5.6	15.475								X					X	
2	11.1	7.4	-5.5	15.497				X				X						
2	11	7.3	-5.4	15.507	X							X						
3	14.8	9.3	-5.1	15.334		X	X					X						
3	13.4	7.8	-4.5	15.46	X							X	X					
3	12.7	7.1	-4.2	15.521								X	X				X	
3	12.6	7.1	-4.1	15.525				X				X					X	
3	12.5	6.9	-4.1	15.535								X	X		X			
4	16.7	9.5	-3.9	15.323		X	X	X				X						
4	16.5	9.2	-3.9	15.343		X	X					X	X					
4	15.6	8.2	-3.5	15.426		X	X					X			X			
4	15.5	8.2	-3.4	15.43		X	X					X		X				
4	15.3	7.9	-3.3	15.453		X	X					X						X
5	17.8	8.6	-2.4	15.392		X	X	X				X	X					
5	17.4	8.2	-2.3	15.428		X	X	X				X		X				
5	17.3	8.1	-2.2	15.434		X	X	X				X			X			
5	17.2	8	-2.2	15.446		X	X	X	X			X						
5	17.1	7.8	-2.1	15.459		X	X	X			X	X						
6	18.2	7	-0.6	15.53		X	X	X			X	X	X					

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
6	18.1	7	-0.6	15.532	X	X	X	X				X	X					
6	18	6.8	-0.5	15.549		X	X	X	X			X	X					
6	17.8	6.6	-0.4	15.562		X	X	X		X		X	X					
6	17.8	6.6	-0.4	15.564		X	X	X				X	X		X			
7	18.5	5.3	1.2	15.672	X	X	X	X			X	X	X					
7	18.3	5	1.3	15.693	X	X	X	X	X			X	X					
7	18.3	5	1.3	15.696		X	X	X	X		X	X	X					
7	18.3	5	1.3	15.697	X	X	X	X				X	X			X		
7	18.2	4.9	1.4	15.706		X	X	X			X	X	X				X	
8	18.7	3.2	3.1	15.84	X	X	X	X			X	X	X			X		
8	18.7	3.2	3.2	15.843	X	X	X	X	X		X	X	X					
8	18.6	3.1	3.2	15.85	X	X	X	X			X	X	X				X	
8	18.6	3	3.2	15.857	X	X	X	X			X	X	X		X			
8	18.5	3	3.2	15.858	X	X	X	X			X	X	X	X				
9	18.8	1	5.1	16.021	X	X	X	X	X		X	X	X			X		
9	18.8	1	5.1	16.023	X	X	X	X	X		X	X	X				X	
9	18.8	1	5.1	16.026	X	X	X	X			X	X	X			X	X	
9	18.8	0.9	5.1	16.028	X	X	X	X	X		X	X	X		X			
9	18.7	0.9	5.1	16.03	X	X	X	X			X	X	X		X	X		
10	19	0	7	16.209	X	X	X	X	X		X	X	X		X		X	
10	18.9	0	7.1	16.212	X	X	X	X	X		X	X	X			X	X	
10	18.9	0	7.1	16.214	X	X	X	X	X		X	X	X		X	X		
10	18.8	0	7.1	16.22	X	X	X	X	X		X	X	X	X		X		
10	18.8	0	7.1	16.22	X	X	X	X	X		X	X	X			X		X
11	19	0	9	16.407	X	X	X	X	X		X	X	X		X	X	X	
11	19	0	9	16.409	X	X	X	X	X	X	X	X	X		X		X	
11	19	0	9	16.415	X	X	X	X	X		X	X	X		X		X	X

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
11	19	0	9	16.415	X	X	X	X	X		X	X	X	X	X		X	
11	18.9	0	9.1	16.418	X	X	X	X	X		X	X	X	X		X	X	
12	19.1	0	11	16.618	X	X	X	X	X	X	X	X	X		X	X	X	
12	19	0	11	16.62	X	X	X	X	X		X	X	X		X	X	X	X
12	19	0	11	16.621	X	X	X	X	X		X	X	X	X	X	X	X	
12	19	0	11	16.624	X	X	X	X	X	X	X	X	X	X	X		X	
12	19	0	11	16.624	X	X	X	X	X	X	X	X	X		X		X	X
13	19.1	0	13	16.841	X	X	X	X	X	X	X	X	X		X	X	X	X
13	19.1	0	13	16.842	X	X	X	X	X	X	X	X	X	X	X	X	X	
13	19	0	13	16.843	X	X	X	X	X		X	X	X	X	X	X	X	X
13	19	0	13	16.847	X	X	X	X	X	X	X	X	X	X	X		X	X
13	18.9	0	13.1	16.855	X	X	X	X	X	X	X	X	X	X		X	X	X
14	19.1	0	15	17.074	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 30. Appendix D—Comparison of Log(BenChlA) to various nutrient, general water quality, and habitat parameters.

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
1	17.6	15.9	0.6	0.2868										X				
1	9.2	7.4	5.4	0.3009											X			
1	8	6.2	6	0.3029									X					
1	5.5	3.5	7.5	0.3071					X									
1	3.7	1.7	8.6	0.31														X
2	24.5	21.3	-1.4	0.2774											X			X
2	21.1	17.8	0.5	0.2835										X				X
2	20.8	17.5	0.7	0.284									X					X
2	20.5	17.2	0.8	0.2845										X		X		
2	20.4	17.1	0.9	0.2848							X			X				
3	28	23.4	-1.5	0.2736			X								X			X
3	27.5	22.9	-1.2	0.2746		X									X			X
3	26.7	22	-0.7	0.2761											X	X		X
3	26.7	22	-0.7	0.2761	X										X			X
3	26.5	21.8	-0.6	0.2766											X		X	X
4	30.9	24.8	-1.1	0.2711											X	X	X	X
4	30	24	-0.6	0.2727			X								X		X	X
4	30	23.9	-0.6	0.2728	X										X		X	X
4	29.8	23.7	-0.5	0.2732		X									X		X	X
4	29.3	23.2	-0.2	0.2741			X						X		X			X
5	32.7	25.3	-0.2	0.2704			X								X	X	X	X
5	32.4	24.9	0	0.2709		X									X	X	X	X
5	32	24.4	0.2	0.2718										X	X	X	X	X
5	31.7	24.1	0.4	0.2724		X	X								X	X		X
5	31.7	24.1	0.4	0.2725	X										X	X	X	X
6	33.8	24.8	1.2	0.2712			X							X	X	X	X	X

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
6	33.7	24.6	1.3	0.2715		X	X								X	X	X	X
6	33.6	24.5	1.3	0.2717		X								X	X	X	X	X
6	33.4	24.3	1.4	0.2721			X	X							X	X	X	X
6	33.3	24.3	1.4	0.2722			X						X		X	X	X	X
7	34.6	24	2.7	0.2727			X				X			X	X	X	X	X
7	34.6	23.9	2.7	0.2728			X	X						X	X	X	X	X
7	34.5	23.9	2.8	0.2728		X	X							X	X	X	X	X
7	34.4	23.7	2.9	0.2732		X					X			X	X	X	X	X
7	34.3	23.7	2.9	0.2732			X	X					X		X	X	X	X
8	35.4	23.1	4.3	0.2742		X	X				X			X	X	X	X	X
8	35.4	23	4.3	0.2743		X	X	X			X		X		X	X		X
8	35.3	23	4.3	0.2745			X	X			X			X	X	X	X	X
8	35.2	22.9	4.4	0.2746		X	X	X						X	X	X	X	X
8	35.2	22.9	4.4	0.2746		X	X	X					X		X	X	X	X
9	36.2	22.2	5.8	0.2758		X	X	X		X	X		X		X	X		X
9	36	22	5.9	0.2763		X	X	X			X			X	X	X	X	X
9	36	22	5.9	0.2763		X	X		X	X	X			X	X	X		X
9	35.9	21.9	6	0.2764		X	X	X			X		X		X	X	X	X
9	35.8	21.8	6	0.2766		X	X	X		X	X			X	X	X		X
10	36.7	20.9	7.5	0.2782		X	X	X	X	X	X		X		X	X		X
10	36.6	20.7	7.6	0.2785		X	X	X	X	X	X			X	X	X		X
10	36.5	20.7	7.6	0.2785		X	X	X		X	X			X	X	X	X	X
10	36.5	20.6	7.6	0.2787		X	X	X		X	X		X		X	X	X	X
10	36.5	20.6	7.7	0.2787		X	X	X		X	X	X	X		X	X		X
11	37.2	19.5	9.2	0.2807		X	X	X	X	X	X	X	X		X	X		X
11	37	19.2	9.4	0.2811		X	X	X	X	X	X		X	X	X	X		X
11	36.9	19.1	9.4	0.2813		X	X	X	X	X	X			X	X	X	X	X

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
11	36.8	19	9.4	0.2814	X	X	X	X	X	X	X		X		X	X		X
11	36.8	19	9.5	0.2815	X	X	X	X	X	X	X			X	X	X		X
12	37.4	17.6	11.1	0.2838		X	X	X	X	X	X	X	X	X	X	X		X
12	37.2	17.4	11.2	0.2842		X	X	X	X	X	X	X	X		X	X	X	X
12	37.2	17.4	11.2	0.2842	X	X	X	X	X	X	X	X	X		X	X		X
12	37.1	17.3	11.3	0.2844	X	X	X	X	X	X	X		X	X	X	X		X
12	37.1	17.3	11.3	0.2844		X	X	X	X	X	X	X		X	X	X	X	X
13	37.5	15.6	13	0.2874		X	X	X	X	X	X	X	X	X	X	X	X	X
13	37.5	15.5	13.1	0.2875	X	X	X	X	X	X	X	X	X	X	X	X		X
13	37.3	15.3	13.2	0.2878	X	X	X	X	X	X	X	X	X		X	X	X	X
13	37.3	15.2	13.2	0.2879	X	X	X	X	X	X	X	X		X	X	X	X	X
13	37.2	15.2	13.2	0.288	X	X	X	X	X	X	X		X	X	X	X	X	X
14	37.6	13.3	15	0.2911	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 31. Appendix D—Comparison of Log(SesChlA) to various nutrient, general water quality, and habitat parameters.

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
1	14.3	12.6	36.1	0.4276												X		
1	9	7.2	41.2	0.4406													X	
1	8.6	6.7	41.6	0.4417											X			
1	6.3	4.4	43.8	0.4471														X
1	4.2	2.2	45.9	0.4522	X													
2	44.1	41.7	9.2	0.349		X	X											
2	22.7	19.5	29.9	0.4103											X	X		
2	19	15.6	33.5	0.4201												X		X
2	17.9	14.5	34.5	0.4228									X			X		
2	17.6	14.2	34.8	0.4236												X	X	
3	47.8	44.5	7.6	0.3406		X	X					X						
3	47.5	44.1	7.9	0.3419		X	X								X			
3	47.4	44	8	0.3422		X	X									X		
3	45.5	42	9.8	0.3482		X	X											X
3	45.4	41.9	9.9	0.3485		X	X						X					
4	51.3	47.1	6.2	0.3326		X	X					X			X			
4	50.9	46.6	6.6	0.3341		X	X								X	X		
4	50.6	46.4	6.8	0.3349		X	X					X				X		
4	50.2	45.9	7.3	0.3365		X	X		X			X						
4	50.1	45.8	7.4	0.3368		X	X					X	X					
5	54.2	49.2	5.3	0.326		X	X					X			X	X		
5	54	48.9	5.6	0.3269	X	X	X								X	X		
5	53.2	48	6.4	0.3299		X	X					X	X			X		
5	52.9	47.6	6.7	0.331	X	X	X					X			X			
5	52.4	47.1	7.1	0.3325		X	X		X			X				X		
6	59.2	53.7	2.5	0.3113	X	X	X					X			X	X		

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
6	58.5	52.9	3.2	0.3139	X	X	X					X	X			X		
6	55.4	49.3	6.3	0.3257	X	X	X							X	X	X		
6	55	48.8	6.6	0.3271		X	X					X		X	X	X		
6	54.9	48.7	6.7	0.3275		X	X					X			X	X	X	
7	60	53.5	3.7	0.3117	X	X	X					X	X	X		X		
7	59.8	53.3	4	0.3126	X	X	X					X			X	X	X	
7	59.8	53.2	4	0.3128	X	X	X					X		X	X	X		
7	59.7	53.1	4.1	0.313	X	X	X					X	X		X	X		
7	59.5	52.9	4.3	0.3139	X	X	X				X	X			X	X		
8	61.6	54.2	4.3	0.3094	X	X	X					X	X	X	X	X		
8	60.7	53.2	5.1	0.3128	X	X	X		X			X	X	X		X		
8	60.6	53	5.2	0.3133	X	X	X	X				X	X	X		X		
8	60.4	52.8	5.4	0.3141	X	X	X					X		X	X	X	X	
8	60.4	52.8	5.4	0.3141	X	X	X				X	X	X	X		X		
9	62.3	54	5.5	0.31	X	X	X					X	X	X	X	X		X
9	61.9	53.5	6	0.3119	X	X	X	X				X	X	X	X	X		
9	61.8	53.5	6	0.312	X	X	X				X	X	X	X	X	X		
9	61.8	53.4	6	0.3122	X	X	X					X	X	X	X	X	X	
9	61.7	53.3	6.1	0.3126	X	X	X		X			X	X	X	X	X		
10	62.6	53.2	7.3	0.3127	X	X	X	X				X	X	X	X	X		X
10	62.5	53.1	7.4	0.3132	X	X	X				X	X	X	X	X	X		X
10	62.4	53	7.4	0.3135	X	X	X					X	X	X	X	X	X	X
10	62.4	53	7.5	0.3136	X	X	X		X			X	X	X	X	X		X
10	62.3	52.9	7.5	0.3138	X	X	X			X		X	X	X	X	X		X
11	62.7	52.2	9.2	0.3163	X	X	X	X			X	X	X	X	X	X		X
11	62.6	52.1	9.2	0.3165	X	X	X	X				X	X	X	X	X	X	X
11	62.6	52.1	9.2	0.3165	X	X	X	X		X		X	X	X	X	X		X

Variables Considered	R-Sq	R-Sq(adj)	Mallow's CP	S	Log(TP)	Log(TN)	Log(An)	TPts	Log(LBM)	Log(Emb)	Log(DP)	NVPB	DOSAT	DO	pH	Log(SPC)	Log(Turb)	WT
11	62.6	52.1	9.2	0.3166	X	X	X	X	X			X	X	X	X	X		X
11	62.5	52	9.3	0.3169	X	X	X			X	X	X	X	X	X	X		X
12	62.8	51.1	11	0.3199	X	X	X	X		X	X	X	X	X	X	X		X
12	62.7	50.9	11.1	0.3203	X	X	X	X			X	X	X	X	X	X	X	X
12	62.7	50.9	11.1	0.3203	X	X	X	X	X		X	X	X	X	X	X		X
12	62.7	50.9	11.2	0.3204	X	X	X	X	X	X		X	X	X	X	X		X
12	62.7	50.9	11.2	0.3205	X	X	X	X		X		X	X	X	X	X	X	X
13	62.9	49.8	13	0.324	X	X	X	X	X	X	X	X	X	X	X	X		X
13	62.8	49.7	13	0.3242	X	X	X	X		X	X	X	X	X	X	X	X	X
13	62.7	49.6	13.1	0.3246	X	X	X	X	X		X	X	X	X	X	X	X	X
13	62.7	49.6	13.2	0.3247	X	X	X	X	X	X		X	X	X	X	X	X	X
13	62.6	49.5	13.2	0.3249	X	X	X		X	X	X	X	X	X	X	X	X	X
14	62.9	48.4	15	0.3285	X	X	X	X	X	X	X	X	X	X	X	X	X	X