FY-2005 104(b)3 Regional Environmental Monitoring and Assessment Program Study

Implementation of a Stream/River Probabilistic Monitoring Network for the State of Oklahoma

Final Report

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FY-2005 Section 104(b)3 Regional Environmental Assessment Program Study: Implementation of a Stream/River Monitoring Sampling Network for the State of Oklahoma

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EXECUTIVE SUMMARY

It is the intent of this Oklahoma Water Resources Board (OWRB) report to advance concepts and principles of the Oklahoma Comprehensive Water Plan (OCWP). Consistent with a primary OCWP initiative, this and other OWRB technical studies provide invaluable data crucial to the ongoing management of Oklahoma's water supplies as well as the future use and protection of the state's water resources. Oklahoma's decision-makers rely upon this information to address specific water supply, quality, infrastructure, and related concerns. Maintained by the OWRB and updated every 10 years, the OCWP serves as Oklahoma's official long-term water planning strategy. Recognizing the essential connection between sound science and effective public policy, incorporated in the Water Plan are a broad range of water resource development and protection strategies substantiated by hard data – such as that contained in this report – and supported by Oklahoma citizens.

Several agencies conduct water quality monitoring in Oklahoma including: (a) the Beneficial Use Monitoring Program (a long-term, fixed-station water quality monitoring network), and (b) the Small-Watershed Rotating Basin Monitoring Program (targeting water quality and ecological conditions in waters flowing from 11-digit hydrologic units). The state recently completed a water quality monitoring strategy that describes their existing programs in detail and the monitoring objectives that cannot be met with existing resources. These objectives include the ability to make statistically valid inferences about environmental conditions throughout the state, based on a probabilistic selection of sites. Meeting this objective will improve the ability to make condition estimates required in section 305(b) of the Clean Water Act. This requirement includes a description of the quality of all lotic waters, and the extent that all waters provide for the protection and propagation of aquatic life.

The Environmental Protection Agency (EPA) recently released guidance establishing the "10 Required Elements of a State Water Monitoring and Assessment Program" (USEPA, 2006a). Among other things, the document states, "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 watershed 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." Until 2005, Oklahoma had several monitoring programs that met these requirements including the Beneficial Use Monitoring Program (BUMP) and the Rotating Basin Monitoring Program (RBMP) (OWRB, 2009b). Furthermore, the state has developed several programs to intensively monitor areas that have been listed on Oklahoma's 303(d) list of impaired waters (ODEQ, 2008).

In 2001, the State requested assistance with the design of a probabilistic approach to stream and river site selection from the U.S. Environmental Protection Agency, Office of Research and Development (ORD), Western Ecology Division (Olsen, 2001). The probability-based survey was designed to assist Oklahoma's water quality managers in several ways. An unequal probability random tessellation stratified (RTS) survey design (Stevens 1997, Stevens and Olsen 2004) was used to select stream sample sites across the state (Olsen, 2001), and was weighted by Strahler stream order categories. For the study, a total of 284 randomly chosen sites were evaluated for candidacy. The survey was a three-year study (2005-2007) with one hundred twenty-six (126) sites sampled. The study was spatially, temporally and hydrologically limited.

To assess ecological and human health, one-time collections were made for a variety of biological, chemical, and physical parameters. All target sites were visited once during a late spring to late summer index period in which fish assemblage was determined and a comprehensive suite of physical habitat measurements was made. In addition, an *in-situ* water quality collection was made for most sites including measurements for water temperature, dissolved oxygen, pH, specific conductance, and turbidity. All selected sites were visited again during an index period from June 1st through August 30 h in which a comprehensive collection of water quality chemistry and microbiology, a collection for benthic macroinvertebrates, short form physical habitat measurements, and a collection of benthic periphyton was made under base flow conditions.

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 of the study were:

1. Estimate the condition of various measures of biological integrity for Oklahoma's waters through a statistically-valid approach.
2. Estimate the extent of stressors that may be associated with biological condition.
3. Evaluate the relationship between stressors and condition for use in various long and short term environmental management strategies.
4. Assess waters for inclusion in Oklahoma's Integrated Water Quality Report.

For data analysis, sites were grouped by Omernik Level III ecoregions based upon proximity and statewide to produce estimates. Regions include the Western Plains/Tablelands, the Temperate Forests, and the Forested Plains/Flint Hills region. Fish data were analyzed using two indices of biological integrity (IBI) commonly used in Oklahoma bioassessment studies—the OKFIBI and the OCCFIBI. The OKFIBI estimated that nearly half of the state has a supporting fish condition over 47% (+/-8%) of the target population, 7% of the population is not supporting, while 28% are undetermined. An additional 16% of the population is lacking adequate biocriteria to determine condition. Conversely, the OCCFIBI estimates an excellent/good condition for 54% (+/- 8%) of the population, while 16% is in poor/very poor and 27% in fair condition. Macroinvertebrate taxonomic results for each site were analyzed to produce a percent of reference score for the OKBIBI. The OKBIBI estimates that 50% (+/-8%) of the population has a supporting macroinvertebrate condition and that 27% and 17% of the population is either slightly or moderately impaired, respectively.

To estimate condition of algal biomass, benthic and sestonic chlorophyll-a concentrations were compared to multiple screening levels. For both benthic and sestonic populations, the greater majority of waterbodies are not exceeding any screening limit, approximately 65-66% (+/-8%) statewide. To create condition estimates, bacteria data were compared to the applicable screening limits, and for enterococci to the OWQS standard. The estimate for not exceeding any indicator screening level or standard is nearly 70% (+/-8%) statewide.

A variety of stressors were used to determine extent and calculate relative risk. Nutrient stressors include measures total phosphorus, total nitrogen (nitrate + nitrite + total Kjeldahl nitrogen), and available nitrogen (nitrate + nitrite + ammonia). General water quality stressors represent a diverse group of parameters—*in situ* and salinity-related parameters *In situ* parameters include pH, dissolved oxygen, turbidity, and water temperature. Salinity-related parameters include conductivity, chloride, sulfate, and total dissolved solids (TDS). Metals were used in stressor studies to provide insight into stressors related to biological condition as well as those related human health beneficial uses—public/private water supply and fish consumption. Habitat stressors include total habitat score, several individual habitat metrics, and an index for sedimentation

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) by Van Sickle et al. (2006). 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. Relative risk was determined for fish, macroinvertebrate, and algal condition

This report marks Oklahoma's first attempt at making a statistically based assessment of the condition of Oklahoma's waters. The OWRB recommends that this report be adopted into the 305(b) section of the integrated report. Second, individual waterbodies not yet included in the integrated report now have some level of assessment including category 5 (impaired), as well as category 3 (not impaired for some uses).

The relative risk analysis produced widely variable results depending upon both condition and stressor and has implications for criteria development, not only at the stressor level, but for biological condition as well. Conclusions based on analysis are: 1) regional reference condition needs to be refined across all Omernik Level III ecoregions to include many Omernik Level IV ecoregions, 2) effective nutrient criteria will lie somewhere between regional screening levels and those in Oklahoma rule, 3) macroinvertebrates tend to respond in a more predictable fashion to water quality stressors than do fish, 4) sestonic algal condition is more easily predicted by nutrient concentrations than benthic algal condition, 5) application of naturally occurring condition protocols can benefit from relative risk analysis, 6) Oklahoma should explore the use of relative bed stability (RBS) as a measure of sedimentation, and 7) regional nuisance benthic algal screening levels are needed.

Additionally, other recommendations can be made from the varied analysis, including: 1) all metals listed in the OWQS (OWRB, 2007a) but not occurring above criteria in ambient monitoring programs should not be monitored further, 2) since most metals occur regionally, a table specifying regional metals of concern should be created, 3) the contact recreation use should be a tiered use much like the aquatic life uses, and 4) refine agriculture criteria to include conductivity as a surrogate for TDS or create a regional criteria for conductivity to use in place of TDS.

In Oklahoma, probabilistic monitoring is an ongoing process. In terms of monitoring, probabilistic design has been completely integrated into both the OWRB and OCC monitoring programs (OWRB, 2009b). The OWRB is currently participating in the National Rivers and Streams Assessment and will use data from it to provide an update to the current report. Also, the third two-year statewide study will begin in winter or summer 2009 and include 50 sites. Substantive changes to the program will include: 1) use of the NRSA protocols for large wadeable and non-wadeable waterbodies, 2) use of NRSA habitat protocols for wadeable streams in concert with the current RBP habitat protocol, 3) inclusion of a second winter macroinvertebrate index period, 4) inclusion of dissolved metals for some analytes, and 5) exclusion of bacteria from program. The OCC initiated a probabilistic program during 2008 that will provide estimates for planning basins throughout the state. Fifty random sites are being monitored per basin over the five-year rotating basin cycle. Lastly, the OWRB will conclude the Illinois River Probabilistic Monitoring Survey in 2009-2010. It is the first regionally based probabilistic study in Oklahoma, and is centered on setting a baseline biological condition to assist in implementation of nutrient criteria in Oklahoma's scenic rivers. Additional plans are in the works for future regionally based studies.

INTRODUCTION

Several agencies conduct water quality monitoring in the State of Oklahoma. These agencies meet complementary monitoring objectives that support the management of Oklahoma's surface waters. The two primary components of the statewide monitoring program include (a) the Beneficial Use Monitoring Program, a long-term, fixed-station water quality monitoring network of the Oklahoma Water Resources Board (OWRB), and (b) Oklahoma Conservation Commission's (OCC) Small-Watershed Rotating Basin Monitoring Program, targeting water quality and ecological conditions in waters flowing from 11-digit hydrologic units. The state recently completed a water quality monitoring strategy that describes their existing programs in detail and the monitoring objectives that cannot be met with existing resources (OWRB, 2009b). These objectives include the ability to make statistically valid inferences about environmental conditions throughout the state, based on a probabilistic selection of sites. Meeting this objective will improve the ability to make condition estimates required in section 305(b) of the Clean Water Act. This requirement includes a description of the quality of all lotic waters, and the extent that all waters provide for the protection and propagation of aquatic life.

The Environmental Protection Agency (EPA) recently released guidance establishing the "10 Required Elements of a State Water Monitoring and Assessment Program" (USEPA, 2006a). Among other things, the document states, "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 watershed 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." Until 2005, Oklahoma had several monitoring programs that met these requirements including the Beneficial Use Monitoring Program (BUMP) and the Rotating Basin Monitoring Program (RBMP) (OWRB, 2009b). Furthermore, the state has developed several programs to intensively monitor areas that have been listed on Oklahoma's 303(d) list of impaired waters (ODEQ, 2008).

In 2001, the State requested assistance with the design of a probabilistic approach to stream and river site selection from the U.S. Environmental Protection Agency, Office of Research and Development (ORD), Western Ecology Division (Olsen, 2001). The study design was completed, but Oklahoma agencies remained unable to initiate further planning and implementation because of a lack of resources and commitment. In 2004, the OWRB and OCC took part in the National Wadeable Streams Assessment (WSA) (USEPA, 2006), which was fortuitous to future planning efforts for several reasons. First, the timing of the study coincided with discussions in the state about implementing a probabilistic design. Although money was a question, staff and management were worried staff time could not be spent performing all of the necessary reconnaissance work or sampling that is required in a random based monitoring program. Participating in the WSA instilled confidence that this type of monitoring could be accomplished without impeding the success of other programs. In fact, this facet of Oklahoma's monitoring program has only enhanced other programs. Second, because the state showed interest in implementing a random design, USEPA Region 6 began working with staff to find appropriate funding. The initial funding came through a Clean Water Act (CWA) Section 104(b)3 grant. This money funded not only the initial year of study (2005), but an outcome was to investigate the feasibility of full implementation (OWRB, 2006a). The study investigated feasibility on two fronts—logistic and funding—finding that the logistic portion could be overcome through proper planning and coordination of staff. The funding, however, was not easily dealt with because of program priorities.

In 2005, another funding opportunity came open when the USEPA announced further funding of the Regional Environmental Monitoring and Assessment Program (REMAP) (OWRB, 2005a). Funding from the REMAP grant allowed the state to continue implementation of probabilistic monitoring for an additional two years through 2007. Funding for the survey is outlined in Table 1.

Table 1. Breakdown of yearly funding and activity funded (OWRB, 2005a).

Study Year	Federal 104(b)3	REMAP	State
SY-2005 (1)	$130,118— recon and sampling of 30 sites; supplies and equipment	No Funding	$55,882—the state 5% match to the 104(b)3 ($6,849); recon and sampling of 12 sites; final reports
SY-2006 (2)	No Funding	$180,000—recon and sampling of all 42 sites; project and data management activities; supplies and equipment	$100,000—project and data management
SY-2007 (3)	No Funding	$140,000—recon and sampling of 32 sites; project and data management; portion of final report	$54,000—recon and sampling of 10 sites (Upper Arkansas Planning Basin); project and data management; portion of final report
3 year Total ($660,000)	$130,118	$320,000	$209,882

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. Estimate the condition of various measures of biological integrity for Oklahoma's waters through a statistically-valid approach.
2. Estimate the extent of stressors that may be associated with biological condition.
3. Evaluate the relationship between stressors and condition for use in various long and short term environmental management strategies.
4. Assess waters for inclusion in Oklahoma's Integrated Water Quality Report.

The current assessment allows the state to make a statistically valid assessment of the condition of all of Oklahoma's 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 one hundred twenty-six (126) sites available for inclusion in data analyses. This sample size allows for a statewide as well as a regional estimate of fish, macroinvertebrate, and algal condition. Also, human health estimates are provided. Additionally, extent is evaluated for a number of potential environmental stressors at both the statewide and regional level. 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. Future work may allow for more comprehensive 303(d) assessments so that the support status of probabilistic sites may be fully vetted.

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 broad 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.

Study Design

An unequal probability random tessellation stratified (RTS) survey design (Stevens 1997, Stevens and Olsen 2004) was used to select stream sample sites across the state (Olsen, 2001). The sample design was weighted by Strahler stream order categories to achieve an approximately equal expected sample size across stream order categories 1st, 2nd, 3rd, and 4th+ to ensure that larger order streams are 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 original 2001 balanced sampling design was modified to a spatially stratified design to support estimates of conditions at the statewide scale within the three-year project period, and to support estimates at the scale of selected planning basins, or combinations of basins (Figures 1 and 2).

Oklahoma's probabilistic survey was originally scheduled for a five-year period but was shortened to a three-year study (study years 2005-2007) with approximately 42 sites sampled annually. During study years one through three, at least fifteen (15) sites were visited annually at the statewide scale, yielding a sample size of forty-five (45) sites. Additionally, a total of twenty-seven (27) sites were visited annually within seven specific planning basins as outlined in Table 2, yielding an additional eighty-one (81) sites. Because of the differing size or geographic area covered by each basin, the number of sites targeted within each planning basin ranged from three to thirty-three sites (Table 3). At the end of the project period, one hundred twenty-six (126) sites were available for inclusion in data analyses.

Table 2. Numbers of sites originally targeted both statewide and within selected basins.

STUDY YEAR (SY)	GEOGRAPHIC SCALE	# SITES SAMPLED
SY-2005 (1)	Lower Red River	27
	Statewide Stations	15
SY-2006 (2)	Grand-Neosho River	15
	Upper North Canadian River	5
	Upper Canadian River	7
	Statewide Stations	15
SY-2007 (3)	Upper Arkansas River	10
	Lower Canadian River	6
	Cimarron River	11
	Statewide Stations	15
SY-2005-7	Total Stations	126

The study was spatially, temporally and hydrologically limited. Spatially, the study excluded all flowing waterbodies receiving major hydrological influence from oxbow lakes because of a lack of developed biological collection protocols. In southeastern Oklahoma, the lower Red River below its confluence with the Kiamichi River and the Little River below its confluence with the Mountain Fork River were excluded. In northeastern and east-central Oklahoma, the McClellan-Kerr Navigational System was excluded below its confluence with the Caney River, encompassing large portions of the lower Verdigris River and Arkansas River as they flow through the state. Temporal limitations were defined by biological index periods. The index period for the fish assemblage in Oklahoma was May 15th through September 15th with an optional extension to October 1st if the stream had not risen above summer seasonal base flow (OWRB, 2004). The index habitat period for the macroinvertebrate assemblage in Oklahoma was June 1st through August 30th with collections completed in as short a time period as possible (OWRB, 2006c). Hydrologically, the study was limited by both an extended drought in SY-2005 as well as excessive rains and flooding in SY-2006-2007. 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.

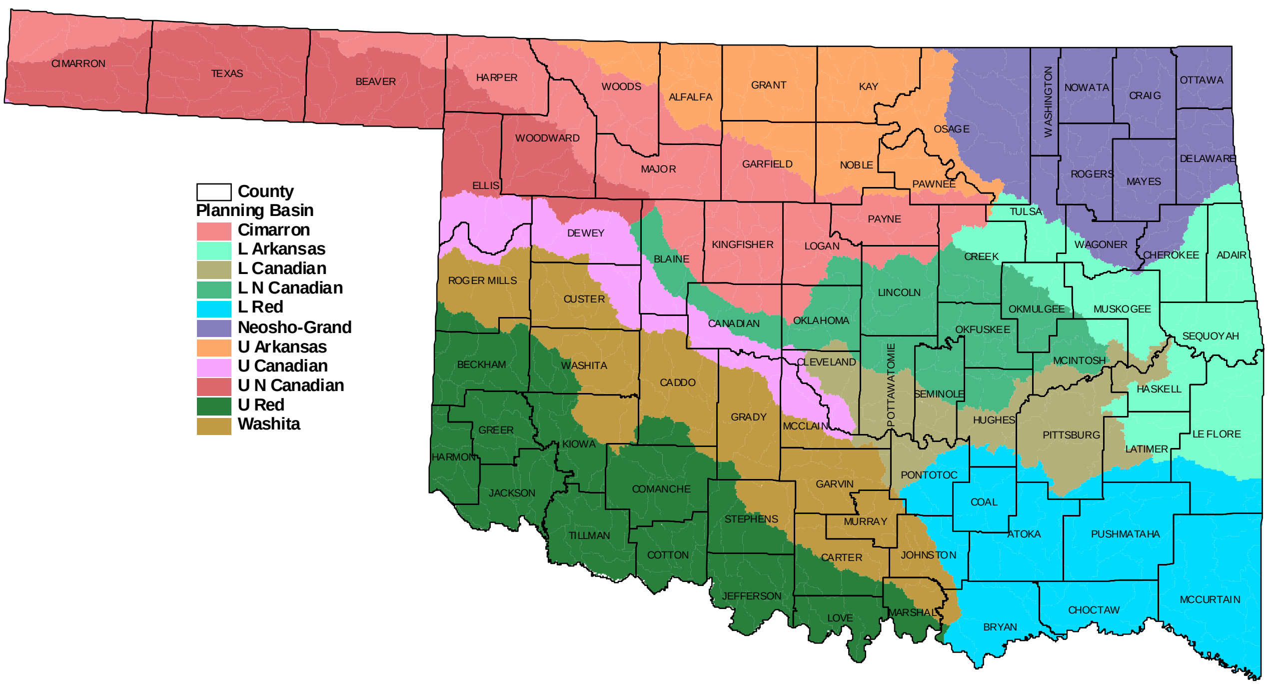


Figure 1. State of Oklahoma Planning Basins

<u>Revised Study Regions</u>

After extent and condition estimates were completed, it was decided that planning basins were not a viable option for examining more refined geographical scales. Because of the limited number of sites visited in many of them (Table 3), confidence intervals were considered to be too broad to draw any valid conclusions about estimates or stressor extent. Several alternatives were explored including the grouping of planning basins by geographic area or only reporting on basins with an adequate number of sites. The most feasible alternative under this scenario involved logically grouping planning basins by geographic area. The Upper Arkansas was joined with the Cimarron planning basin, which is one of its major sub-basins. A Lower Arkansas basin group was formed, including the Upper and Lower North Canadian, Upper and Lower Canadian, and Neosho-Grand planning basins. And, the entire Red River basin was grouped to encompass the Upper and Lower Red and the Washita planning basins. The final sample sizes are given in Table 3. It was concluded that these groups still produced sample sizes too low to make meaningful estimates. Eventually, the decision was made to move away from the planning basin approach for this report. Although considered unique to Oklahoma's study design, implementation was not possible over the three year study period. Consideration was given to future needs for planning basin work. The OCC is currently in the process of implementing a probabilistic approach in each of the eleven planning basins as part of their five year Rotating Basin Monitoring Program (OWRB, 2009b). Eventually, this will yield estimates that can be used in the state's 305(b) reporting. The current study will still benefit that work by providing a template methodology for approaching analysis. On the other hand, drawing potentially poor conclusions because of inadequate sample size does not benefit those future endeavors.

Table 3. Numbers of sites sampled within selected basins geographical groupings.

Geographical Groupings	Planning Basin	# of Sites
Ecoregion Option (Final Choice)	Temperate Forests	40
	Forested Plains/Flint Hills	41
	Western Plains/Tablelands	45
Alternate Planning Basin Design	Alternate Lower Arkansas	60
	Alternate Red River	40
	Alternate Upper Arkansas	27
Original Planning Basin Design	Cimarron	12
	Grand Neosho	23
	Lower Arkansas	8
	Lower Canadian	11
	Lower North Canadian	3
	Lower Red	33
	Upper Arkansas	15
	Upper Canadian	7
	Upper North Canadian	8
	Upper Red	7

After exploring options that kept planning basins intact, other potential regional groupings were investigated. The most reasonable alternative was to group sites by Omernik Level III ecoregions based upon proximity. Several considerations were given when making these groupings. Foremost, water quality should be similar and habitat should not be greatly divergent. Secondly, groupings should be supported by some previously published sources such as Omernik Level II ecoregions. The final regional groupings are presented in Table 3 and Figure 2.

The Western Plains/Tablelands region is comprised of the Central Great Plains, Southwestern Tablelands, and Western High Plains Level III ecoregions (Woods, 2005), which are encompassed by the South Central Semi-arid Prairies Level II ecoregion (NACEC, 2001, Omernick, 1987). Generally, in stream habitat is comprised mostly of loose bed substrates with extensive shoreline vegetation. Habitat structure is dominated by extensive glides and moderate to shallow pools, with extensive sand bar formation and braiding in larger systems. Coarse substrates are present in some areas but are not common. Water quality varies within the area, but is unique in one respect when compared to the rest of Oklahoma. Conductivity throughout the region typically is abnormally high, with normal ranges from 1,000-3,000 microsiemens (OCC, 2005a, 2005b, 2006a, 2007; OWRB, 2008). In the Red Prairie and Red River Tablelands of southwestern Oklahoma, conductivity ranges from 2,500 up to greater than 75,000 below the gypsum outcroppings of the Elm Fork River. In northwestern Oklahoma along both the Cimarron and Beaver Rivers, similar conductivity ranges are present. Human influence is mostly row crop agriculture and pasture/grazinglands with influence from several major urban centers in the eastern portion of the region including the Oklahoma City Metro, Enid, and Lawton. Moderate sized communities (e.g., Woodward or Altus) are spread throughout the area east of the panhandle to the eastern border with the Cross Timbers. Oil and gas exploration is common throughout the region.

Figure 2 . Ecoregion groupings used for regional assessment of sites.

The Temperate Forests region is located along the eastern border of Oklahoma and encompasses the South Central Plains, Ouachita Mountains, Arkansas Valley, Boston Mountains, and Ozark Highlands (Woods, 2005). These areas are all contained with the Eastern Temperate Forests Level I ecoregion, with most being in the extensive Ozark, Ouachita-Appalachian Forests Level II ecoregions. The South Central Plains are in the Southeastern USA Plains Level II ecoregion. With the exception of parts of the valleys and plains regions, the majority of streams are dominated by coarse substrates and bedrock, with extensive gravel bar formation. Gradients vary throughout, but riffle-run complexes are common with relatively deep pools in all sized waterbodies. In-stream habitat is widely diverse with a variety of ledges and interstitial spaces as well as in-stream vegetation and large woody debris. From a water quality perspective, the area has widely varying nutrient concentrations, but is dominated by relatively low conductivity water, 10-350 microsiemens on a gradient from south to north (OCC, 2005a, 2005b, 2008; OWRB, 2008). Because most streams are cool water communities, dissolved oxygen is typically higher, except in far eastern portions of the South Central Plains which have natural dissolved oxygen levels well below 3 ppm. Another naturally-occurring variation is low pH (below 6.5) in the central and eastern Ouachita Mountains, which is dominated by waters with extremely low buffering capacities (hardness < 10 ppm). Human influence is mostly forestry with light to moderate agriculture, mostly pasture and grazinglands. Row crop agriculture is rare except in the Arkansas Valley and South Central Plains. However, there are a number of confined animal feeding operations throughout the region and in western Arkansas. Several moderately sized population centers are in the area, including Grove and Tahlequah to the north with McAlester and Idabel/Broken Bow in the south.

The Forested Plains/Flint Hills region is a hodgepodge of central and eastern Oklahoma, including the Cross Timbers, Central Irregular Plains, and Flint Hills Level III ecoregions (Woods, 2005). The East Central Texas Plains ecoregion did not have any sites located within its boundaries, but likely would have been considered for inclusion here. The area is wholly contained within the Great Plains Level I ecoregion, but encompasses both the South Central Semi-arid Prairies and Temperate Prairies Level II ecoregions (NACEC, 2001, Omernick, 1987). With the exception of the Arbuckle Uplift is the south central portion of the area, the region is mostly different from the Temperate Forests region for several reason. Although coarse substrates are common in many areas of the region, fine substrates are generally in greater concentrations and commonly more dominant in areas throughout the Cross Timbers (OCC, 2005a, 2006a, 2006b, 2007, 2008; OWRB, 2008). Additionally, conductivity throughout the region is relatively high when compared to the Temperate Forests region, ranging from 200-1000 microsiemens in most parts. Parts of the Cimarron and Canadian basins do range from 1000-4000 microsiemens. The major differences in comparison to the Western Plains/Tablelands are domination by riparian forests in all but the Flint Hills and generally more riffle-run complexes with deeper pools. Human influence in the area is mixed agriculture including row crops, pasture, and grazinglands. A number of major urban centers are present including the Oklahoma City and Tulsa Metro areas as well as Muskogee in the east, Ardmore and Ada in the south and central, and Stillwater and Ponca City/Bartlesville to the north. Moderate sized communities are spread throughout the area. Oil and gas exploration as well as refining is common throughout the region.

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 first year of this study (OWRB, 2006a), the OWRB developed (with assistance from EPA documentation) and implemented a three-stage reconnaissance plan.

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, 2005d), and other GIS mapping tools. For each site, a site reconnaissance and tracking form (Figure 3) 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 or personal visits to nearby residences. Finally, a landowner permission packet was sent to each landowner, including a standardized permission letter (Figure 4), 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.

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 o-nsite initial visit to complete the planning phase. Concerns did arise about the cost versus benefit of an extra site visit. However, over the course of three years, crews discovered that much of the information collected during the initial on-site planning visit was of great benefit on the actual day of sampling. 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 3. Template site reconnaissance and tracking form used during study.

Date

John Doe Trust
C/O Jane Doe
Rt. 1 Box 1
Anywhere, OK 74534

Dear Sir/Madam:

The Oklahoma Water Resources Board (OWRB) is conducting a five-year project to perform environmental assessments on 210 to 220 randomly selected streams across Oklahoma. 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 Creek located on your property in Section 1, Township 1 N, Range 1 E, in Your County, Oklahoma. We have enclosed a copy of a topographic map with the site identified by an "X" at the specific point on the stream to be sampled.

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 no more than three visits to your land. The first visit will be for site reconnaissance and will occur sometime between March and April of 2006. A crew of one to two people will use your land to access the site and only gather information about site accessibility. In addition, one or two more visits will be made between May and October of 2006 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.   Fish will only be collected during one of these 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 respons bly.

If you are agreeable to the activities descr bed 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 Date. 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. Thank you for your consideration. If you have any questions about this request, please contact Jason Childress (Project Coordinator) or myself at 405-530-8800.
Sincerely,

Monty Porter
Water Quality Programs Streams/Rivers Monitoring Coordinator

Enclosures: Topo map
Duplicate original of letter
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: ____________________________________

Landowner's Daytime Phone No.

Figure 4. Template landowner permission letter used during study.

Data Collection
To assess ecological and human health, one-time collections were made for a variety of biological, chemical, and physical parameters (Table 4). When sites were verified as target, a sampling schedule was implemented. All target sites were visited once during a late spring to late summer index period in which fish assemblage was determined and a comprehensive suite of physical habitat measurements was made. In addition, an *in-situ* water quality collection was made for most sites including measurements for water temperature, dissolved oxygen, pH, specific conductance, and turbidity. All selected sites were visited again during an index period from June 1st through August 30th in which a comprehensive collection of water quality chemistry and microbiology, a collection for benthic macroinvertebrates, short form physical habitat measurements, and a collection of benthic periphyton was made under base flow conditions. Depending on circumstances, information was collected during the same site visit.

Table 4. 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
Total Dissolved Solids—gravimetric	Chlorides	Sulfates
Total Settleable Solids	Total Suspended Solids	
Laboratory Variables—Metals		
Arsenic	Cadmium	Chromium
Copper	Lead	Mercury
Nickel	Selenium	Silver
Zinc	Thallium	Calcium
Barium	Iron	Magnesium
Potassium	Sodium	
Laboratory Variables—Microbiological		
Fecal Coliform	*Escherichia coli*	Enterococci
Biological Variables		
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, 2006d). Several variables (pH, dissolved oxygen, water temperature, and specific conductance) were monitored *in-situ* utilizing a Hydrolab® Minisonde or YSI® multi-probe instrument or with single parameter probes. Regardless of instrumentation and in accordance with manufacturer's specifications and/or published SOP's, all instruments (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. 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 channels and were aliquotted into sample bottles using a clean splitter-churn. Each sample included three bottles for general chemistry analyses (two ice preserved and one sulfuric acid preserved), one bottle for metals analysis (nitric acid preserved), and one bottle each for field chemistry analysis and sestonic chlorophyll-a (ice preserved and kept dark). Two bottles for microbiological analysis (ice preserved) were collected using only a grab sample technique. For benthic chlorophyll-a, a sample was composited, placed on ice to be preserved, and kept dark. The Oklahoma Department of Environmental Quality-State Environmental Laboratory (ODEQ-SEL) in accordance with the ODEQ's Quality Management Plan (QTRACK No. 00-182) (ODEQ, 2007) analyzed samples for most parameters listed in Table 4. OWRB or OCC personnel measured hardness and alkalinity using Hach® titration protocols, and nephelometric turbidity using a Hach® Portable turbidometer.

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, 2006b). 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 a 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).

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, 2004). 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 photodocumentation and representative vouchers. All other fish were preserved in a 10% formalin solution and sent to the University of Oklahoma Sam Noble Museum Of Natural History (OUSNMNH) for identification to species and enumeration. Several collections made by OCC were processed by Brooks Tramell. 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 the summer index period of each study year (OWRB, 2006c). 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 fill 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 (OWRB, 2006c). After sorting, the "100-count subsample" was sent to EcoAnalysts, Inc. for identification and enumeration, and the large and rare sample was identified and enumerated by OWRB staff. Taxonomic data for each sample were grouped by EcoAnalysts and metrics were calculated. 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, 2005c). 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 the OWRB, 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.

RESULTS—EXTENT AND BIOLOGICAL CONDITION ESTIMATES

Extent Estimates

For the study, a total of 284 randomly chosen sites were evaluated for candidacy representing a total of 34,379 stream miles. Using pie charts, results are illustrated for statewide and regional extent in Figure 5. Stream miles determined to be target, or sampleable, totaled 14,284 miles statewide (42%, +/- 6%). Regionally, the total stream miles assessed break out as follows: 4,846 of 10,544 total miles in the Forested Plains (46%, +/-12%), 4,411 of 10,569 total miles in the Temperate Forests (42%, +/-9%), and 5,027 of 13,276 total miles in the Western Plains (38%, +/-9%). Stream miles that did not meet the target criteria were divided into two categories—non-sampleable and no access. The non-sampleable stream length totaled 6,556 miles (19% +/-11%) and were divided into four sub-categories—dry channel (4,308 miles), impounded (1,026 miles), temporary/persistent flooding conditions (1,103 miles), and wetland (and 119 miles). Stream length with no access equaled 13,540 (39%, +/-7%), which was nearly equivalent to the totaled sampled length. Reasons for lack of access varied but can be divided into three general sub-categories—access permission denied (13,169 miles), physical barrier to access (231 miles), and no existing protocols (140 miles). The last category was for extremely large rivers (e.g., the Arkansas River portion of the McClellan-Kerr Navigational System) where attempting to apply rapid bioassessment protocols was neither feasible nor practical.

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 (OWRB, 2008b). In addition, an IBI commonly used by the OCC's Water Quality Division was used to provide an alternative bioassessment (OCC, 2005a and 2008). 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 5). 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 example, if the final IBI score is between 25-34, the status for sites in the Ouachita Mountain Ecoregion is deemed undetermined. Likewise, for scores greater than 34 and less than 25, the status is supported or not supported, respectively.

The OCCFIBI uses "a modified version of Karr's Index of Biotic Integrity (IBI) as adapted from Plafkin et al., 1989" (OCC, 2008). The metrics as well as the scoring system are in Table 6. 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 2005). 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 6, 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 6. 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 7 and an integrity classification is assigned with scores falling between assessment ranges classified in the closest scoring group.

Figure 5. Statewide extent estimates representing considered and sampled stream miles.

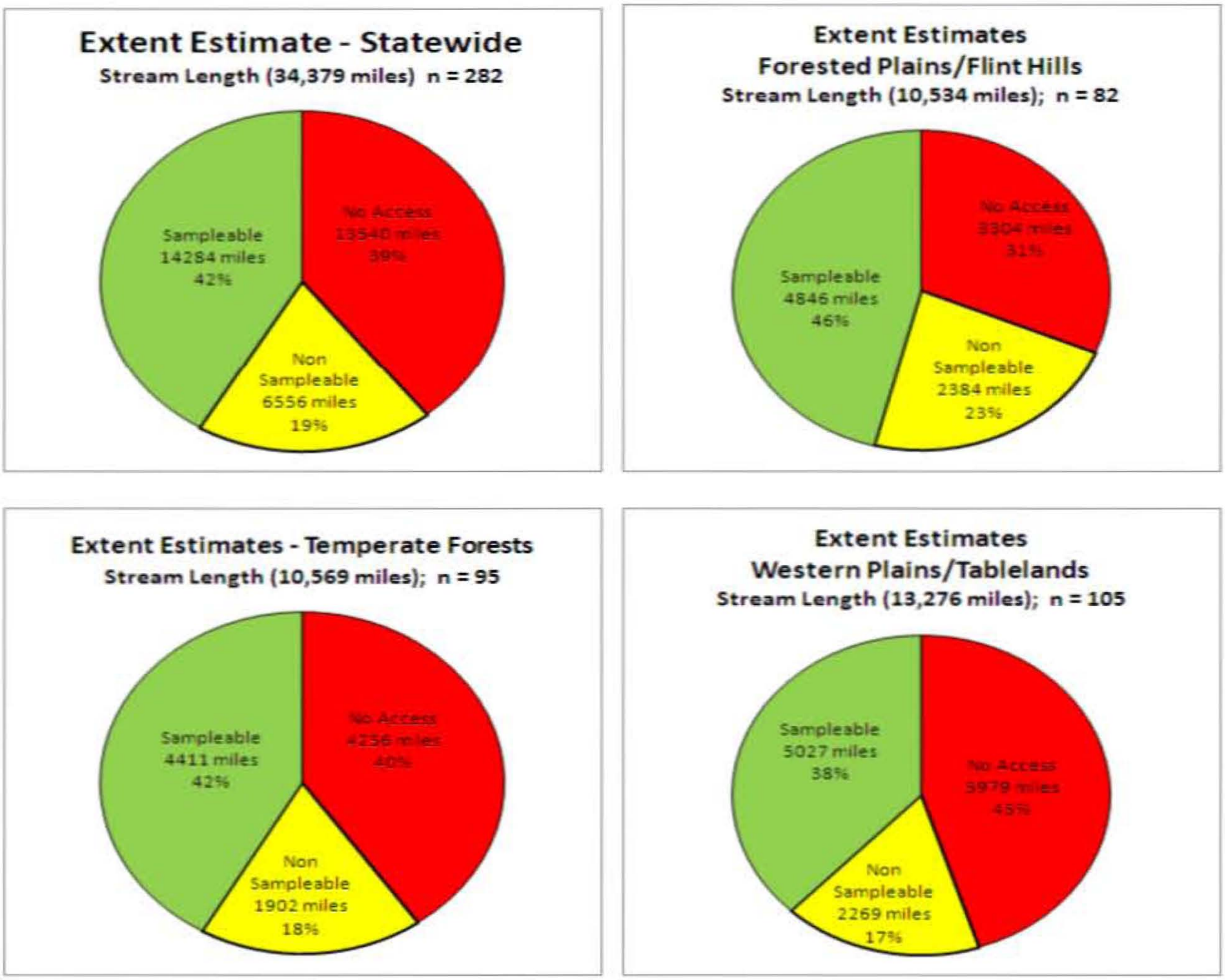


Table 5. Index of biological integrity used to calculate scores for Oklahoma's biocriteria. Referenced figures may be found in OAC 785:15: Appendix C (OWRB, 2008b).

Metric	Value	Scoring 5	3	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	
Number 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 6. 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 7. 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 calculated for each of the four previously discussed geographical scales. The OKFIBI condition estimates are presented using the three classifications discussed previously as well as estimates for "no biocriteria". Biocriteria do not exist for certain Omernik Level III ecoregions, including the Flint Hills, High Plains, and Southwestern Tablelands. Likewise, the OCCFIBI condition estimates are presented using three classifications. For ease of reporting condition estimates, fair is reported as a class, while certain classes are grouped, including excellent/good and poor/very poor. Additionally, estimates are given at each geographic scale for the four sites where no collections were made, which is approximately 3% of the total stream miles. The OCCIBI also includes one "no collection" estimate for a site that did not have a valid reference location. Each IBI gives a somewhat different statewide estimate (Figure 6). For the sampled target population (14,284 stream miles), the OKFIBI estimates that fish condition is supported in 49% of the population, not supported in 7% of the population, and undetermined in 30% of the population. An additional 11% of the population is lacking adequate biocriteria to determine condition. For the same sampled population, the OCCFIBI estimates an excellent/good condition of 49% and a poor/very poor condition of 17%, similar to the OKFIBI support and non support statuses. However, an estimated 29% are in fair condition, which could be comparable to the undetermined status above. In the three regional areas, more divergent estimates are seen between the IBI's. For the OKFIBI, supporting condition is estimated in a population range of 42-58%, which closely encompasses the statewide estimate (Figures 6 and 7). Likewise, the Forested

Plains/Flint Hills and Western Plains/Tablelands closely mirror the statewide non-supporting estimate at 10%, whereas the Temperate Forests are estimated to have only 1% of the population not-supporting fish biocriteria. Undetermined status resembles the statewide estimate with a condition estimate range of 27% in the Forested Plains/Flint Hills to 33% in the Western Plains/Tablelands. On the other hand, the regional OCCIBI estimates do not resemble the statewide estimates. Excellent/good estimates range from 28% of the sampled target population in the Forested Plains/Flint Hills to 75% in the Temperate Forests, while the Western Plains/Tablelands estimate of 48% does closely resemble the statewide result of 50%. The estimates of poor/very poor condition are highly variant with a statewide condition estimate of 17% for the sampled population and a regional range of 4-32%. Fair condition is also disparate amongst regions. The Temperate Forests and Western Plains/Tablelands estimate 13 and 20% respectively, of the population in fair condition. However, over half (54%) of the Forested Plains/Flint Hills is estimated in fair condition. The statewide estimate of sampled stream miles is far condition is 29%.

Analysis of Macroinvertebrate Biological Condition

Macroinvertebrate data were analyzed using a Benthic-IBI (B-IBI) developed for Oklahoma benthic communities (OCC, 2005a) and commonly used by the OCC and OWRB Water Quality Divisions (OCC, 2008; OWRB, 2009a). The metrics and scoring criteria (Table 8) 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, 2008). Metrics were calculated by EcoAnalysts, Inc., and IBI calculations were made using the OWRB’s “B-IBI Assessment Workbook”, an automated calculator built by OWRB Staff in Microsoft Excel (OWRB, 2008a).

Calculation of the B-IBI is similar to the fish OCC-IBI 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, 2008). Species richness (total and EPT) and modified HBI values are compared to the composite reference value to obtain a “percent of reference”. A score of 6, 4, 2 or 0 is then given the site depending on the percentages outlined in Table 8, 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 8.   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 9 and an integrity classification is assigned with scores falling between assessment ranges classified in the closest scoring group.

Macroinvertebrate taxonomic results for each site were analyzed to produce a percent of reference score for the OKBIBI. From these scores, biological integrity classifications were assigned, and condition estimates calculated for each of the four previously discussed geographical scales (Figure 8). The OKBIBI condition estimates for the target population (total sampled stream miles) are presented using three classifications discussed previously, non-impaired, slightly impaired, and moderately impaired. None of the target population was ranked as severely impaired. Additionally, nearly 5% of the population was not sampled and is represented at each geographic scale. The OKBIBI estimates that 49% of the population has a supporting macroinvertebrate condition and that 32% and 14% of the population is either slightly or moderately impaired, respectively. Population estimates for the three regional areas present a range around the statewide estimates.

Figure 6. Fish condition estimated statewide and in the Temperate Forests region using the OKFIBI and OCCFIBI. (Label represents total sampled miles in particular category).

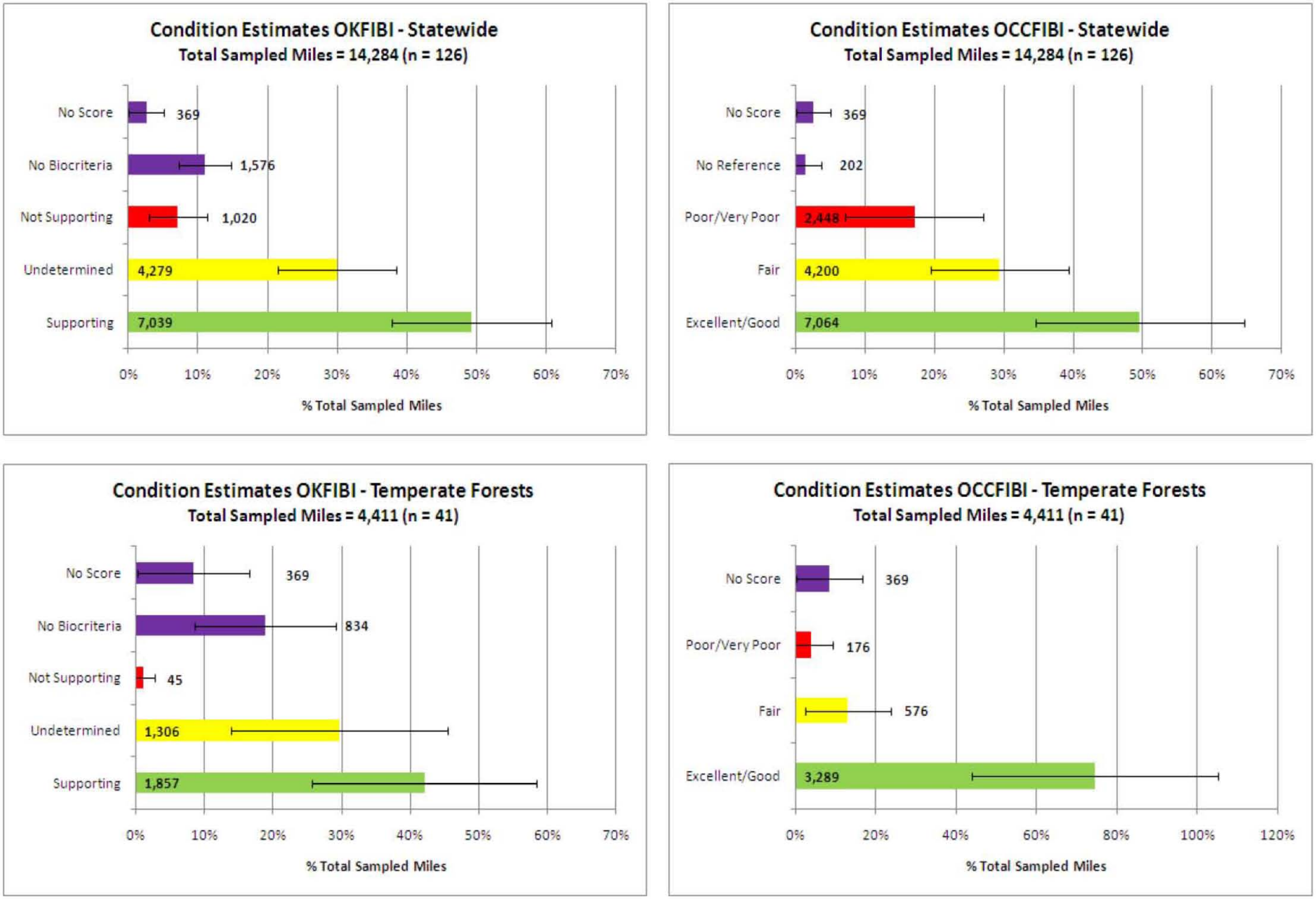
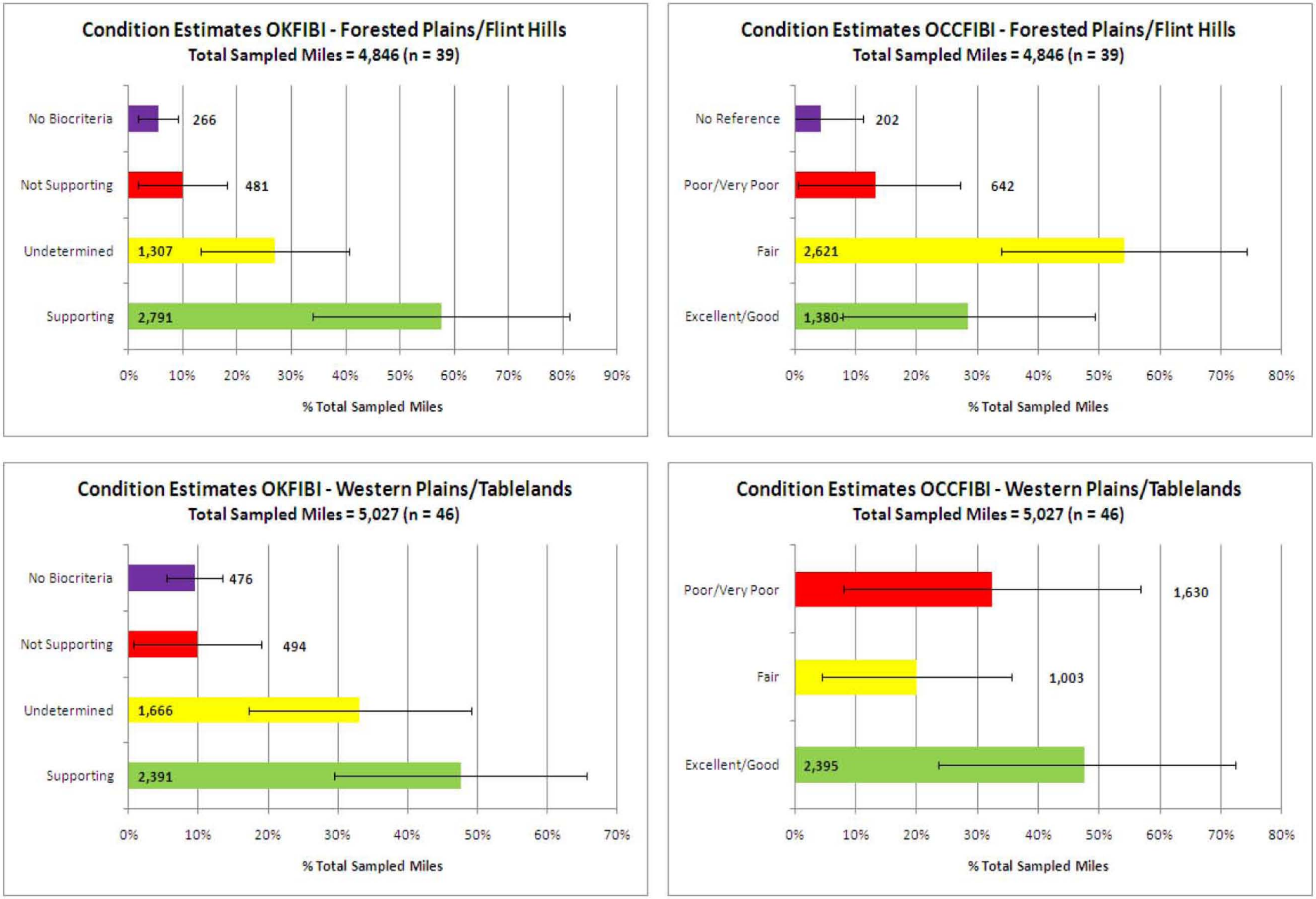


Figure 7. Fish condition estimated in the Forested Plains/Flint Hills and Western Plains/Tablelands. (Label represents total sampled miles in particular category).



Non-impaired condition estimates vary from 32% in the Forested Plains/Flint Hills to 67% in the Temperate Forests, while the 50% estimate for the Western Plains/Tablelands is nearly equivalent to the statewide estimate. Likewise, the slightly impaired condition varies drastically between geographical regions ranging from 12% of the population in the Temperate Forests to 48% in the Forested Plains/Flint Hills. The moderately impaired condition shows little variation ranging from 13-15% of the regional total stream miles.

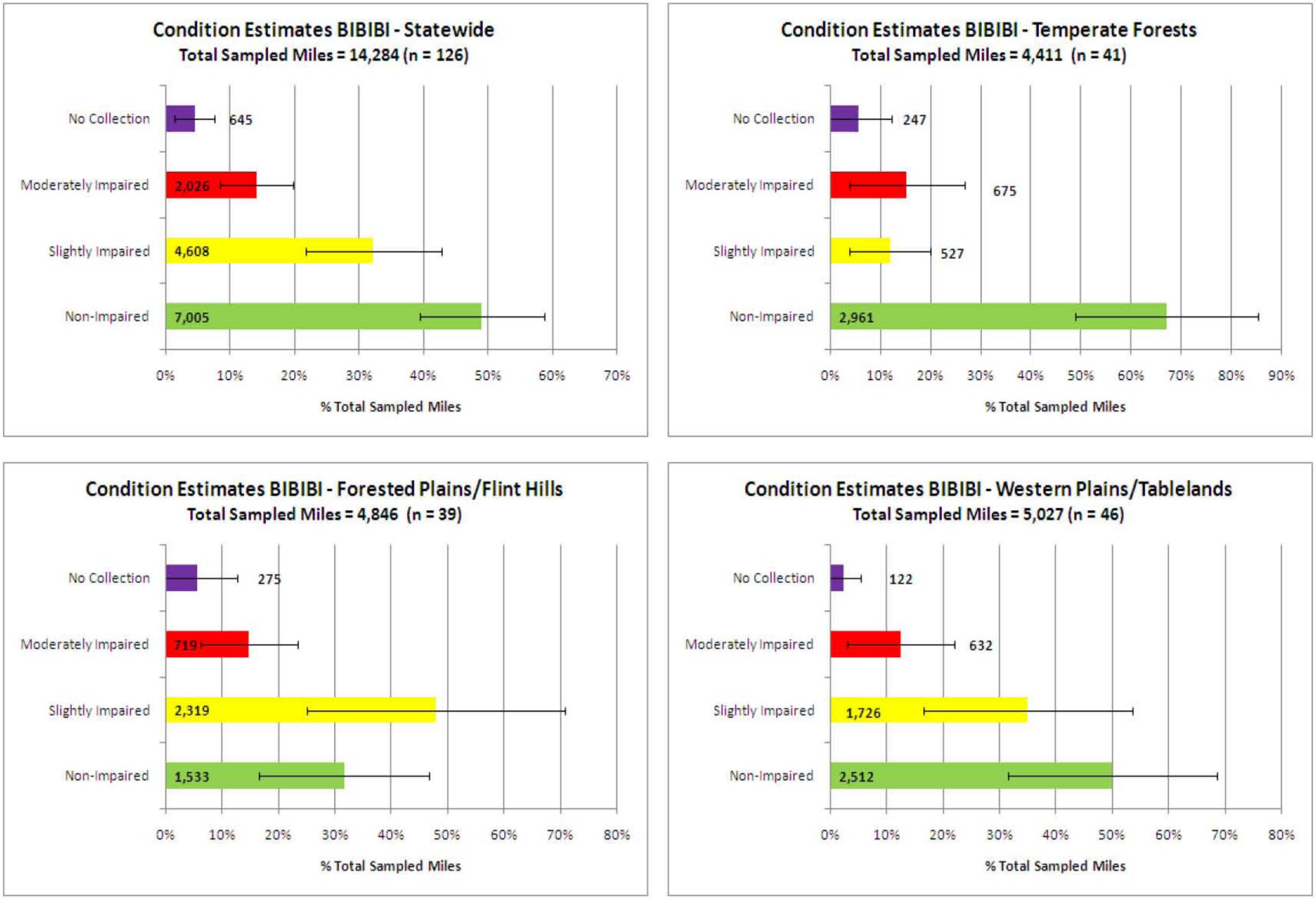
Table 8. Metrics and scoring criteria used in the calculation of the B-IBI (OCC, 2008).

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 9. Integrity classification scores and descriptions used with the B-IBI (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 and 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

Figure 8. Macroinvertebrate condition estimated Statewide and in the Temperate Forests, Forested Plains/Flint Hills, and Western Plains/Tablelands using OKBIBI. (Label represents total sampled miles in particular category).



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 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 OWQS (OWRB, 2008b) provides screening levels for both periphyton and sestonic chlorophyll-a. At each of the four geographical scales, the distributions are illustrated in boxplots for both periphyton and sestonic chlorophyll-a concentrations (Figure 9).

To estimate condition of algal biomass, chlorophyll-a concentrations were compared to multiple screening levels. For benthic chlorophyll-a, several screening levels were used. First, Oklahoma's Use Support Assessment Protocols (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 (BenUSAPSL). Second, the OWRB has collected periphyton chlorophyll-a across the state for several programs throughout the years. To provide an alternate screening level, the 25^{th} percentile of all OWRB benthic data was calculated at 45.7 mg/m^2 (BenP25). Similarly, three screening levels were established for sestonic chlorophyll-a. The Oklahoma Water Quality Standards (OWQS) includes a standard for sensitive water supplies of 10 mg/m^3 (SesChl10) of chlorophyll-a (OWRB, 2007a). Moreover, the USAP (OWRB, 2008b) provides a threshold trophic state index (TSI) of 62 under the aesthetics beneficial use. The threshold is based on chlorophyll-a concentration of 25 mg/m^3 (SesChl25). Last, as with benthic algae, the distribution of all OWRB sestonic chlorophyll-a data were considered as a screening level. The mean of all concentrations calculates at 19 mg/m^3 (SesChlMean).

Data from each site were compared to each screening level, and the results are presented in bar charts at each geographical scale for each screening level (Figure 10). For ease of viewing, benthic and sestonic values are grouped. Percentages represent the percent of the sites exceeding a particular screening limit, and estimates are not weighted. Included are estimates of the percentage of sites not exceeding any of the screening levels as well as an estimate of unassessed sites for benthic algae. For both benthic and sestonic populations, the greater majority of sites are not exceeding any screening limit, approximately 65-66% (+/-8%) statewide. Temperate Forests estimates exceed 80% (+/-14%), while in the Forested Plains/Flint Hills an estimated 81% of the sites do not exceed benthic screening limits. However, in the same region, more than an estimated 50% of the sites exceed some screening level. For the benthic population, the BenP25 is exceeded at a rate nearly twice that of the BenUSAPSL. The nuisance screening level is exceeded nearly 14% of the time statewide, but ranges broadly in areas across the state with estimates of only 3% in the Temperate Forests and 27% in the Western Plains/Tablelands. Similarly, the 25^{th} percentile estimate shows extensive variation. At the statewide level, an estimated 29% of sites exceed, while 47% exceed in the Western Plains/Tablelands and 20% in the other two regions. For the sestonic screening limits, statewide estimated exceedances range from 15% (SesChl25) to 35% (SesChl10). The mean-based screening level estimates more closely favors SesChl25 (19%). The regional estimates vary somewhat. In the Forested Plains/Flint Hills, the SesChlMean and SesChl25 estimates are nearly identical to the statewide estimates, but the SesChl10 exceeds a 51% estimate. In the Western Plains/Tablelands, the divergence between the screening levels is similar to statewide estimates, but the percentages are 6-9% higher. Lastly, the Temperate Forests are the anomaly for sestonic estimates with screening levels at less than third of the statewide estimates.

Figure 9. Boxplots depict distribution of benthic and sestonic chlorophyll-a at the statewide and regional scales.

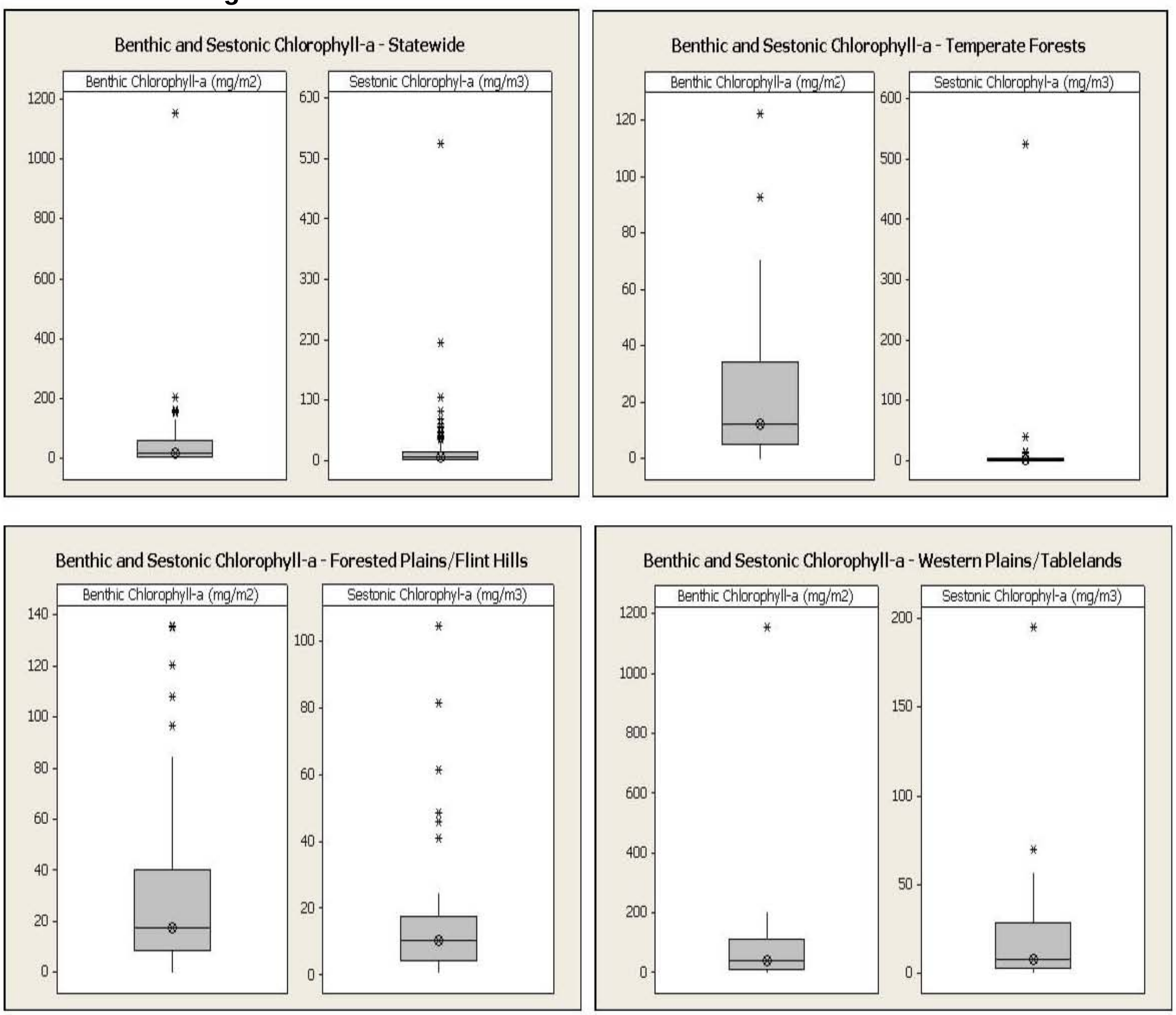
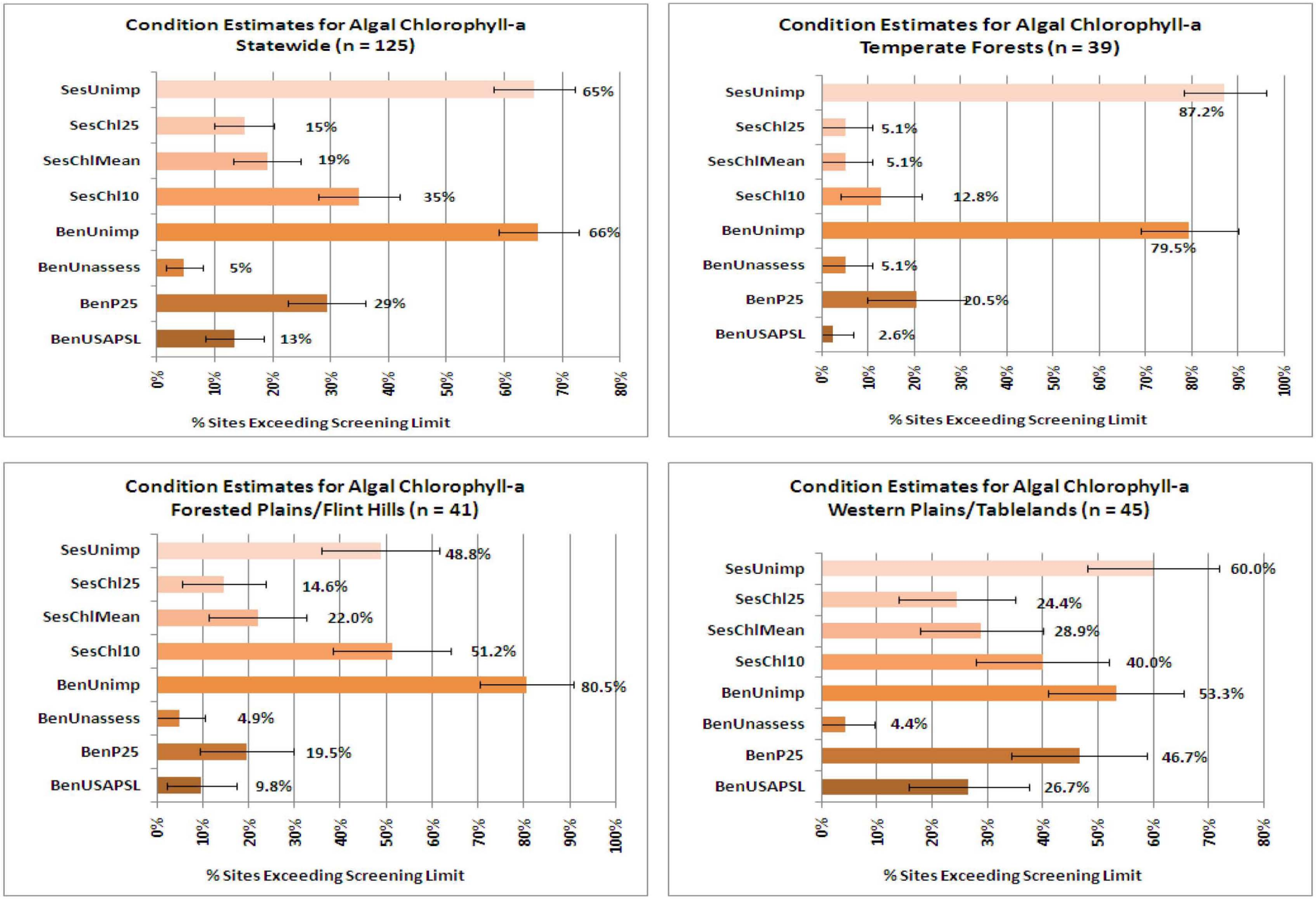


Figure 10. Algal chlorophyll-a condition estimated for all geographic scales. Upper and lower bounds represent a 90% confidence interval. (Refer to Table 10 for stressor descriptions.)

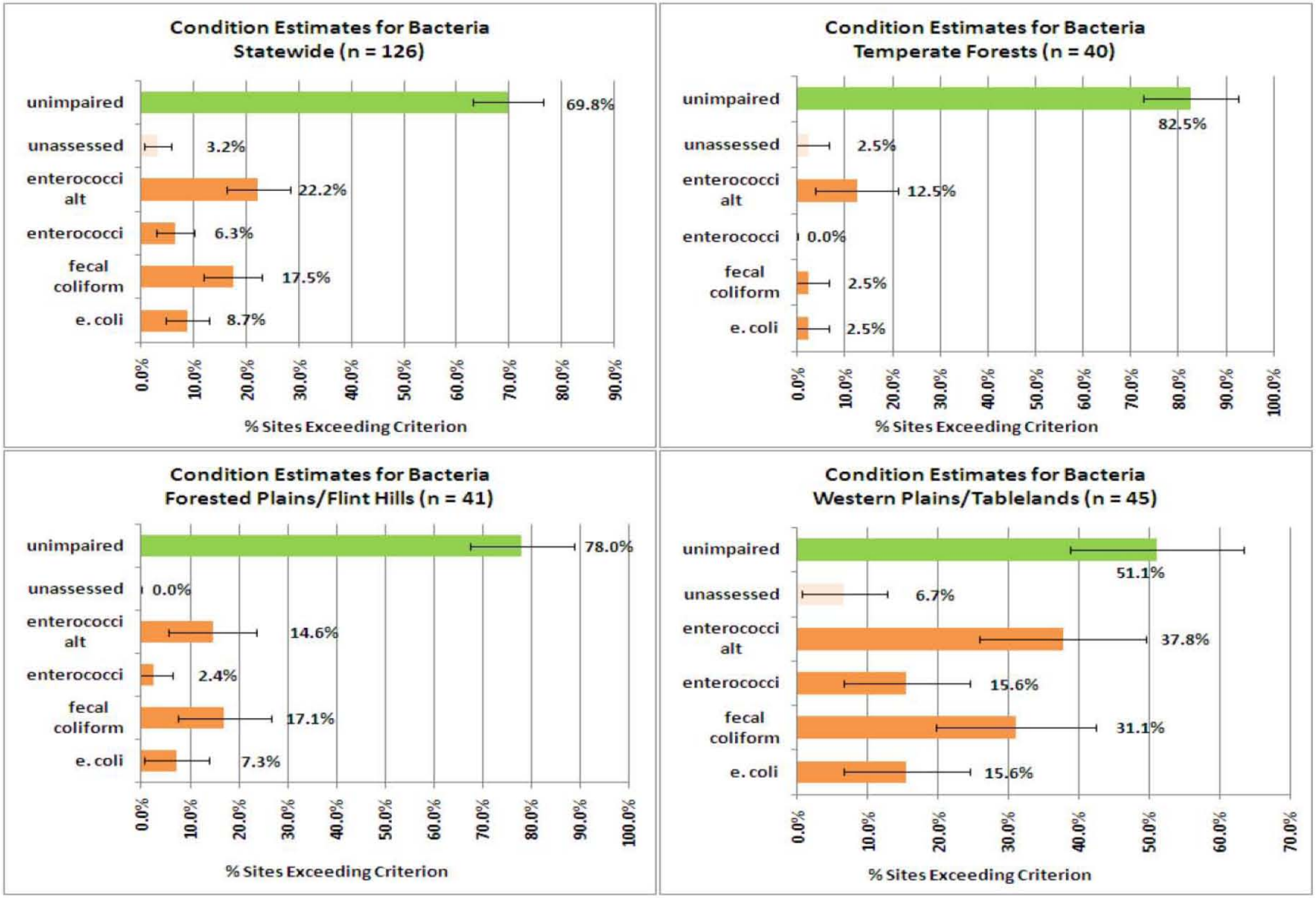


Analysis of Bacteria

Presence of indicator bacteria in rivers and streams is an important marker of potential human health impacts during recreational activities. Under the body contact recreation beneficial use, the OWQS (2007a) and USAP (OWRB, 2008b) provide criteria and screening levels for two indicator groups and one indicator organism. The screening levels represent single sample maximums and are assessed by comparison individual samples. Fecal coliform bacteria have both a standard and screening limit of 400 cfu/mL, while the *Escherichia coli* standard and screening limit are set at 406 cfu/mL. The second indicator group is enterococci, which have a screening level set at 406 cfu/mL and a single sample standard of 108 cfu/mL. Each indicator also has a geometric mean set in standards and USAP, however it is not applicable because of the nature of the dataset.

To create condition estimates, bacteria data were compared to the applicable screening limits, and for enterococci to the OWQS standard. (Figure 11). Estimates are based on percentages that represent the number of sites exceeding the applicable screening limit and are not weighted. Included are estimates of the percentage of the sites not exceeding the screening levels for any indicator bacteria as well as an estimate of the unassessed proportion of the population. The estimate for not exceeding any indicator screening level or standard is nearly 70% (+/-8%) statewide and approximately 80% (+/-14%) in the Forested Plains/Flint Hills and Temperate Forests regions. In contrast, the number of unimpaired waterbodies is only 51% for the Western Plains/Tablelands. Of the three indicators, *E. coli* shows the smallest estimate of impairment at 9% statewide, with an estimated high of 16% in the Western Plains/Tablelands and 3% in the Temperate Forests. Fecal coliform bacteria have a moderate impairment estimate of 18% statewide, with an estimated high of 31% in the Western Plains/Tablelands and 3% in the Temperate Forests. Enterococci have variable estimates depending on whether the screening limit or standard is applied. When the screening limit is used, the estimates are similar to the *E. coli* indicator and are generally smaller. For the Temperate Forests, no impairment exists, and in the Forested Plains/Flint Hills, only an estimated 2% of the population is impaired. On the contrary, when the enterococci standard is used, the highest estimates of impairment are generally seen. An estimated 22% of streams statewide are impaired, while in the Western Plains/Tablelands the estimate increases to 38% of streams. In the Temperate Forests, the estimate of 13% is relatively low in comparison to other areas, but the estimate is nearly five times that of any other indicator in the region. In only the Forested Plains/Flint Hills does the estimate (15%) rank below another indicator (Fecal Coliform = 17%).

Figure 11. Bacteria condition estimated for all geographic scales. Enterococci alternate represents the water quality standard. Upper and lower bounds represent a 90% confidence interval.



Stressor Methodology

During each visit a number of physical and water quality parameters were collected. These included nutrients, *in situ* measurements, metals, and measures of salinity. 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 nutrients 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. For each set of stressors, statewide extent estimates were developed as well as regional extent estimates for the Forested Plains/Flint Hills, Temperate Forests, and Western Plains/Tablelands regions. Stressor descriptions are given in Table 12.

Analysis of Nutrient Stressors

Nutrient stressors include measures of total phosphorus, total nitrogen (nitrate + nitrite + total Kjeldahl nitrogen), and available nitrogen (nitrate + nitrite + ammonia). For comparison, three sources were used to determine screening levels for each parameter giving a variety of nutrient levels based upon stream characteristics and/or regional variation (Table 12). Housed under the aesthetics beneficial use, the Oklahoma USAP has screening limits for both nitrogen and phosphorus, which are based upon Strahler order and gradient (OWRB, 2008b). Although the nitrogen limits are for nitrate/nitrite, the following analyses will use the screening levels to compare to total nitrogen and available nitrogen. Oklahoma regional nutrient screening levels were developed by the OCC (OCC, 2005b, 2006a, 2006b, 2007, 2008). They are Omernik Level III ecoregion specific and represent the mean of all data collected at high quality sites. They are also specific to warm water and cool water aquatic life tiers. USEPA regional nutrient criteria were also developed based on Omernik Level III ecoregions and represent the 25th percentile of data from a variety of sources (USEPA, 2000a, 2000b, 2001a, 2001b). However, the reports do not delineate criteria for the separate aquatic life tiers.

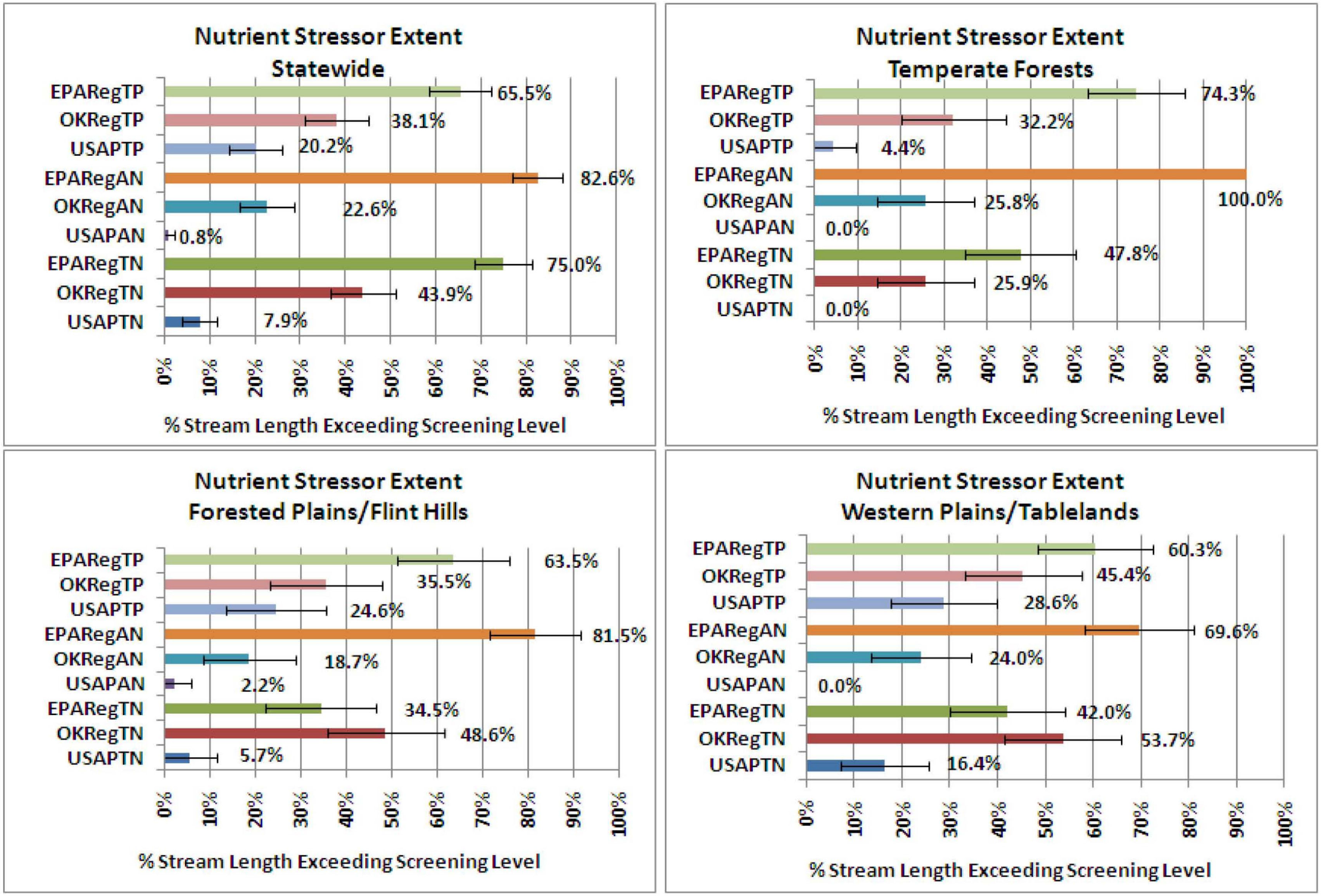
Weighted extents of all nutrient stressors are illustrated by bar graphs in Figure 12. Stressors were weighted using final weights given each site during calculation of extent and condition estimates. Weights are based upon an individual site's stream miles in relation to the sampled population. Three general patterns are noteworthy across all geographical scales. First, with the exception of total nitrogen, extent estimates increase in a consistent pattern for all test parameters. The USAP screening limits produce the smallest estimates of extent, while USEPA regional criteria the largest. In both the Forested Plains/Flint Hills and Western Plains/Tablelands, the OKRegTN has the highest extent estimates for the parameter group. Second, nearly all Oklahoma regional screening limits and USEPA regional criteria as well as the USAP total phosphorus screening limit are consistently estimated above 20%. Exceptions to this include OKRegAN in the Forested Plains/Flint Hills (19%) and the USAPTP in the Temperate Forests. Conversely, the USAP nitrogen screening limit estimates are inordinately low at less than 10% for all estimates except the USAPTN in the Western Plains/Tablelands. Additionally, several stressors produce unrealistic 0% estimates. Third, USEPA regional criteria produce the only extent estimates greater than 50%, with the exception of OKRegTN in the Western Plains/Tablelands (54%). Furthermore, across all geographical scales, all EPARegTP and EPARegTN estimates are greater than 60% and 70%, respectively, and have highs in the Temperate Forests region of 74% (TP) and 100% (TN). On the whole, the Oklahoma regional criteria seem to represent the most reasonable estimates of extent for each parameter.

Table 10. Descriptions of stressors affecting biological condition.

Stressor Description	Stressor (code)	Source
Total nitrogen SL housed in Oklahoma's USAP	USAPTN	OWRB
Total nitrogen SL based on regional high quality sites	OKRegTN	OCC
Total nitrogen SL based on USEPA's regional nutrient criteria development	EPARegTN	USEPA
Available nitrogen SL housed in Oklahoma's USAP	USAPAN	OWRB
Available nitrogen SL based on regional high quality sites	OKRegAN	OCC
Available nitrogen SL based on USEPA's regional nutrient criteria development	EPARegAN	USEPA
Total phosphorus SL housed in Oklahoma's USAP	USAPTP	OWRB
Total phosphorus SL based on regional high quality sites	OKRegTP	OCC
Total phosphorus SL based on USEPA's regional nutrient criteria development	EPARegTP	USEPA
Dissolved oxgyen SL housed in USAP and based on 1 mg/L excursion from OWQS	DO	OWRB
pH criteria housed in OWQS	pH	OWRB
Turbidity criteria housed in OWQS	Turb	OWRB
Water temperature criteria housed in OWQS	WTemp	OWRB
Conductivity SL based on regional OWRB historical data	OKRegCond	OWRB
Chloride criteria based on water quality management segments; housed in App F of OWQS	USAPCl	OWRB
Chloride SL based on regional high quality sites	OKRegCl	OCC
Sulfate criteria based on water quality management segments; housed in App F of OWQS	USAPSu	OWRB
Sulfate SL based on regional high quality sites	OKRegSu	OCC
TDS criteria based on water quality management segments; housed in App F of OWQS	USAPTDS	OWRB
Habitat total points scored from Oklahoma's Rapid Bioassessment Protocol (ORBP)	HTPts	OWRB/OCC
Percent loose bed substrate metric from ORBP and used in Sediment USAP by scoring against regional reference condition	%LBS	OWRB/OCC
Percent embeddedness metric from ORBP and used in Sediment USAP by scoring against regional reference condition	%Emb	OWRB/OCC
Percent deep pool metric from ORBP and used in Sediment USAP by scoring against regional reference condition	%DP	OWRB/OCC
Percent non-vegetated point bar metric from ORBP and used in Sediment USAP by scoring against regional reference condition	%NVPB	OWRB/OCC
Sediment assess. prot. based on 1 of 4 metrics deviating from reference; housed in USAP	USAPSed1	OWRB/OCC
Sediment assess. prot. based on 2 of 4 metrics deviating from reference; housed in USAP	USAPSed2	OWRB/OCC
Metals acute criteria for fish/wildlife prop. ben. use housed in App. G, Table 2 of OWQS	XxAcute	OWRB
Metals chronic criteria for fish/wildlife prop. ben. use housed in App. G, Table 2 of OWQS	XxChronic	OWRB
Metals criteria for public/private water supply ben. use housed in App. G, Table 2 of OWQS	XxPPWS	OWRB

Metals criteria for fish consumption-water column in App. G, Tab. 2 of OWQS	XxFCW	OWRB

Figure 12. Nutrient stressors extent estimated for all geographic scales. Upper and lower bounds represent a 90% confidence interval. (Refer to Table 10 for stressor descriptions.)



Analysis of General Water Quality Stressors

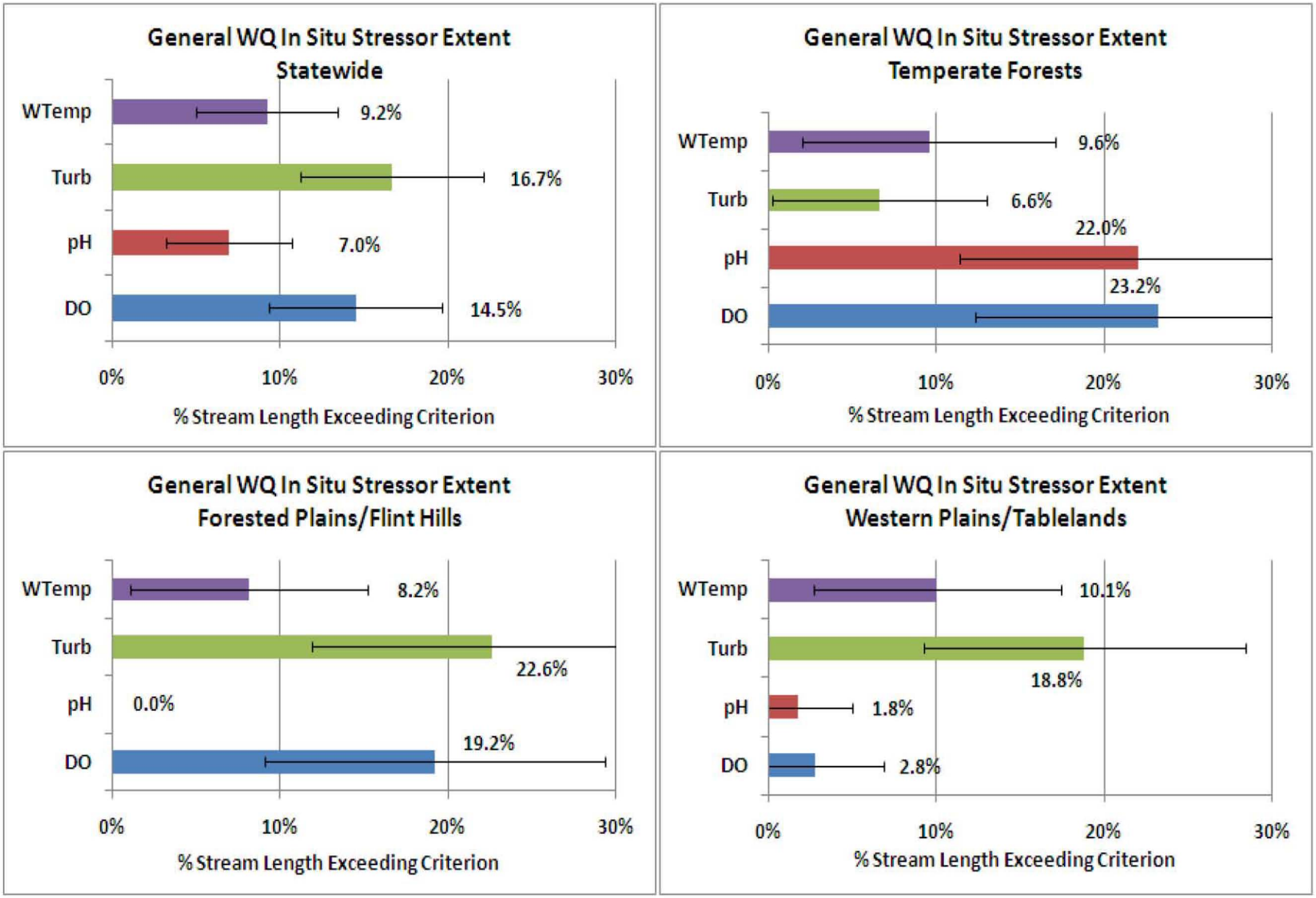
General water quality stressors represent a diverse group of parameters. For analysis purposes, the parameters will be discussed in two groups—*in situ* and salinity-related parameters (Table 12). The discussion of salinity-related parameters provides insight into both the extent of exceedances of sample standards housed in the agriculture beneficial use of the OWQS (OWRB, 2007a) as well as stressors that may affect biological condition.

In situ parameters include pH, dissolved oxygen, turbidity, and water temperature. Criteria for each of these are housed under the fish/wildlife propagation beneficial use of the OWQS (OWRB, 2007a), and protocols for assessment are included in Oklahoma's USAP (OWRB, 2008b). Because these criteria are commonly accepted for various aquatic life tiers, no regionally based criteria are included in this report. For pH, the OWQS gives a statewide range of 6.5-9.0 standard units statewide, but does allow for variance outside this range if due to naturally occurring conditions. Recently, a study published by the OWRB (2009a) determined pH values of less than 6.5 as being naturally occurring in three areas of the Ouachita Mountains level III ecoregion—the Little, Kiamichi, and Upper Mountain Fork River watersheds. Furthermore, evidence suggests that low levels of dissolved oxygen may be naturally occurring in the far eastern portion of the South Central Plains (OCC, 2009). 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 29.8^{o}C for cool water communities.

Population extents for the four *in situ* stressors are illustrated by bar graphs in Figure 14. Several notable patterns are detectable. First, turbidity and DO generally have the highest extent of criteria exceedance with statewide estimates of 17% and 15%, respectively. In the Forested Plains/Flint Hills, this pattern holds with estimates of 23% for turbidity and 19% for DO. In the other two regions, the pattern is the same for one of the two parameters, with DO at 23% in the Temperate Forests and Turbidity at 19% in the Western Plains/Tablelands. Second, pH extent is usually the lowest with nearly non-detectable levels and Western Plains/Tablelands (2%) and an estimate of 0% in the Forested Plains/Flint Hills, while statewide only 7% of the population are estimated to be outside the acceptable range of pH. The Temperate Forests have a comparatively high level of pH and DO exceedances (22-23%), but as discussed earlier, parts of this area are considered to have naturally occurring low pH levels and may have naturally occurring low DO. Lastly, water temperature extent estimates are consistently between 8-10% across all geographical levels.

Salinity-related parameters include conductivity, chloride, sulfate, and total dissolved solids (TDS). For comparison, two sources were used to determine criteria or screening levels for each parameter. Criteria for chloride (USAPCl), sulfate (USAPSu), and TDS (USAPTDS) are housed in Appendix F of OWQS (OWRB, 2007a), and protocols for assessment of the agriculture beneficial use are included in Oklahoma's USAP (OWRB, 2008b). They are based upon the 6-digit management segments, as defined in Appendix A of OWQS. Both yearly mean standards and sample standards were developed from data at one or more stations located in each 6-digit segment. Because the sample standard is compared to single samples as defined by the USAP, it is used to determine extent estimates. Given that Appendix F standards were developed for assessment of the agricultural beneficial use, screening levels were developed for this report based on OCC high quality site data (OCC, 2005a). Levels are based on Omernick Level III ecoregions and represent the 75^{th} percentile of all data for conductivity (OKRegCond), chloride (OKRegCl), and sulfate (OKRegSu) (Table 11). Two ecoregions have alternate levels based on regional variation.

Figure 13. General water quality (*in situ*) stressors extent estimated for all geographic scales. Upper and lower bounds represent a 90% confidence interval. (Refer to Table 10 for stressor descriptions.)



Extent of the six salinity-related stressors is illustrated by bar graphs in Figure 13. A number of noteworthy trends are apparent. First, extent estimates based upon USAP standards are generally at or below 15%, except in the Western Plains/Tablelands. In this region noted for higher salinity, all USAP standards are at or near a 20% estimate. Second, regional screening levels are estimated to be much higher in relation to USAP standards. Compared to the USAPCl, the OKRegCl, estimates are six times higher statewide and nearly forty times higher in the Temperate Forests. Likewise, the OKRegSu estimates, when compared to the USAPSu, are four times higher statewide. In the Temperate Forests region, the USAPSu is never exceeded while the regional sulfate screening level has a 95% exceedance estimate. Similarly, the conductivity screening level estimates are consistently three to four times higher than the USAPTDS estimates. Third, OKRegCl estimates are higher than OKRegSu estimates, with the exception of the Temperate Forests. And last, conductivity and TDS estimates are consistent across all geographic scales.

Table 11. Screening levels OKRegCond, OKRegCl, and OKRegSU based on The 75th percentile of OCC High Quality Data.

Omernick Level III Ecoregion Name	Conductivity (umhos/cm)	Chloride (mg/l)	Sulfate (mg/l)
Southwest Tablelands	2298.0	147.3	882.5
Central Great Plains	2925.8	189.8	1424.9
Central Great Plains-Broken Red Plains	274.2	8.8	20.3
Flint Hills	451.7	11.0	21.2
Cross Timbers	547.0	47.0	27.0
Cross Timbers-Arbuckle Uplift	496.5	18.0	10.0
South Central Plains	178.0	9.5	10.5
Ouachita Mountains	63.6	6.0	6.2
Arkansas Valley	159.0	10.3	14.0
Boston Mountains	213.0	5.0	15.3
Ozark Highlands	286.0	10.0	7.5
Central Irregular Plains	461.7	28.5	88.4

Analysis of Metal Stressors

Numerical criteria for metals are housed in Appendix G, Table 2 of the OWQS (OWRB, 2007a). The OWQS provides criteria for a number of metals but only those listed in Table 10 are considered for this study. This discussion provides insight into stressors related to biological condition as well as those related human health beneficial uses—public/private water supply and fish consumption.

Extents of metals stressors related to biological condition are illustrated by bar graphs in Figure 15. Notably, only chronic lead, chronic and acute selenium, and chronic and acute zinc exceed their respective criteria and generally less than 6% of the time. Acute and chronic zinc criteria as well as acute selenium criteria are only exceeded once at different sites in the Western Plains/Tablelands. Chronic selenium and lead criteria are exceeded at six sites spread over the Forested Plains/Flint Hills and Western Plains/Tablelands. No metals exceed criteria in the Temperate Forests.

Extent of metals stressors related to human health criteria are illustrated by bar graphs in Figure 16. As was the case with biological condition, very few parameters show any exceedances of their respective criteria. The selenium public/private water supply is exceeded by only two sites, one each in the Forested Plains/Flint Hills and Western Plains/Tablelands. Similarly, the lead fish consumption-water is exceeded at four and two sites in the same regions, respectively. And, no metals exceed criteria in the Temperate Forests.

Figure 14. General water quality (salinity-related) stressors extent estimated for all geographic scales. Upper and lower bounds represent a 90% confidence interval. (Refer to Table 10 for stressor descriptions.)

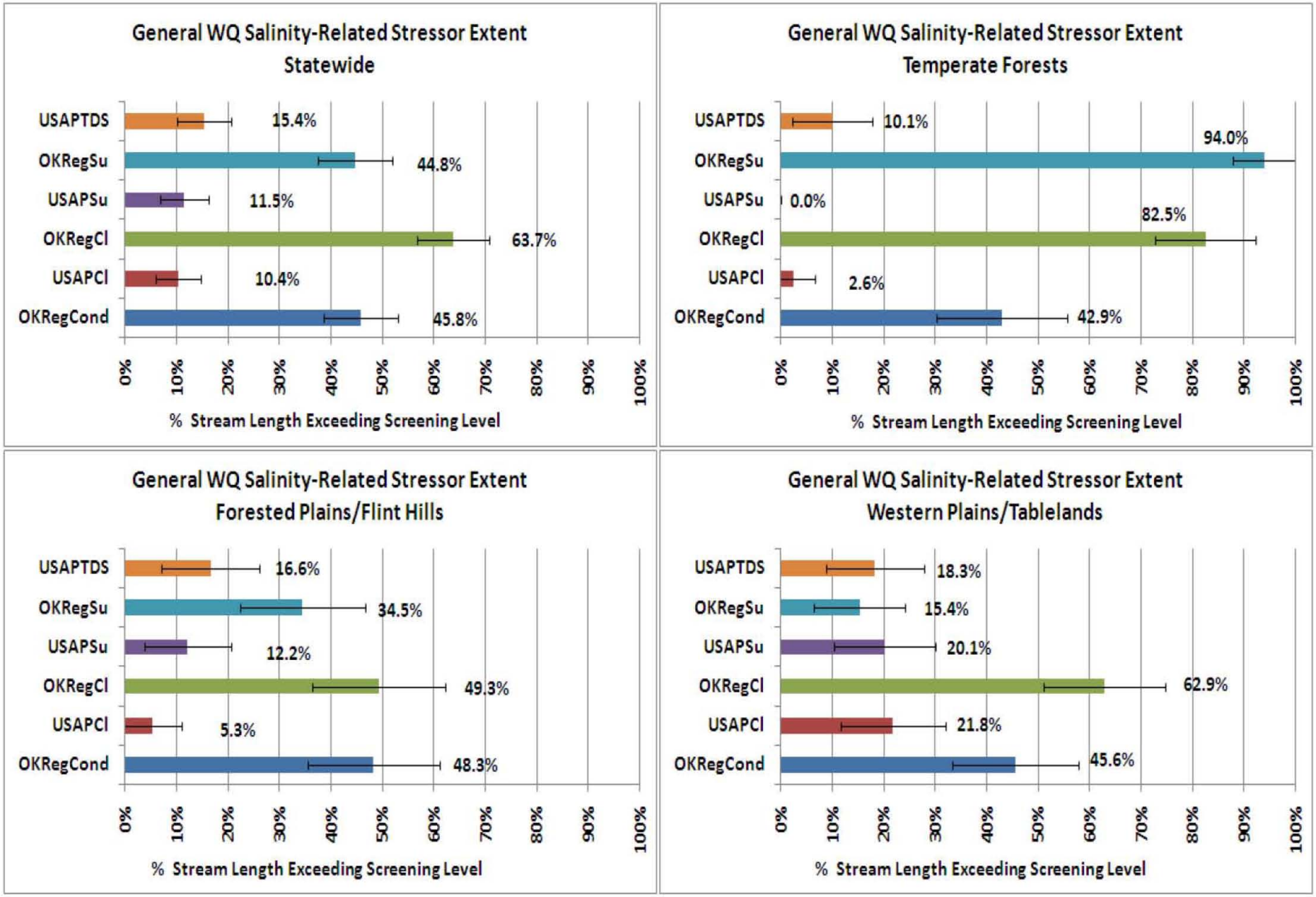


Figure 15. Metal stressors related to biological condition with extent estimated for all geographic scales. (Refer to Table 10 for stressor descriptions.)

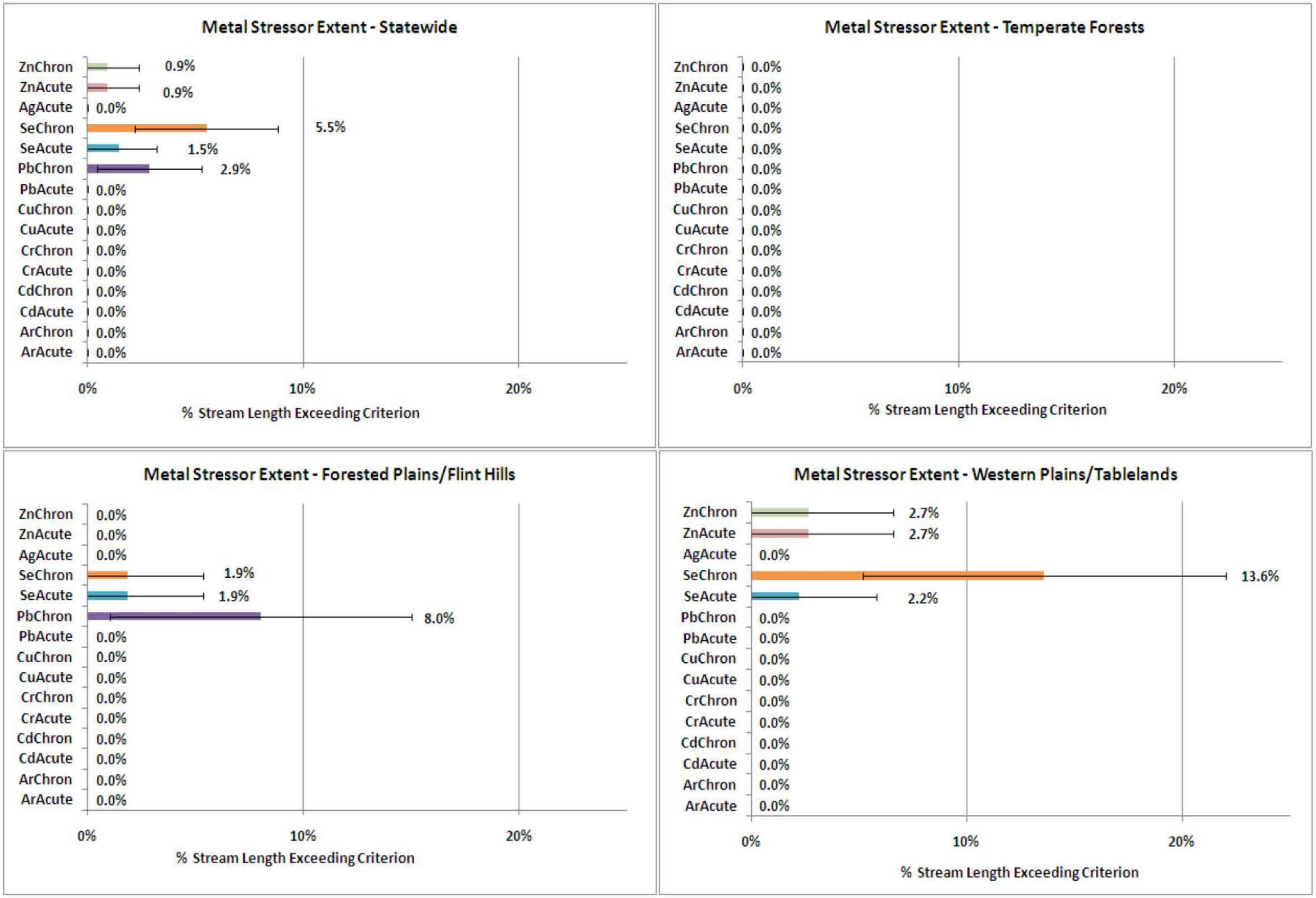
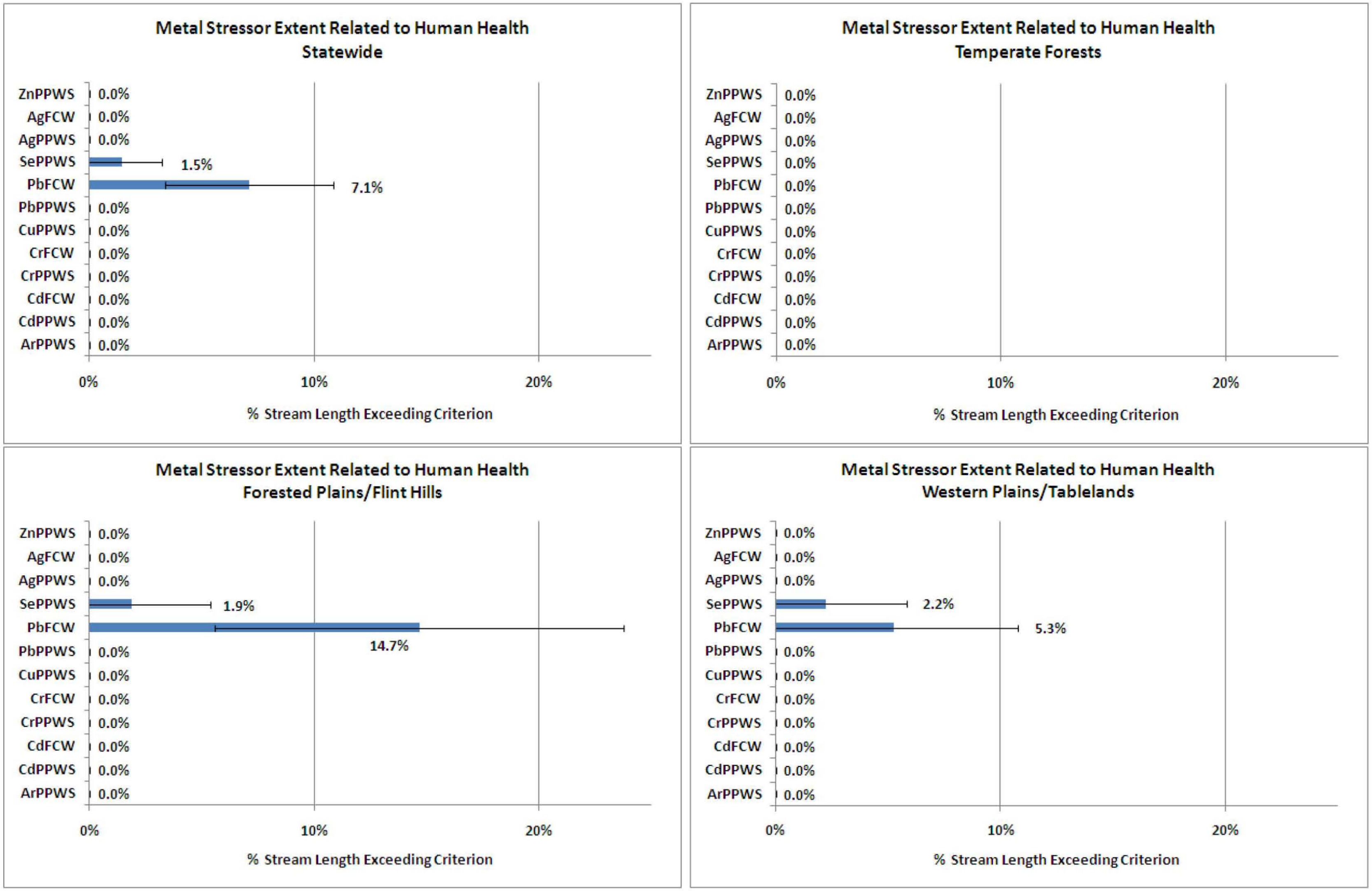


Figure 16. Metal stressors related to human health with extent estimated for all geographic scales. (Refer to Table 10 for stressor descriptions.)

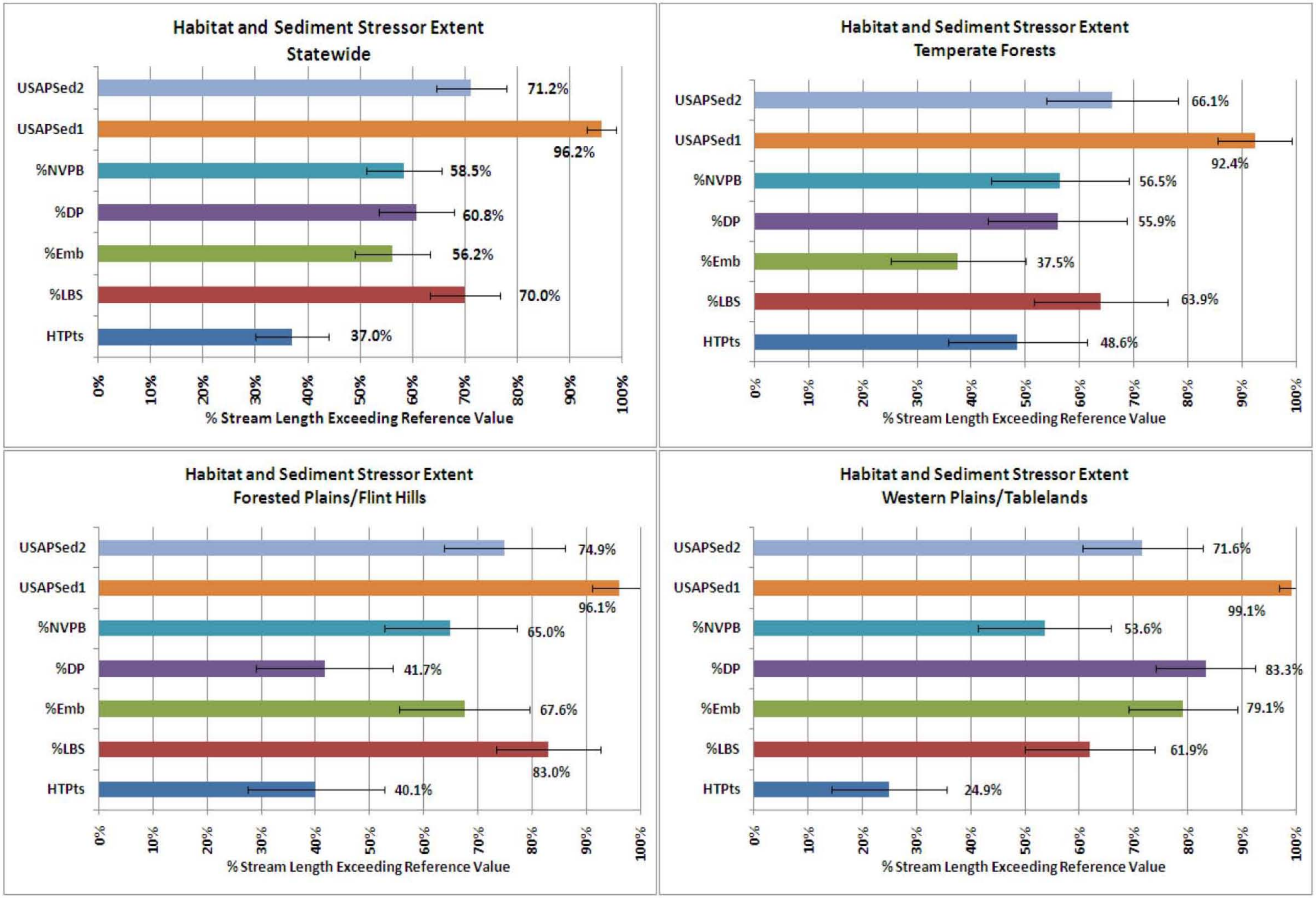


Analysis of Habitat Stressors

Habitat stressors include total habitat score, several individual habitat metrics, and an index for sedimentation (Table 10). Total habitat score (HTPts) was calculated for each site based on habitat metrics in Oklahoma's Rapid Bioassessment Protocol (OWRB, 1999, 2005b). 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 is derived from the habitat scores for ecoregionally based high quality sites developed by the OCC (2005a). For the most part, all high quality sites in a Omernik Level III ecoregion were used to develop reference condition. However, in certain ecoregions, some Omernik Level IV ecoregions were broken out from the whole. Omernik Level IV ecoregions used are the Broken Red Plains and Cross Timbers Transition of the Central Great Plains and the Arbuckle Uplift of the Cross Timbers. Additionally, the reference condition used is separated by aquatic life tier, and 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.

Extent of the seven habitat stressors are illustrated by bar graphs in Figure 17. Three general patterns are noteworthy. First, the score for total habitat points typically has the lowest estimated extent with all geographical scales scoring below 50%. Second, it is expected that USAPSed1 would have a greater extent estimate than USAPSed2. However, the ratio of extent estimates is consistent across all geographic scales, and the sedimentation extents are similar over the several geographic regions. This may validate the concept of using a combination of metrics to determine if sedimentation is impairing biological condition. Third, unlike other stressor groups, the individual habitat metrics influence each geographic region differently. In the Forested Plains/Flint Hills, %LBS has the largest deviation from reference (83%) and %DP the lowest (42%). Conversely, the Western Plains/Tablelands are most heavily influence by %DP (83%) and least by %NVPB (54%), with %LBS at a much lower extent (62%) than in the Forested Plains/Flint Hills. In the Temperate Forests, habitat metric extents generally score lower than in the other two regions. Within the region, there are similar extents for %NVPB (57%), %DP (56%), and %LBS (64%), with %Emb (38%) being much lower in extent than the other three metrics. Interestingly, the extent of total habitat score deviating from reference is the highest in the Temperate Forests, indicating that high quality sites in the region have exceptional habitat.

Figure 17. Habitat and sediment stressors extent estimated for all geographic scales. Upper and lower bounds represent a 90% confidence interval. (Refer to Table 10 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. 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. Additionally, relative risk is determined for each condition at each geographical scale. The analysis uses 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.

For the following analysis, 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. This was necessitated because of the large number of sites (approximately 43%) that either have no biocriteria or have an undetermined support status using the OKFIBI. 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 92 sites ranked as good and 31 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.

Statewide relative risk for nutrients, general water quality, and habitat/sediment are illustrated in Figure 18. For nutrients, the only significant risk is USAPTN which is likely to affect fish 2.5 times more when above the screening level. Several other risks exceed 1.0 but are not significant. On the whole, general water quality parameters demonstrate no significant risk to fish condition, although both turbidity and dissolved oxygen have relative risks above 1.0 with high upper confidence bounds. Likewise, no sediment or habitat stressor has significant associated risk. Notably, USAPSed1 (RR = 1.51) is not significantly related to fish condition but has an extremely high upper confidence bound of nearly 7.0.

Relative risk of stressors to fish condition in the Temperate Forests region is illustrated in Figure 19. No stressor is linked significantly to fish condition. However, several parameters across all stressor groups have relative risks exceeding 1.0 associated with high upper confidence bounds. These include the nutrient stressors OKRegTN, OKRegTP, and EPARegTP. Sediment stressors with high confidence bounds are %DP and % Emb. Finally, a number of general water quality parameters have extremely high confidence bounds—DO, pH, OKRegCond, and OKRegSu.

Relative risk for nutrients, general water quality, and habitat/sediment for the Forested Plains/Flint Hills region are illustrated in Figure 20. Much like the Temperate Forests, nearly all stressors relationships are insignificant, except total habitat points. Fish condition is 3.7 times more likely to be affected when HTPts scores below the regional average. Insignificant stressors with noticeably high upper confidence bounds include USAPTN, %Emb, turbidity, and water temperature.

Relative risk in the Western Plains/Tablelands region is illustrated in Figure 21. Significant risk is associated with USAPTN, which is 2.18 times more likely to affect fish condition. The other two total nitrogen stressors are insignificant but have upper confidence bounds above 3.0 and relative risks above 1.5. Several general water quality stressors demonstrate significantly associated risk for decreased fish condition. High conductivity and dissolved oxygen are 2.2 and 2.3 times more likely to negatively affect fish condition. Finally, no sediment or habitat stressors are significant, but %LBS and %Emb display upper confidence bounds above 3.0 and have relative risks greater than 1.0.

Figure 18. Relative risk of nutrient, general water quality, habitat, and sediment stressors affecting fish condition at statewide scale.   Upper and lower bounds represent a 90% confidence interval. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)

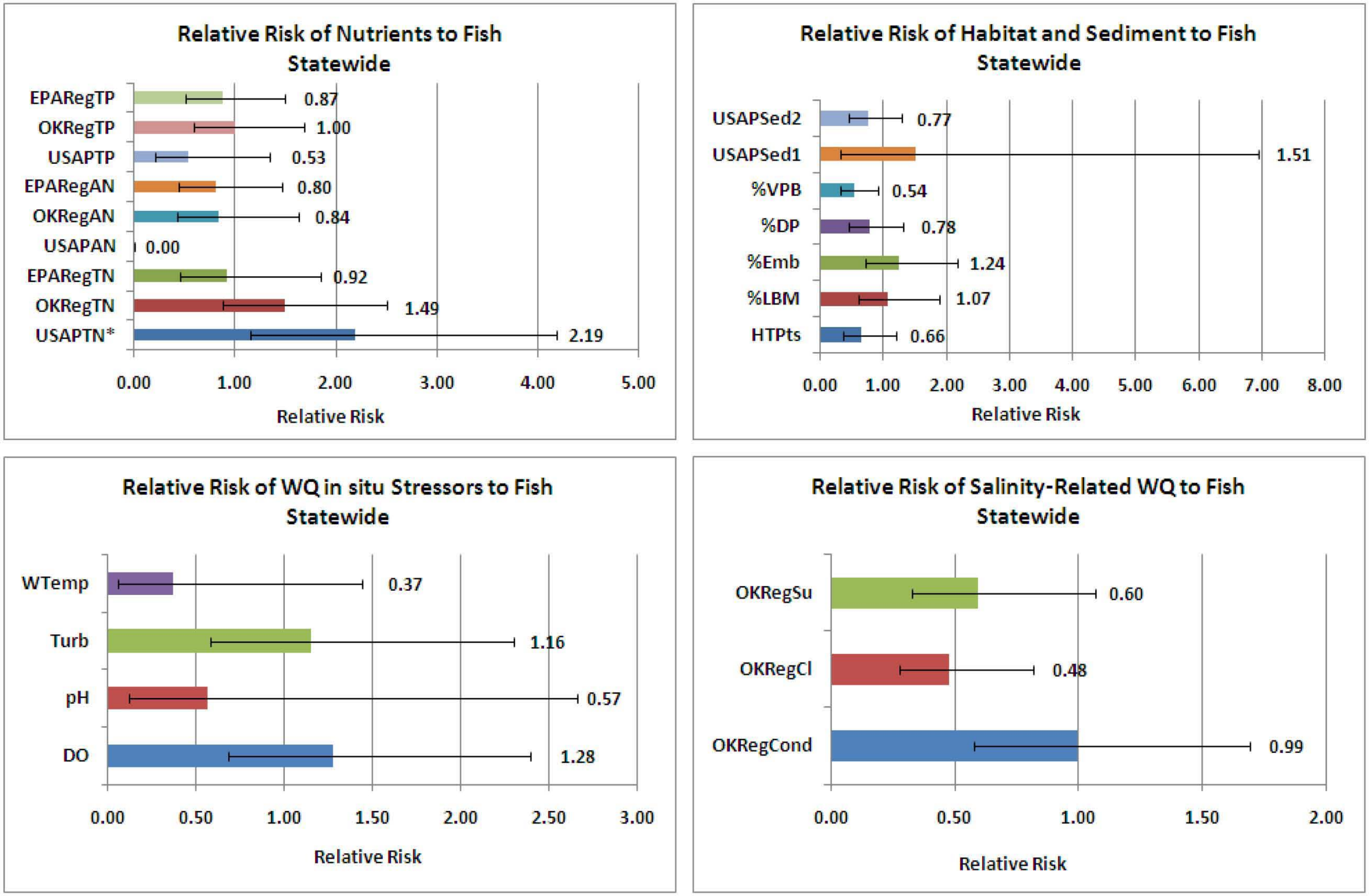


Figure 19. Relative risk of nutrient, water quality, habitat, and sediment stressors affecting fish condition in Temperate Forests region. Upper and lower bounds represent 90% confidence interval. Red values estimated. (No significant relative risk) (Refer to Table 10 for stressor descriptions.)

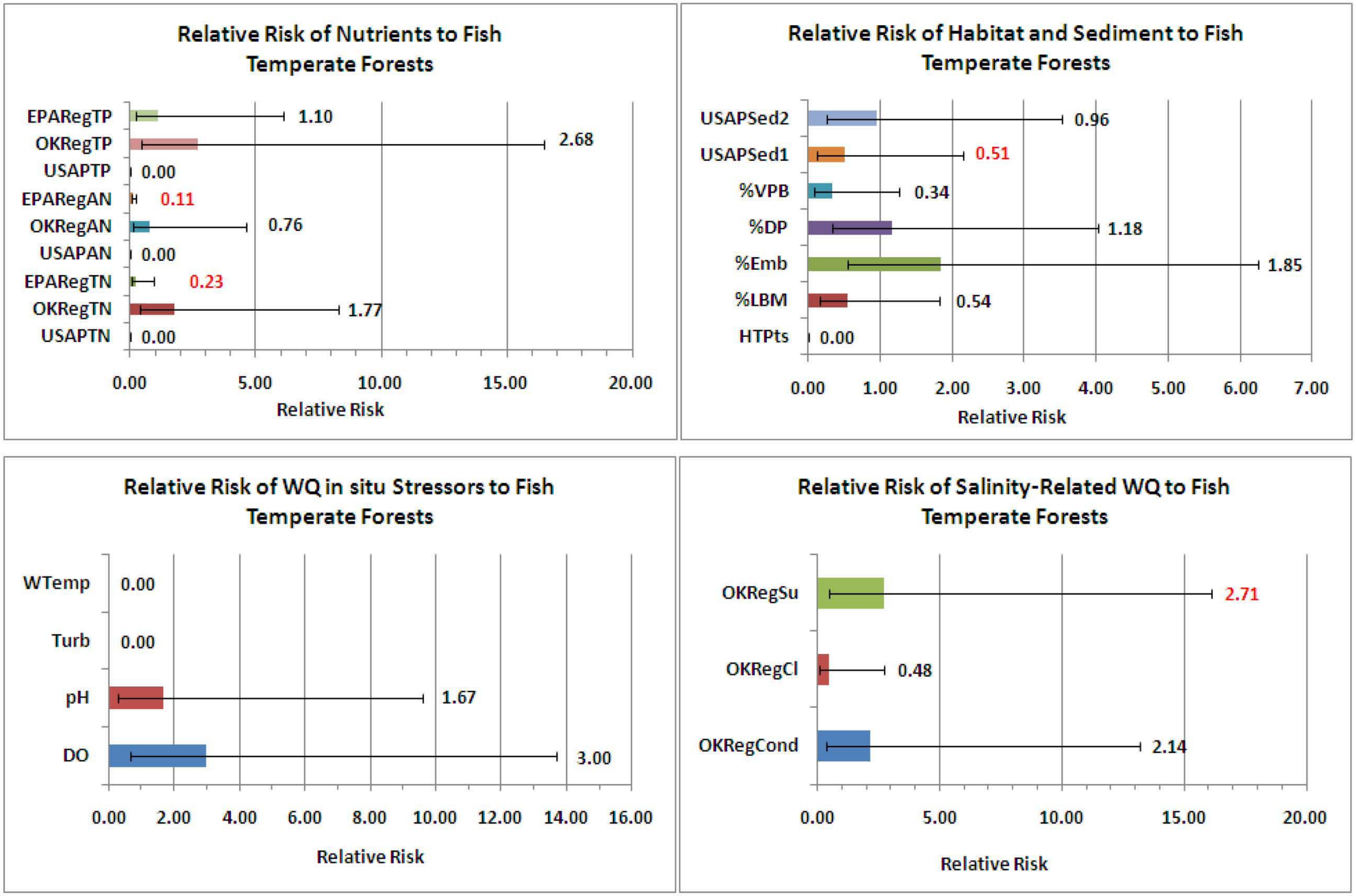


Figure 20. Relative risk of nutrient, water quality, habitat, and sediment stressors affecting fish condition in Forested Plains/Flint Hills region. Upper and lower bounds represent 90% confidence interval. Red values estimated. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)

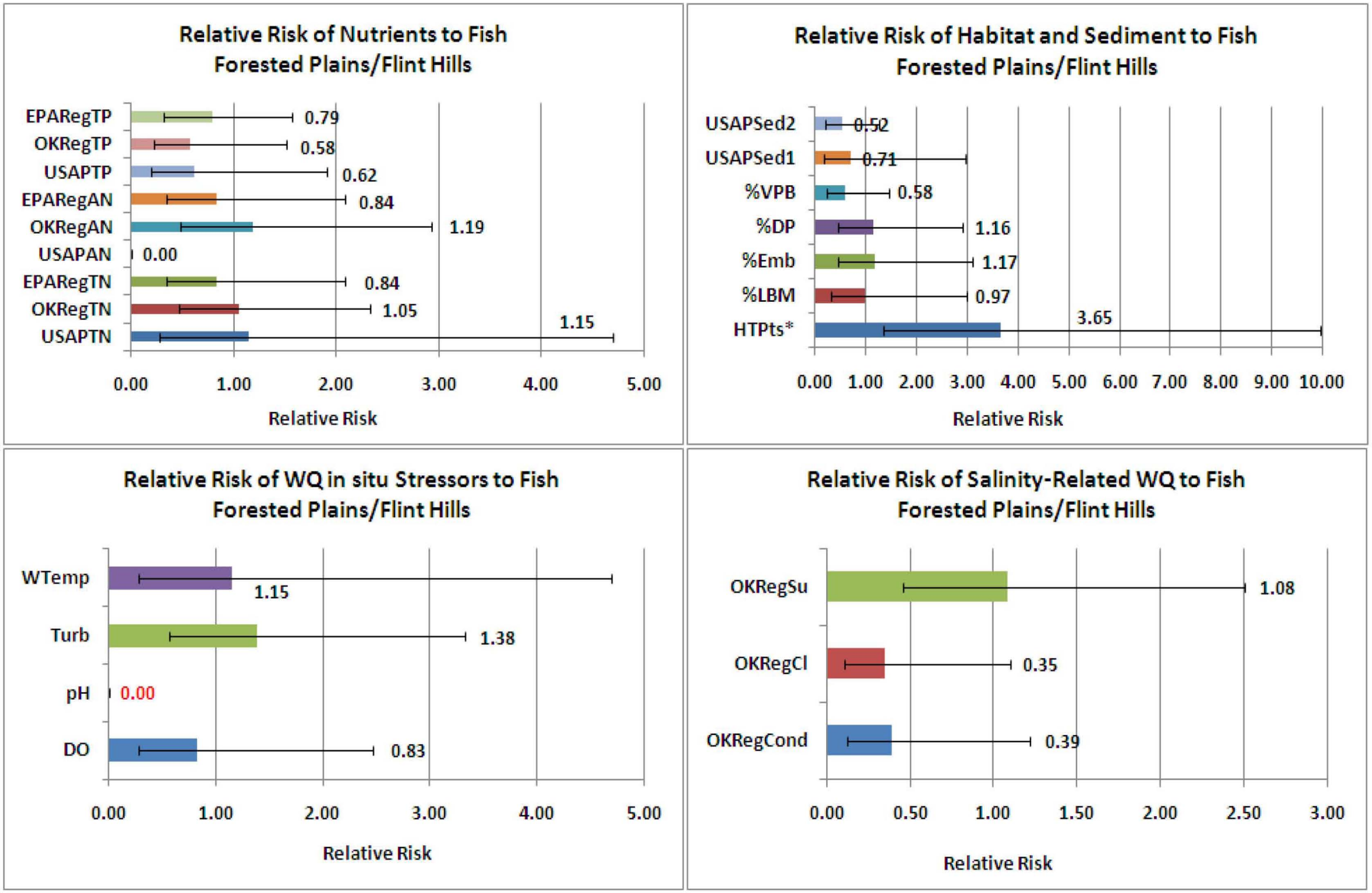
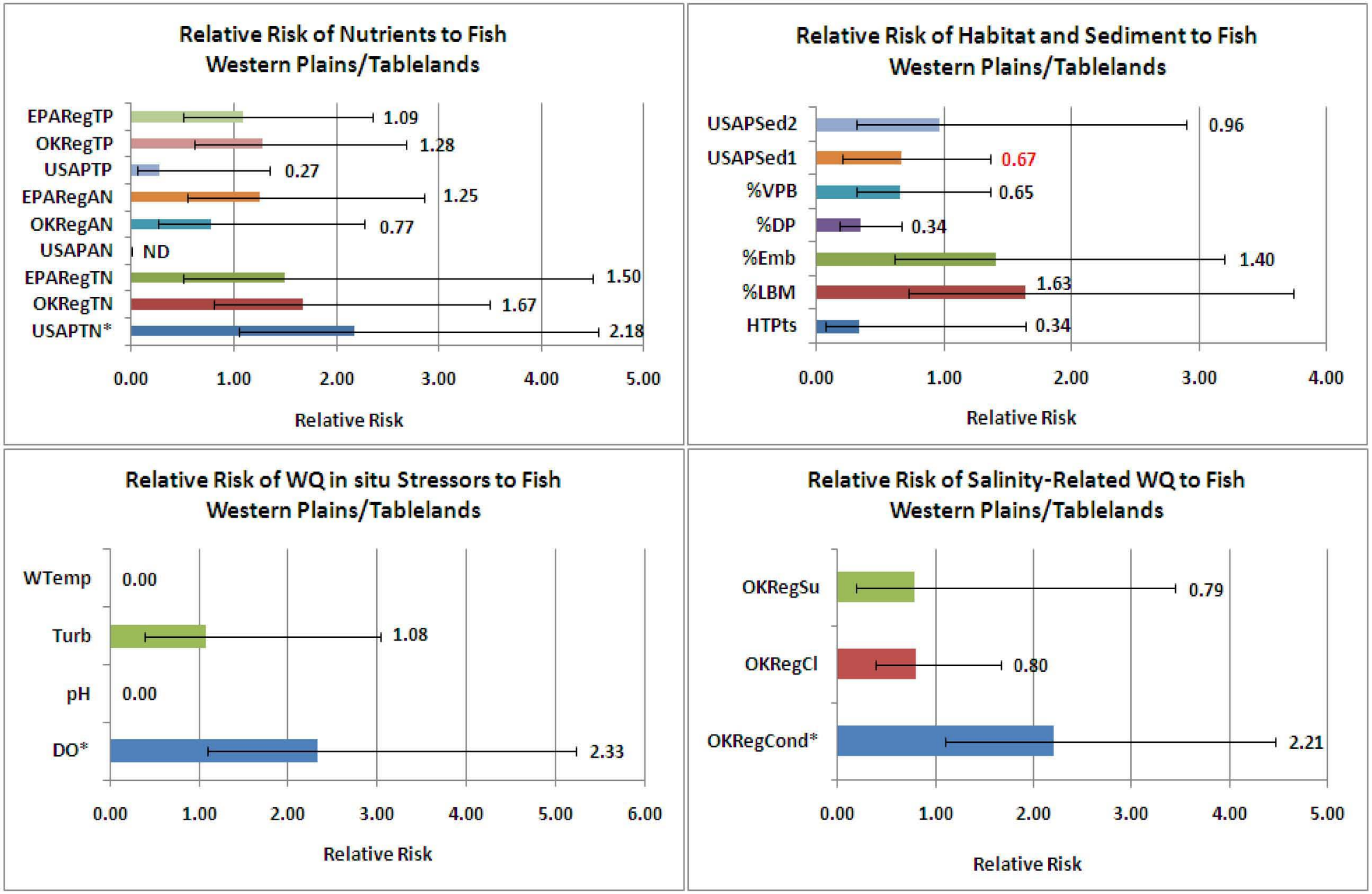


Figure 21. Relative risk of nutrient, water quality, habitat, and sediment stressors affecting fish condition in Western Plains/Tablelands. Upper and lower bounds represent 90% confidence interval. Red values estimated. (* = significant at 0.90) (Refer to Table 10 for stressor descriptions.)



Relative Risk to Macroinvertebrate Biological Condition
As with fish, relative risk to macroinvertebrate condition is considered for a variety of stressors. To create a good/poor classification for macroinvertebrate condition, a percent of reference score of 75 was used. The final breakdown was 72 sites ranked as good and 46 sites ranked as poor. Also, the following analysis will be separated by geographical scale.

Statewide relative risk for nutrients, general water quality, and habitat/sediment are illustrated in Figure 22. In contrast to fish, many nutrient stressors may significantly affect macroinvertebrate condition. The OKRegTN and USAPTN stressors are 1.8 to 2.5 times more likely to lower condition, while the USAPAN is 2.6 times more likely to do the same. And, although the EPARegTN stressor is not significant, it does have a relative risk of 1.9 and a high upper confidence bound. Likewise, the OKRegTP and USAPTP stressors are 1.5 to 2.0 times more likely to significantly affect condition. Overall, general water quality parameters have low relative risks. However, low dissolved oxygen is 1.7 times more likely to significantly affect macroinvertebrate condition. No sediment or habitat stressor is significant, although USAPSed1 has a high upper confidence bound.

Stressor related risk in the Temperate Forests is graphically shown in Figure 23. Several general water quality parameters demonstrate significant associated risk. Macroinvertebrate condition is 9.3 times more likely to be affected when dissolved oxygen is below applicable screening levels. Likewise, high conductivity is 6.0 times more likely to lower condition. Additionally, each of the regional nutrient stressors developed from Oklahoma data, as well as chloride, have high upper confidence bounds even thought they carry no significantly associated risk to macroinvertebrate condition.

Relative risks in the Forested Plains/Flint Hills are given in Figure 24. Similar to the statewide nutrient risk assessment, all phosphorus and total nitrogen stressors as well as USAPAN carry significant risk to macroinvertebrate condition. Notably, EPARegTN is 5.9 times more likely to affect condition when above the prescribed ecoregion criteria. Other total nitrogen parameters carry associated risks of 1.7 to 2.1. Phosphorus levels above all three screening limits are 1.6 to 2.0 times more likely to significantly affect condition. Furthermore, when total habitat points are below regional reference score, condition is 2.5 times more likely to be significantly affected. And, although not significant, %LBS (RR = 3.2) and USAPSed1 (RR = 1.0) have high upper confidence bounds. No general water quality stressors have significant risk.

Lastly, stressor risk in the Western Plains/Tablelands are displayed in Figure 25. When above the screening limit, the USAPTN stressor is significant and 2.2 times more likely to result in poor macroinvertebrate condition. Except USAPAN, all other nutrient stressors have relative risks greater than 1.0 and upper confidence bounds approaching 3.0, but are not significant. Several general water quality parameters demonstrate significantly linked risk to condition, including pH (RR = 2.5), turbidity (RR = 1.8), and OKRegSu (RR = 2.0). Also, dissolved oxygen, though insignificant, has a relatively high upper confidence bound. No habitat stressors are significant. The two USAPSed stressors are also insignificant, but have high upper confidence bounds.

Figure 22. Relative risk of nutrient, water quality, habitat, and sediment stressors affecting macroinvertebrate condition statewide. Upper and lower bounds represent 90% confidence interval. Red values estimated. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)

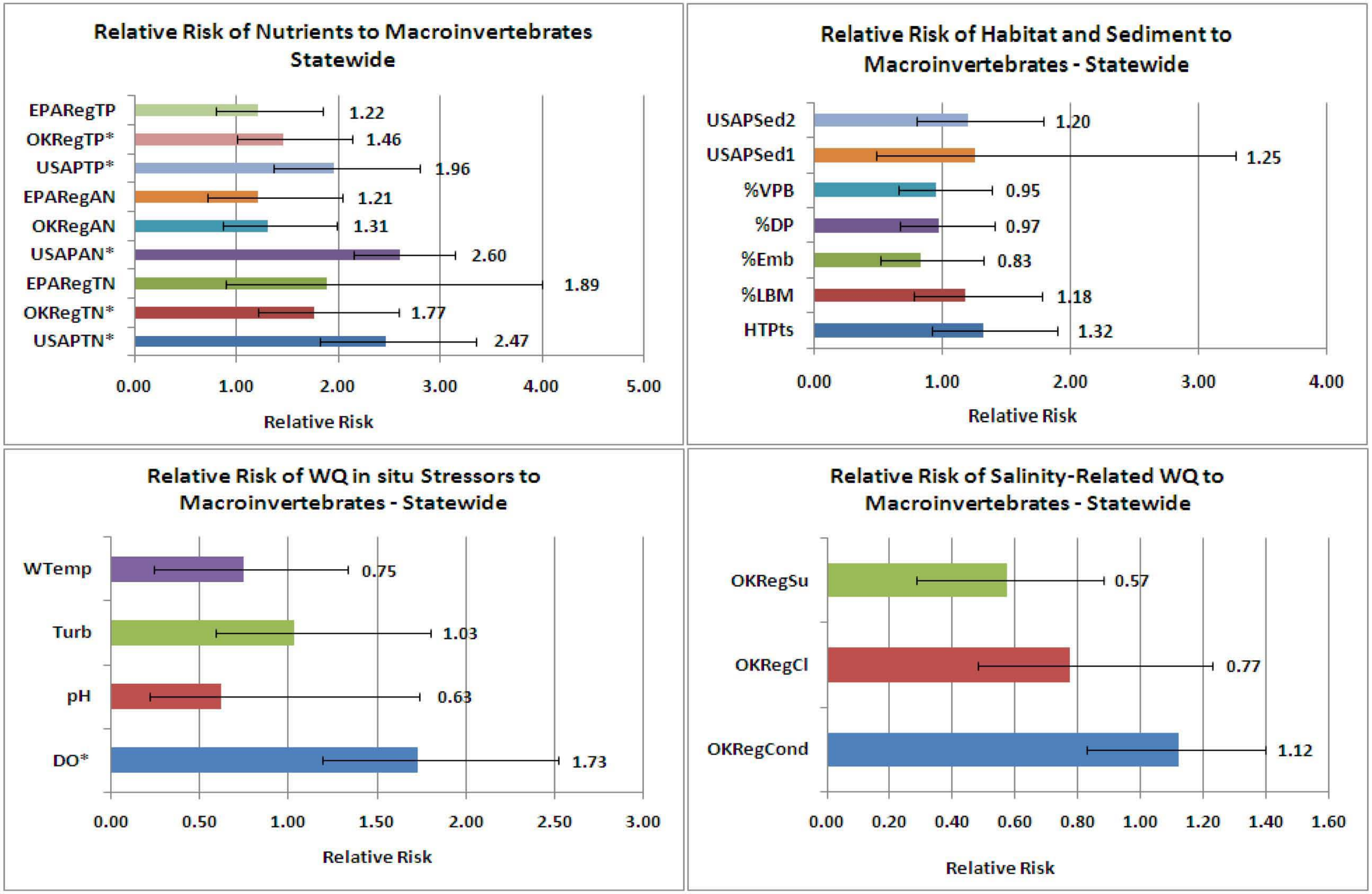


Figure 23. Relative risk of nutrient, water quality, habitat, and sediment stressors affecting macroinvertebrate condition in Temperate Forests. Upper and lower bounds represent 90% confidence interval. Red values estimated. (* = significant at 0.90) (Refer to Table 10 for stressor descriptions.)

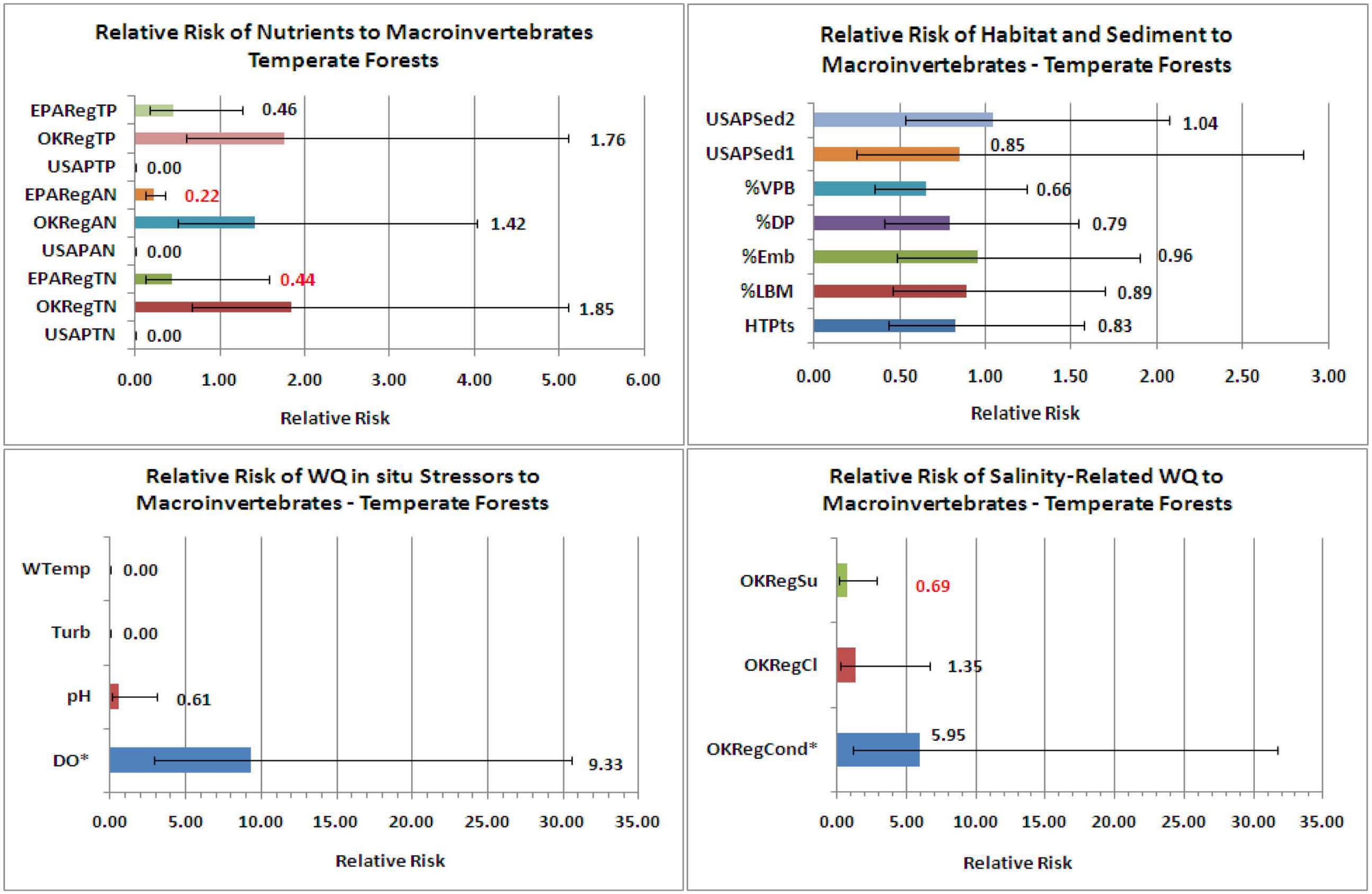


Figure 24. Relative risk of nutrient, water quality, habitat, and sediment stressors affecting macroinvertebrate condition in Forested Plains/Flint Hills. Upper/lower bounds represent 90% confidence interval. Red values estimated. (* = significant at 0.90) (Refer to Table 10 for stressor descriptions.)

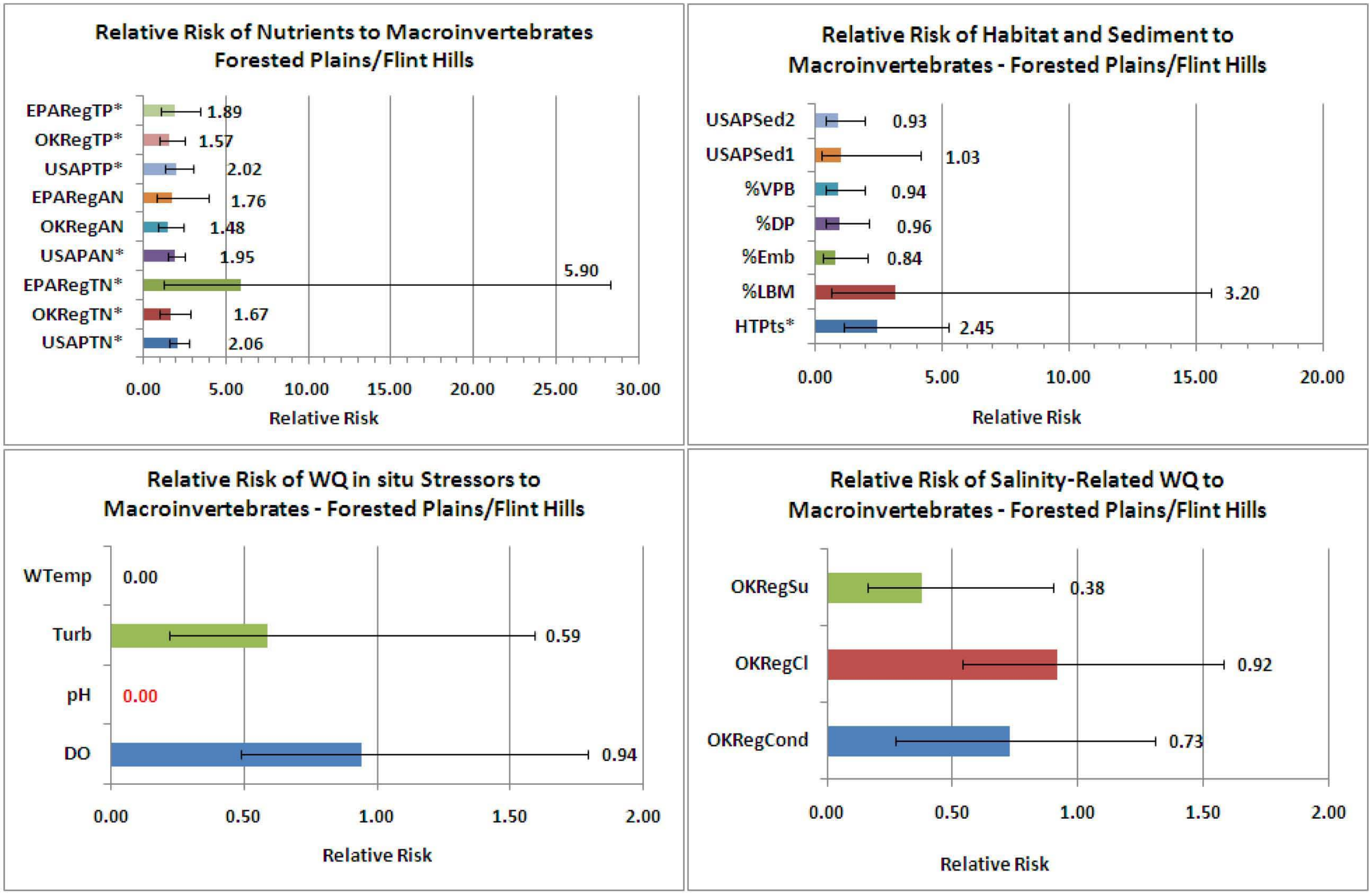
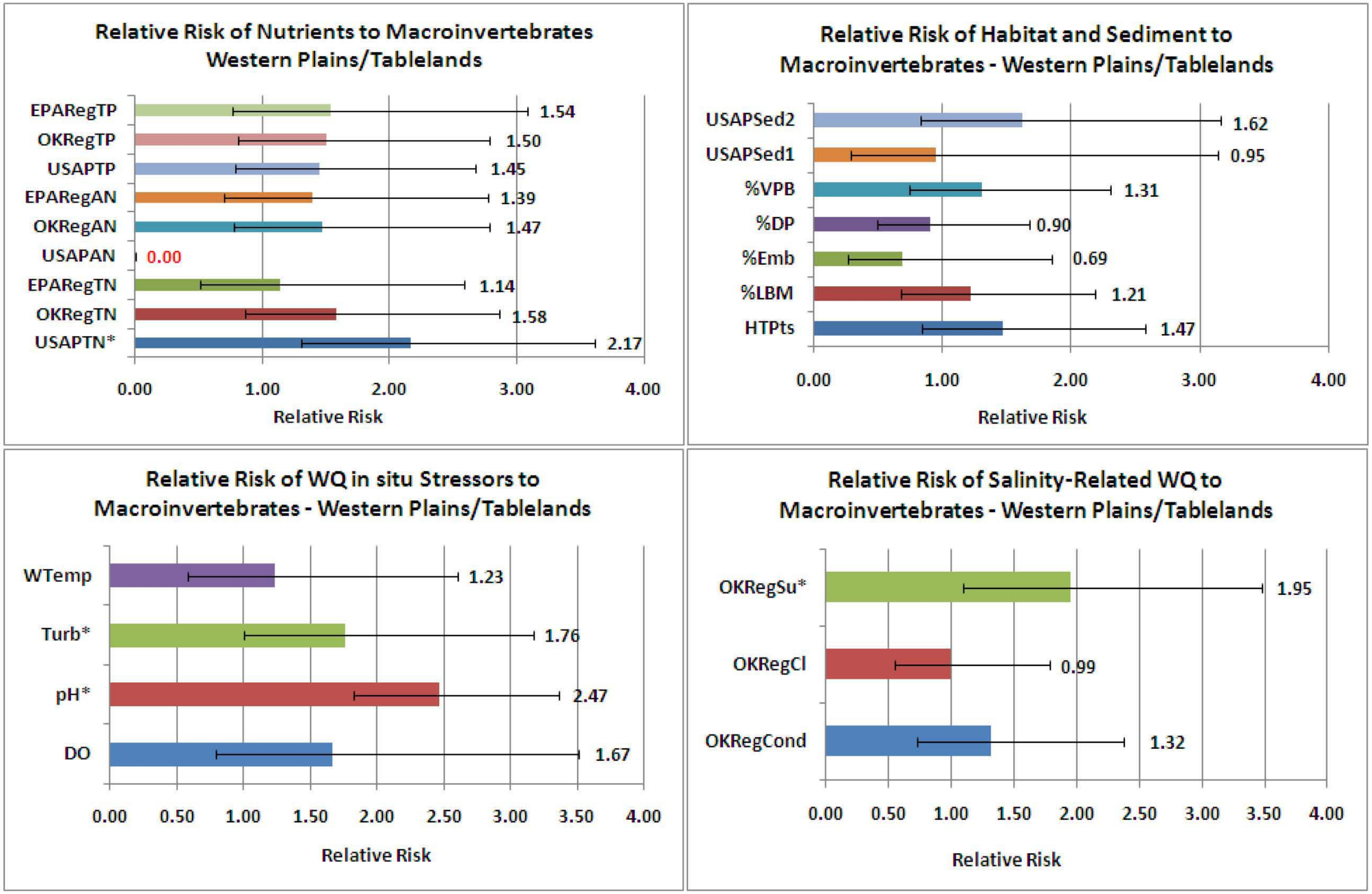


Figure 25. Relative risk of nutrient, water quality, habitat, and sediment stressors affecting macroinvertebrate condition in Western Plains/Tablelands. Upper and lower bounds represent 90% CI. Red values estimated. (* = significant at 0.90) (Refer to Table 10 for stressor descriptions.)



Relative Risk to Algal Biomass

Relative risk to both benthic and sestonic algal condition is considered for all nutrient stressors. Condition for algal biomass was based upon whether a particular sample was above or below a variety of screening levels. For benthic algae, these include the 100 mg/m^2 nuisance level found in Oklahoma's USAP and a screening level based on the 25^{th} percentile of OWRB historical data (45.7 mg/m^2). The following analysis will be separated by geographical scale. For both the Temperate Forests and the Forested Plains/Flint Hills (Figures 26 and 27), no stressor significantly affected benthic algal biomass. A variety of parameters did show high upper confidence bounds.

Statewide relative risk to benthic algae is illustrated in Figure 26. For the BenP25 screening level, both the OKRegTP (RR= 1.7) and the EPARegTP (RR= 1.8) were significantly related to excessive benthic algal biomass. No other nutrient stressors using the 25^{th} percentile or the USAP nuisance screening level as a condition significantly affected algal condition. However, several stressors returned relatively high upper confidence bounds. The BenUSAPSL was significantly affected by none of the stressors.

Lastly, stressor/benthic algal relationships for the Western Plains/Tablelands are displayed in Figure 27. Like the statewide results, the significant relationships are associated with 25^{th} percentile condition. The condition is 1.7 to 2.5 times more likely to be above the screening level when phosphorus values exceed regional screening levels. Moreover, the 25^{th} percentile of benthic algal data is 2.1 times more likely to be exceeded when the OKRegAN screening limit is high. No other stressors are significantly related to benthic algal condition in this region although several have high upper confidence bounds.

Sestonic algal relationships to stressors are illustrated in Figures 28-31. Unlike other condition versus stressor risk estimates, the majority of the relationships are significant across all screening levels. Furthermore, the pattern can be seen across all geographic scales except the Temperate Plains region (Figure 29). Many parameters across condition levels are at or near a value of 0 for relative risk. Interestingly, the Oklahoma regional stressors, although insignificant, have relatively high upper confidence bounds.

For statewide estimates (Figure 28), every total phosphorus stressor at each screening level is significantly related to excess sestonic algal growth, with relative risks as high as 9.1 for the SesChl25. Risk trends upward as the screening level increases with the lowest risks associated with SesChl10 (RR = 1.9 to 2.7) and the highest linked to SesChl25 (RR = 4.6 to 9.1). Likewise, at every screening level, two the total nitrogen parameters (USAPTN and OKRegTN) demonstrate significant risks to condition. Relative risks associated with total nitrogen vary with relative risk values ranging from 2.8 (USAPTN vs. SesChl10) to 22.9 (OKRegTN vs. SesChl25). Other notable values are 7.7 (EPARegTN vs. SesChl10), 6.8 (USAPTN vs. SesChl25, and 6.4 (OKRegTN vs. SesChlMean. Also, when trying to compare both stressor and algal condition level, there seems to be no clear pattern for total nitrogen, with the exception of the extremely high values associated with OKRegTN in relation to two algal conditions. All perform well as a predictor of risk at each level. Also, when available nitrogen exceeds the OKRegAN screening level, there is associated relative risk for increased sestonic algae at each condition level. Lastly, the USAPAN stressor scored 0 at each condition level.

Figure 26. Relative risk of nutrient stressors affecting benthic algal condition Statewide and in the Temperate Forests region. Upper and lower bounds represent 90% confidence interval. Red values estimated. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)

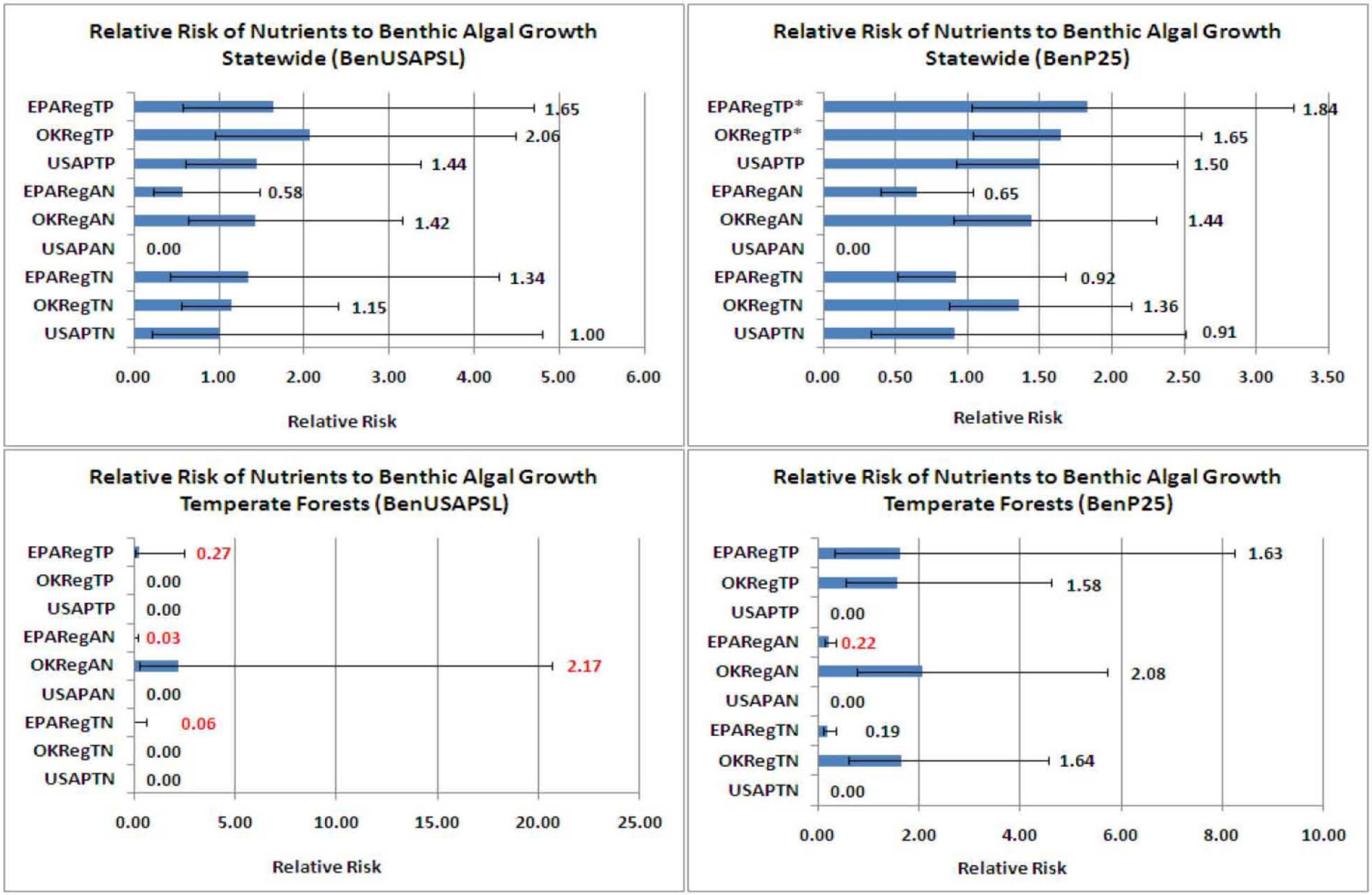
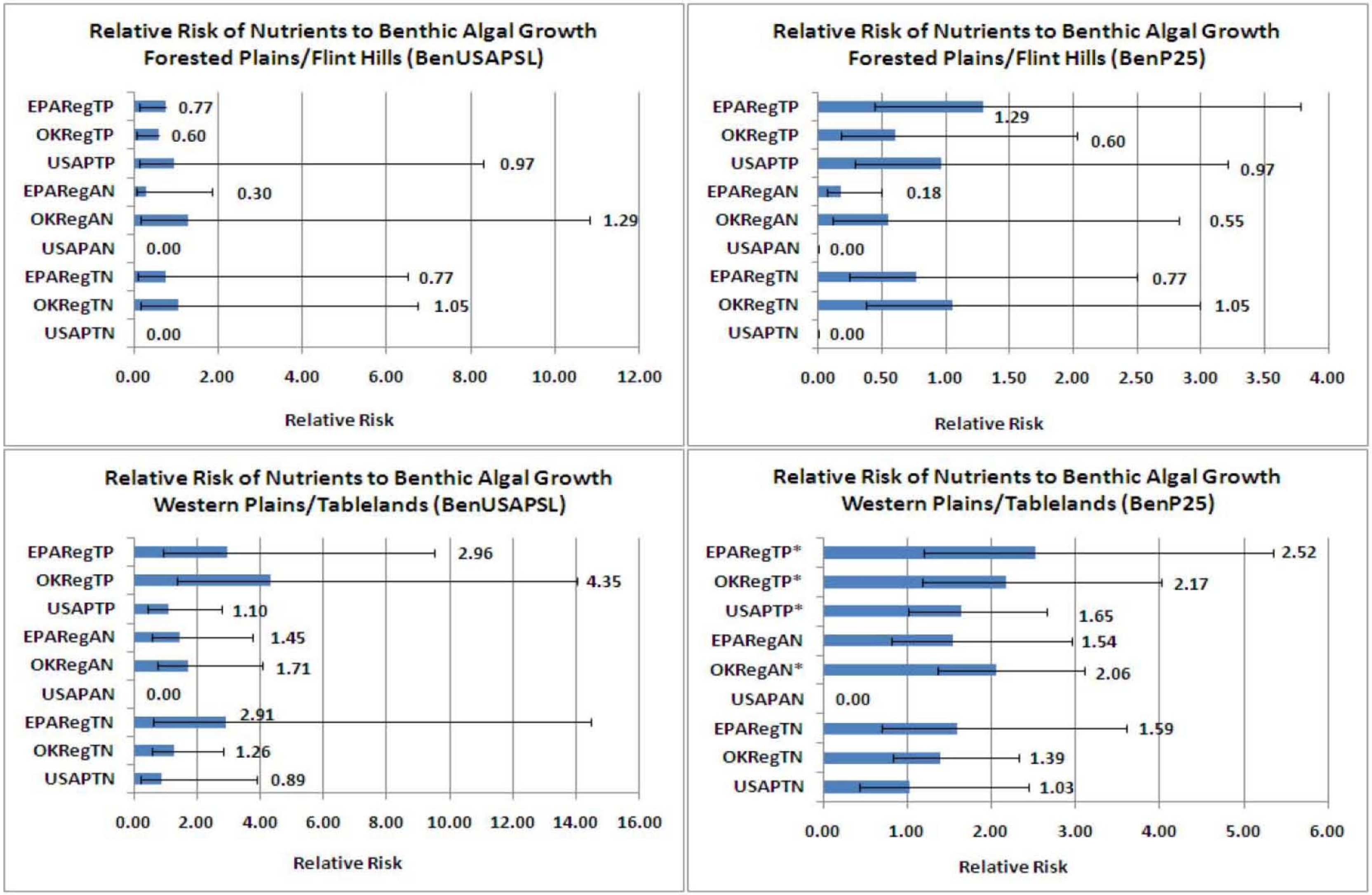


Figure 27. Relative risk of nutrient stressors affecting benthic algal condition in the Forested Plains/Flint Hills and Western Plains/Tablelands regions. Upper and lower bounds represent 90% confidence interval. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)



The Forested Plains/Flint Hills is very similar to the statewide estimates of relative risk (Figure 30). All phosphorus stressors are associated with risk of increased sestonic algae at each condition level, with relative risk values ranging from 1.9 to 15.5 and commonly above a value of 3.0 for relative risk. Likewise, at least two total nitrogen parameters are associated with significant relative risk for each algal condition. Range of relative risk is 1.3 to 6.6, and again, the regional Oklahoma stressor is associated at each condition level. Additionally, when available nitrogen (OKRegAN) values are above screening levels, algal biomass is 1.8 times more likely to be above the SesChl10 and SesChlMean condition levels and is 3.6 times more likely to be above a concentration of 25 mg/m^3. Again, all USAPAN values show 0 relative risk to algal condition.

In the Western Plains/Tablelands region, stressors do not perform as thoroughly, but at least one stressor in each parameter group demonstrates significant associated risk to increased algal growth at each condition level (Figure 31). Patterns that are the same include: 1) at least 2 total nitrogen parameters showing significant risks at all condition levels, 2) the OKRegAN being significant across all conditions, 3) several high total nitrogen relative risk values including 14.3 (SesChl25 vs.OKRegTN) and 15.0 (SesChlMean vs.OKRegTN), and 4) no relative risk associated with USAPAN, and 5) no significant risk associated with EPARegAN but extremely high upper bounds. Notably, the Oklahoma regional values again performed well across the board with the exception of the total phosphorus screening limit compared to SesChl10.

Figure 28. Relative risk of nutrient stressors affecting sestonic algal condition Statewide. Upper and lower bounds represent 90% confidence interval. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)

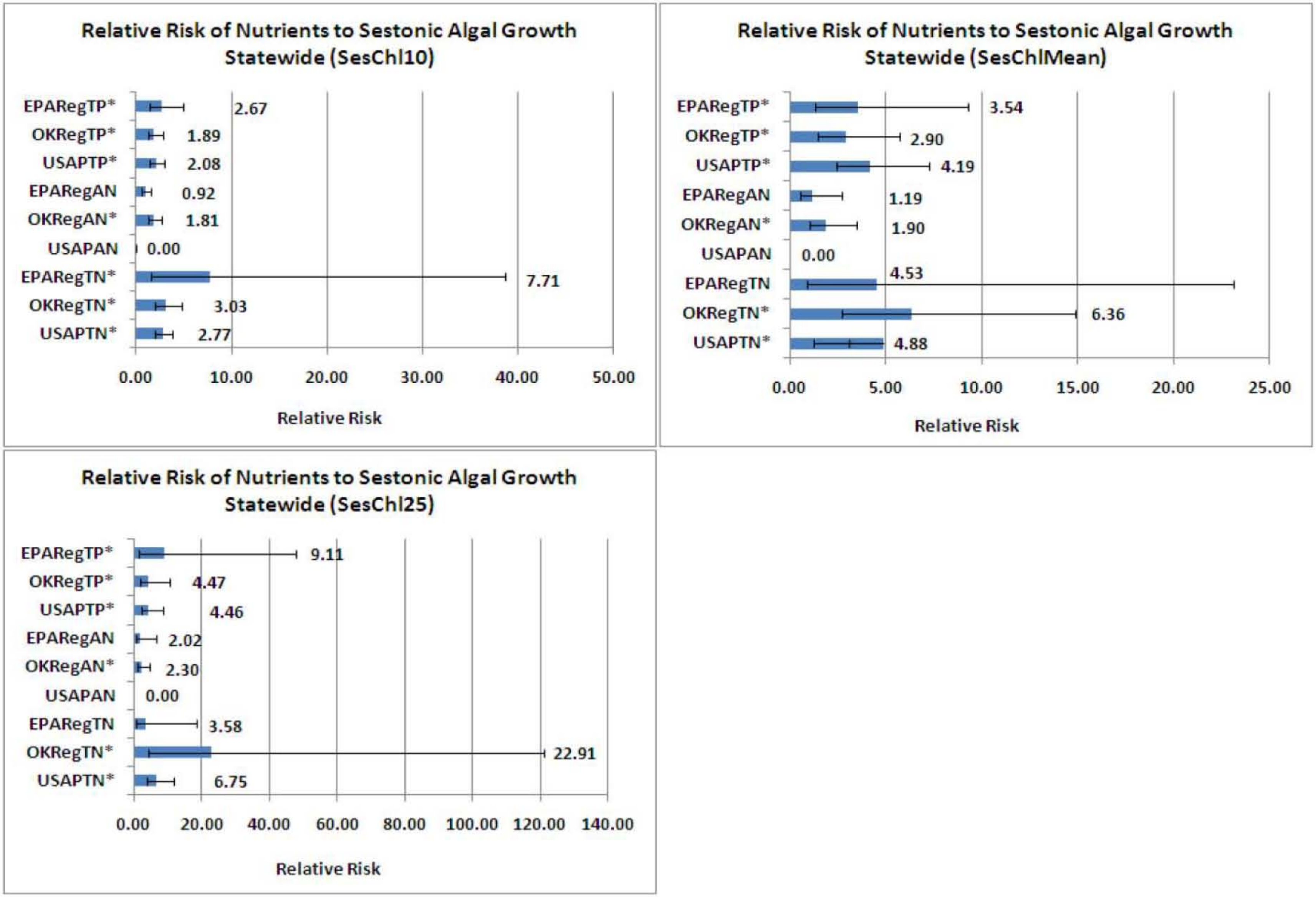
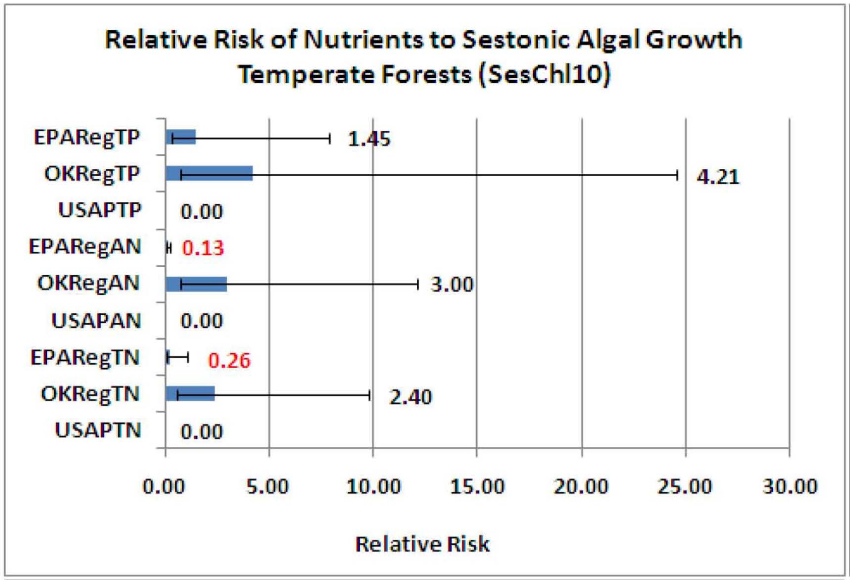
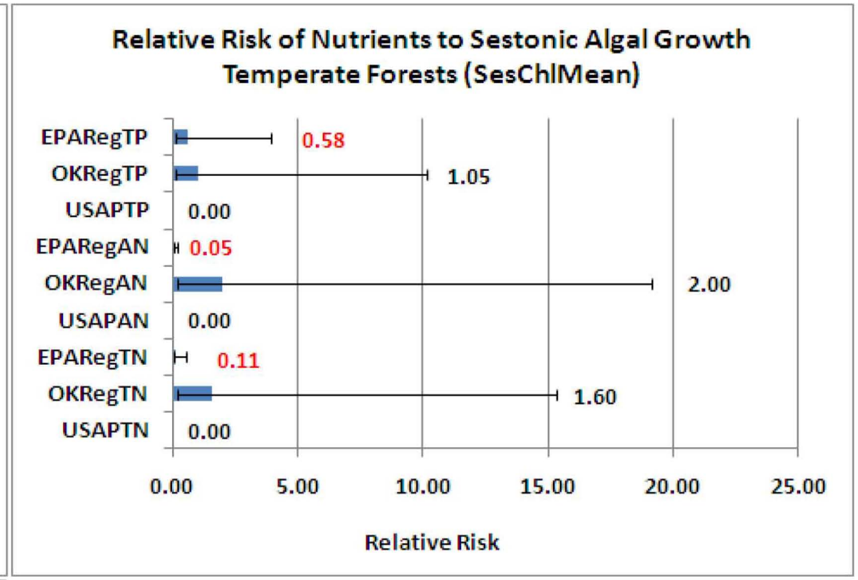


Figure 29. Relative risk of nutrient stressors affecting sestonic algal condition in the Temperate Forest region. Upper and lower bounds represent 90% confidence interval. Red values estimated. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)





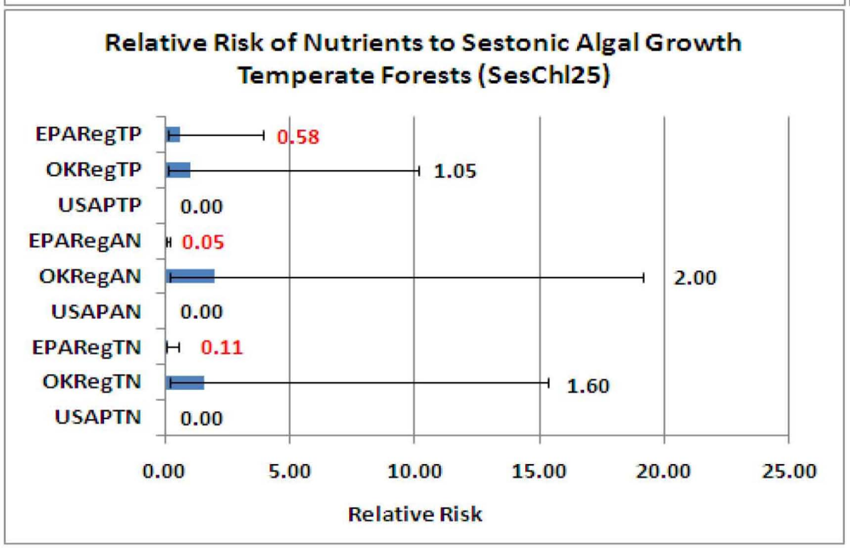
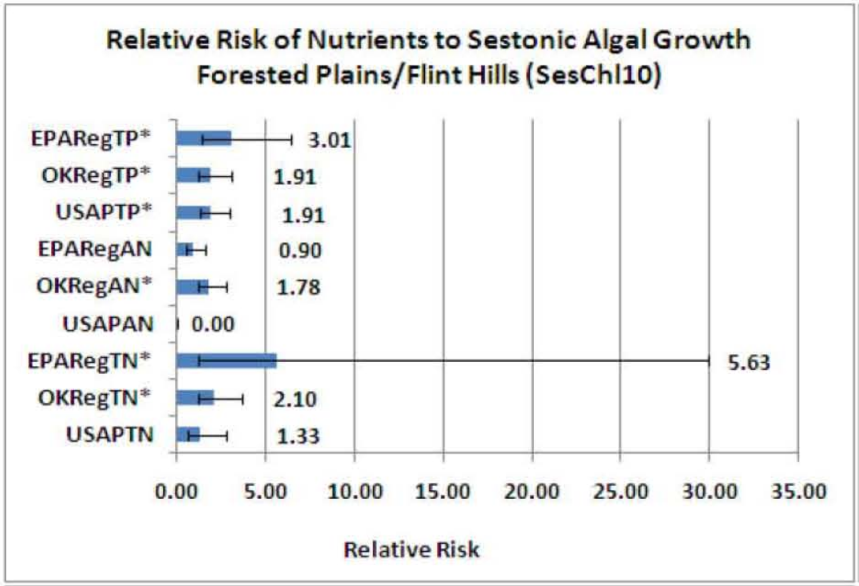
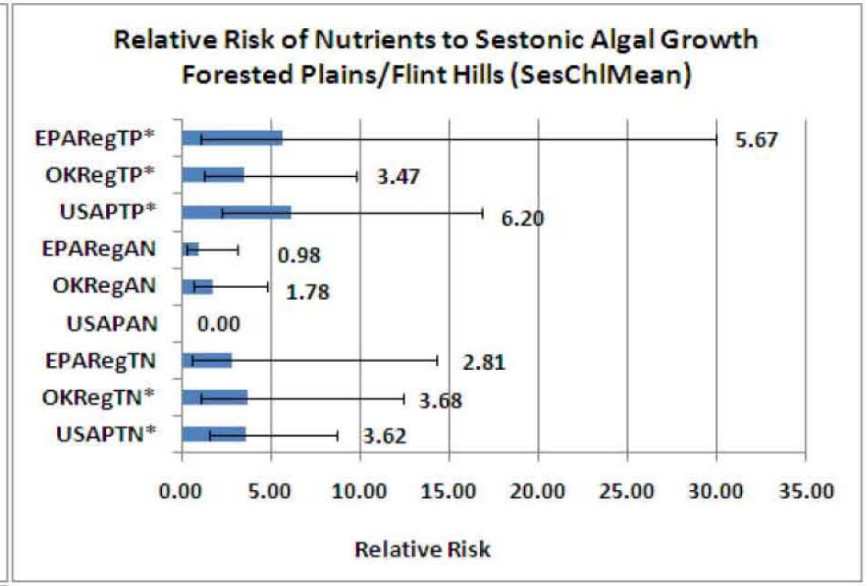


Figure 30. Relative risk of nutrient stressors affecting sestonic algal condition in the Forested Plains/Flint Hills region. Upper and lower bounds represent 90% confidence interval. (* = significant at alpha of 0.90)





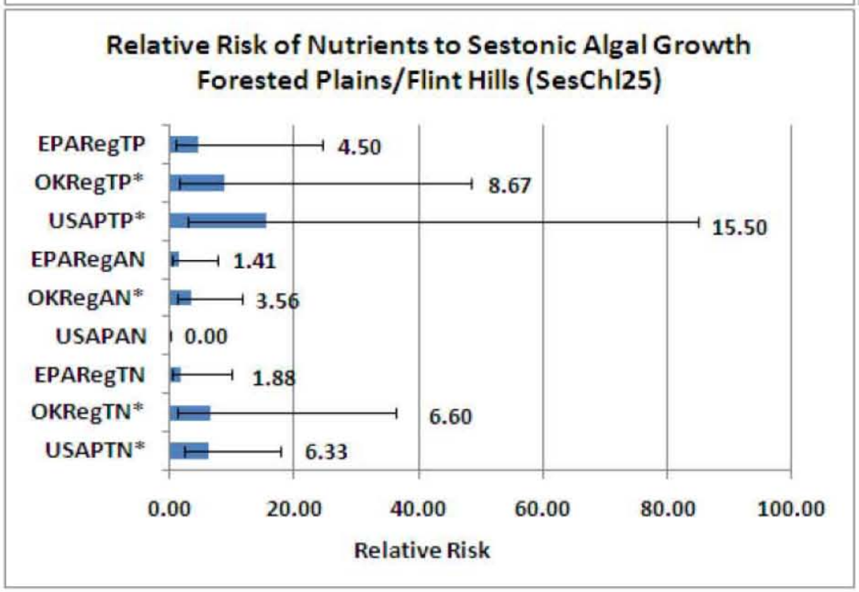
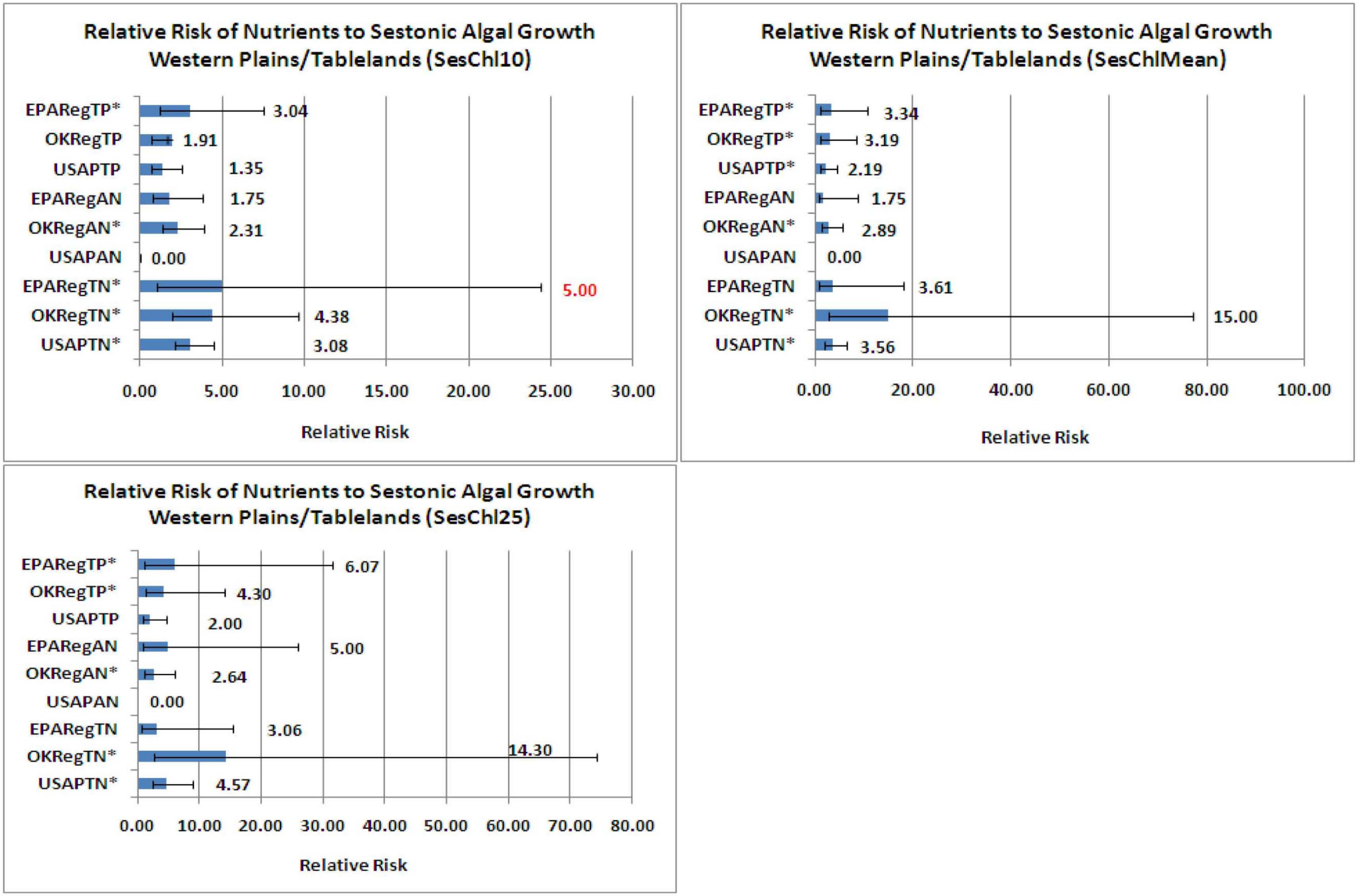


Figure 31. Relative risk of nutrient stressors affecting sestonic algal condition in the Western Plains/Tablelands region. Upper and lower bounds represent 90% confidence interval. Red values estimated. (* = significant at alpha of 0.90) (Refer to Table 10 for stressor descriptions.)



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 of these waters. These reports are compiled to the biannual Oklahoma Water Quality Assessment Integrated Report (ODEQ, 2008b).

The current study benefits this report in several ways. First, this report marks Oklahoma's first attempt at making a statistically based assessment of the condition of Oklahoma's waters. The OWRB recommends that this report be adopted into the 305(b) section of the integrated report. Included graphics can be used to show overall statewide and regional condition. 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 2009. 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, application of the sediment criteria, and a single sample maximum of 200 mg/m^3 for benthic chlorophyll-a. 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.

Relative Risk-Fish and Macroinvertebrates

The relative risk analyses produced widely variable results depending upon both condition and stressor. To explore potential outcomes, matrices for the various conditions and stressors were developed (Tables 12, 13, and 14). 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.

For the most part, the attempt to draw relationships of stressors to fish condition using relative risk produced mostly unsuccessful results (Table 12). In all, only four parameters demonstrated significantly increased risk to fish condition. For nutrients, risk of increased total nitrogen associates significantly both statewide and in the west, although only for the highest of the three screening levels. No other parameter or geographic area demonstrated significant risk although nutrient extent estimates for all regions were extremely high. This could be the result of IBI's calculating fish condition too high or nutrient screening levels not being appropriate. Relative risk compares the difference of bad condition/low stressor versus bad condition/high stressor. In this case, regional stressors were calculated as extensive throughout the population (rarely below 30%), while the USAP stressors had typically low extents, only once greater than 20% and typically less than 10%. Inevitably the ratio expressed above would near 1.0 because stressors are not sensitive enough given the comparative condition, or vice-versa. When significant relationships did exist, it was when stressor extent was less than 20% (USAPTN both statewide and in the west). Unfortunately, the problem likely lies on both ends. A logical next step would be to take various percentiles of the Oklahoma nutrient dataset and apply them to various fish metrics or score ranges of the two IBI's. Also, reference condition likely needs refinement on a regional basis.

Relative risk of nutrient stressors to macroinvertebrate condition produced more tangible results than with fish (Table 12). For nutrients, a broad range of parameters expressed relative risk both statewide and in the Forested Plains/Flint Hills. The USAP, Oklahoma regional, and EPA regional screening levels performed exceptionally well at both geographic scales as all but two parameters (OKRegAN and EPARegAN) showed significantly increased risk to lowered condition, although it should be noted that the USAP parameters show relatively low extent. On the other hand, the Oklahoma and EPA regional screening levels generally had high extents at both geographic scales. For the Western Plains/Tablelands, USAP total nitrogen was again significantly related. Finally, as with fish, the Temperate Forests region did not have a nutrient parameter significantly related to condition. Unlike fish, there seems to be a promising relationship between the current IBI and proposed stressor levels in at least the western ¾ of the state. On the other hand, the eastern highlands and forests still are producing confounding results. For the Oklahoma regional screening levels, relative risks coupled with high upper confidence bounds suggests that a number of sites are rating as good for both condition and stressor extent. Also, the USAP relative risks and extents are all at 0 or near to it. This may suggest that the problem is reference condition. A number of streams in the region are cool water aquatic communities and have exceptional habitat, when compared to the rest of the state. Refining the reference condition will likely produce a better relationship between known stressors (Figure 12) and condition.

For general water quality parameters in comparison to fish, several results were expected including the significant risk of low dissolved oxygen and high conductivity in the Western Plains/Tablelands region (Table 12). Low dissolved oxygen is likely a product of riparian condition and stream depth. Most riparian areas are composed of a mixed grass/light forest with very little shading in most waterbodies, and because streams usually have long and shallow sandy bottom runs, they are prone to increased heating. Couple that with increased nutrient loading (Figure 12), and the risk for low DO affecting condition certainly exists. It should be noted that the extent of the population with DO below screening levels (3%) is moderately low in the western region. In relation to other parts of Oklahoma, conductivity is relatively high in western Oklahoma. Conductivity throughout the region typically ranges from 1,000-3,000 microsiemens (OCC, 2005a, 2005b, 2006a, 2007; OWRB, 2008). In the Red Prairie and Red River Tablelands of southwestern Oklahoma, conductivity ranges from 2,500 up to greater than 75,000 below the gypsum outcroppings of the Elm Fork River. In northwestern Oklahoma along both the Cimarron and Beaver Rivers, similar conductivity ranges are present. Predictably, the extent of conductivity above regional screening values is high (47%) although not abnormal when compared to the rest of the state (Figure 13). However, in western Oklahoma, the extent of the stressor coupled with the potential for abnormally high values creates a significant associated relative risk to fish condition, which it does not in the rest of the state. Why other stressors are not related is likely due to several reasons. First, naturally occurring conditions exist for a variety of water quality parameters including pH and turbidity. A study recently completed by OWRB (2009a) revealed that low pH in southeastern Oklahoma is likely a naturally occurring condition. This was further borne out by results from this study. In the Temperate Forests, the extent of pH below criterion is 22%, yet there is zero relative risk of low pH to fish condition in the area. Other potential candidates for study based on data presented here as well as results from other programs include turbidity throughout Oklahoma and dissolved oxygen in parts of southeastern Oklahoma.

Table 12. Matrix showing results of relative risk studies for fish and bacteria. (* = significant at alpha of 0.90; NS = not significant) (Refer to Table 10 for stressor descriptions.)

	Condition	Fish				Macroinvertebrates			
Stressor Group	Stressor/ Geographic Region	Statewide	Temperate Forests	Forested Plains/ Flint Hills	Western Plains/ Tablelands	Statewide	Temperate Forests	Forested Plains/ Flint Hills	Western Plains/ Tablelands
Total Nitrogen	USAPTN	* (2.19)	NS	NS	* (2.18)	* (2.47)	NS	* (2.06)	* (2.17)
	OKRegTN	NS	NS	NS	NS	* (1.77)	NS	* (1.67)	NS
	EPARegTN	NS	NS	NS	NS	NS	NS	* (5.90)	NS
Available Nitrogen	USAPAN	NS	NS	NS	NS	* (2.60)	NS	* (1.95)	NS
	OKRegAN	NS	NS	NS	NS	NS	NS	NS	NS
	EPARegAN	NS	NS	NS	NS	NS	NS	NS	NS
Total Phosphorus	USAPTP	NS	NS	NS	NS	* (1.96)	NS	* (2.02)	NS
	OKRegTP	NS	NS	NS	NS	* (1.46)	NS	* (1.57)	NS
	EPARegTP	NS	NS	NS	NS	NS	NS	* (1.89)	NS
General WQ in situ	DO	NS	NS	NS	* (2.33)	* (1.73)	* (9.33)	NS	NS
	pH	NS	NS	NS	NS	NS	NS	NS	* (2.47)
	Turb	NS	NS	NS	NS	NS	NS	NS	* (1.76)
	WTemp	NS	NS	NS	NS	NS	NS	NS	NS
General WQ - Salinity	OKRegCond	NS	NS	NS	* (2.21)	NS	* (5.95)	NS	NS
	OKRegCl	NS	NS	NS	NS	NS	NS	NS	NS
	OKRegSu	NS	NS	NS	NS	NS	NS	NS	* (1.95)
Habitat and Sediment	HTPts	NS	NS	* (3.65)	NS	NS	NS	* (2.45)	NS
	%LBM	NS	NS	NS	NS	NS	NS	NS	NS
	%Emb	NS	NS	NS	NS	NS	NS	NS	NS
	%DP	NS	NS	NS	NS	NS	NS	NS	NS
	%VPB	NS	NS	NS	NS	NS	NS	NS	NS
	USAPSed1	NS	NS	NS	NS	NS	NS	NS	NS
	USAPSed2	NS	NS	NS	NS	NS	NS	NS	NS

As with pH, the extent of DO in southeastern Oklahoma is relatively high (23% compared to 15% statewide), but the risk is below 1.0, whereas it is above 1.0 in all other parts of the state and significant in the west. Turbidity has extents near to or slightly above 20% in the western three-quarters of the state as well as relative risks above 1.0 but never significant. Furthermore, the upper confidence bounds of relative risk indicate that a number of sites with good fish condition also have high turbidity. This may be in part due to the sensitivity of the fish IBI's but is also likely due to naturally occurring high turbidity in some parts of Oklahoma.

General water quality for macroinvertebrates is a mixed bag (Table 12). Statewide, only DO has associated significant relative risk, coupled with moderate extent of 17% (Figure 13). In the Temperate Forests, only DO and conductivity demonstrate significant risk to condition. Dissolved oxygen has a relatively high extent at 23%, while conductivity at 43% is in line with other regions and the statewide extent estimate (Figure 14). Interestingly, both relative risk values have extremely high upper confidence bounds (Figure 23), suggesting that the condition estimate is able to delineate sites with good water quality. In the Western Plains/Tablelands, condition is significantly affected by pH, turbidity, and sulfate. While the turbidity and sulfate extents are above 15% (Figures 13 and 14), the pH extent is extremely low. Moreover, each risk calculation is coupled with a relatively high upper confidence bound, suggesting that when each of the stressors is above criteria or screening level, condition is likely stressed. Finally, in the Forested Plains/Flint Hills, no significant relative risk exists for any general water quality parameter. As mentioned in the introduction, this area is a mix of eastern forests and western plains in habitat and water quality. This could indicate that more work should be done at the Omernik Level IV ecoregion scale to produce a more viable reference condition.

Finally, habitat and sediment stressors performed poorly. Only one stressor (HTPts) is significantly related to lowered condition, for fish and macroinvertebrates in the Forested Plains/Flint Hills (Table 12). However, stressors are exceeding reference condition at high extents throughout the state (Figure 17). Several parameters have relatively high upper confidence bounds including %Emb in the east, USAPSed1 statewide and in the west and east, and %LBS (fish) in the west. This means that a number of streams in good condition also have low stressor extents, indicating that either the IBI's or the stressor screening levels are not sensitive enough to detect risk. Increasing sensitivity of the IBI's through more refined reference condition could solve this issue because both the stressor and IBI are related to reference. Also, Oklahoma should explore the use of relative bed stability (RBS) as a measure of sedimentation. Data already exists from the WSA (USEPA, 2006) and is being gathered statewide as part of the National Rivers and Streams Assessment. Furthermore, the OWRB as part of its biological collection programs will begin next year to routinely collect habitat measures needed to calculate RBS.

Relative Risk-Benthic and Sestonic Algae

Relationships between benthic algal condition and nutrient stressors are summarized in Table 13. For all geographic regions and stressors, the benthic nuisance level in Oklahoma's USAP (OWRB, 2008b) is not significantly related to poor algal condition. However, several parameters had high upper confidence bounds including regional phosphorus screening levels both statewide and in the west, a mix of total nitrogen parameters statewide and in the western three-quarters of the state, and the Oklahoma regional available nitrogen stressor throughout the state and in every region. For the BenP25 screening level (which is less than half of the USAP level), the same general pattern of insignificant relative risks greater than 1 coupled with high upper confidence bounds is present to a lesser extent in the Forested Plains/Flint Hills, but more prevalently in the Temperate Forests region. In the west and statewide, increased total phosphorus is nearly always a significant predictor of decreased algal condition when based on the 25th percentile. The same is true in the west for the Oklahoma regional available nitrogen stressor. Based on available information, several conclusions can be drawn. First, the current USAP screening level may not be an adequate measure of benthic nuisance algal condition. When using wide ranging nutrient screening levels for both phosphorus and nitrogen, the indicator performs poorly in attempting to determine when high nutrient concentrations are affecting condition. Second, the 25th percentile seems to be a good indicator of phosphorus condition in the west and generally statewide. However, it is poorly associated with nitrogen concentrations. The population tends to be above the level regardless of nitrogen stressor extent. The lack of any risk association in the eastern two-thirds of the state suggests that regional nuisance benthic algal screening levels may be needed. As more data are gathered throughout the state, the screening level can potentially be refined to one that is more regionally based.

The relationship between sestonic algal growth and nutrient concentration is perhaps the most promising of any of the four biological condition/stressor relationship analyses (Table 14). At first glance, several general conclusions are evident in the data. First, biological condition in the Temperate Forests again performs low when compared to stressor extent, confirming that this region of the state needs to be dealt with separately when creating either nutrient criteria or biological indices/screening levels. Regardless of condition level, the presence of many high upper confidence bounds for the regional criteria suggests the inability of the lower screening limits to predict sestonic algal growth in the region. On the other hand, the USAP nutrient screening levels had 0 relative risks, suggesting that an appropriate nutrient screening level is somewhere between the regional levels and the USAP nutrient levels. Second, total nitrogen and phosphorus generally performed well as an indicator of increased algal growth at each screening level over the rest of the state. And, the Oklahoma regional screening level consistently performed well regardless of the condition level. Finally, an appropriate screening level for the western three-quarters of the state might lie between 10 and 19 mg/m^3. When viewing the relative tightness of confidence bounds for phosphorus and total nitrogen at each condition level, generally the narrowest are present in the SesChl10 and SesChlMean.

<u>Other Condition Estimates</u>

Metals were included in this study as both an indicator of ecological condition and human health. For both analyses, only lead, selenium and zinc were above criteria, and with the exception of lead, exceedances were regionally associated. These results are in accordance with what has been found through ambient monitoring programs in the state (OWRB, 2008c), and included in Oklahoma's 303(d) list of impaired waters (ODEQ, 2008). Other metals that sometimes occur on a regional basis and are listed as impaired are cadmium, copper, and silver. Based on this information, several recommendations can be made for ambient surface water quality programs in Oklahoma. First, all metals listed in the OWQS (OWRB, 2007a) but not occurring above criteria in ambient monitoring programs should not be monitored further. These include arsenic, chromium, nickel, and thallium. Second, since most metals occur regionally, a table specifying regional metals of concern should be created and included in either USAP (OWRB, 2008b) or the CPP (ODEQ, 2006a). This would benefit agencies in planning and allow for better use of often limited funds.

Table 13. 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.)

	Geographic Region	Statewide		Temperate Forests		Forested Plains/Flint Hills		Western Plains/ Tablelands	
Stressor Group	Stressor/Condition	BenUSAPSL	BenP25	BenUSAPSL	BenP25	BenUSAPSL	BenP25	BenUSAPSL	BenP25
Total Nitrogen	USAPTN	NS	NS	NS	NS	NS	NS	NS	NS
	OKRegTN	NS	NS	NS	NS	NS	NS	NS	NS
	EPARegTN	NS	NS	NS	NS	NS	NS	NS	NS
Available Nitrogen	USAPAN	NS	NS	NS	NS	NS	NS	NS	NS
	OKRegAN	NS	NS	NS	NS	NS	NS	NS	* (2.06)
	EPARegAN	NS	NS	NS	NS	NS	NS	NS	NS
Total Phosphorus	USAPTP	NS	NS	NS	NS	NS	NS	NS	* (1.65)
	OKRegTP	NS	* (1.65)	NS	NS	NS	NS	NS	* (2.17)
	EPARegTP	NS	* (1.84)	NS	NS	NS	NS	NS	* (2.52)

Table 14. 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.)

	Geographic Region	Statewide			Temperate Forests			Forested Plains/Flint Hills			Western Plains/ Tablelands		
Stressor Group	Stressor/Condition	SesChl 10	SesChl Mean	SesChl 25	SesChl 10	SesChl Mean	SesChl 25	SesChl 10	SesChl Mean	SesChl 25	SesChl 10	SesChl Mean	SesChl 25
Total Nitrogen	USAPTN	*2.77	*4.88	*6.75	NS	NS	NS	NS	*3.62	*6.33	*3.08	*3.56	*4.57
	OKRegTN	*3.03	*6.36	*22.91	NS	NS	NS	*2.10	*3.68	*6.60	*4.38	*15.00	*14.30
	EPARegTN	*7.71	NS	NS	NS	NS	NS	*5.63	NS	NS	*5.00	NS	NS
Available Nitrogen	USAPAN	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	OKRegAN	*1.81	*1.90	*2.30	NS	NS	NS	*1.78	NS	*3.56	*2.31	*2.89	*2.64
	EPARegAN	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Total Phophorus	USAPTP	*2.08	*4.19	*4.46	NS	NS	NS	*1.91	*6.20	*15.50	NS	*2.19	NS
	OKRegTP	*1.89	*2.90	*4.47	NS	NS	NS	*1.91	*3.47	*8.67	NS	*3.19	*4.30
	EPARegTP	*2.67	*3.54	*9.11	NS	NS	NS	*3.01	*5.67	NS	*3.04	*3.34	*6.07

Bacteria were also included as an indicator of human health. The results produced some disparate results when compared to ambient water quality data (OCC, 2005b, 2006a, 2006b, 2007, 2008; OWRB, 2008c; ODEQ, 2008). Oklahoma's integrated report lists upwards of 85% of Oklahoma's streams as impaired for some indicator organism. Conversely, data collected as part of this program indicate that nearly 70% of the population is not exceeding any indicator. Why the difference in data? First, the ambient programs collect multiple samples during the recreational season over multiple years and at various flow regimes, whereas this program collected a single sample at baseflow condition. Second, the real condition probably lies somewhere in the middle. Two things could make these results come more into line. First, better criteria and potentially better indicators are being developed by the USEPA and due out for public review in 2012. High impairment percentages are likely due in part to potentially inappropriate criteria. Second, the contact recreation use should be a tiered use much like the aquatic life uses. Tiers could be based on probabilities of waters to serve as a recreational source as well as other regional characteristics. However, the study design used is not likely the best for determining bacteria impairments, but may be useful for determining baseline bacteria concentrations at baseflow.

Lastly, the agriculture beneficial use was considered only nominally in this report. However, much information can potentially be drawn from probabilistic data to refine criteria for the use. Results from this study are generally in line with what is seen in ambient programs (OCC, 2005b, 2006a, 2006b, 2007, 2008; OWRB, 2008c; ODEQ, 2008). However, refining the criteria to include conductivity as a surrogate for TDS could save programs money and would likely provide an improved measure in regards to repeatability and accuracy. By combining probabilistic data with the wealth of ambient data, conductivity could be compared to TDS data and regional conversion factors for conductivity could be produced. Or, regional criteria could be developed for conductivity and adopted into the agriculture beneficial use in place of TDS.

Future Plans

In terms of monitoring, probabilistic design has been completely integrated into both the OWRB and OCC monitoring programs (OWRB, 2009b). The OWRB is currently participating in the National Rivers and Streams Assessment and will use data from it to provide an update to the current report. Also, the third two-year statewide study will begin in winter or summer 2009 and include 50 sites. Substantive changes to the program will include: 1) use of the NRSA protocols for large Wadeable and non-wadeable waterbodies, 2) use of NRSA habitat protocols for wadeable streams in concert with the current RBP habitat protocol, 3) inclusion of a second winter macroinvertebrate index period, 4) inclusion of dissolved metals for some analytes, and 5) exclusion of bacteria from program. The OCC initiated a probabilistic program during 2008 that will provide estimates for planning basins throughout the state. Fifty random sites are being monitored per basin over the five-year rotating basin cycle. Lastly, the OWRB will conclude the Illinois River Probabilistic Monitoring Survey in 2009-2010. It is the first regionally based probabilistic study in Oklahoma, and is centered on setting a baseline biological condition to assist in implementation of nutrient criteria in Oklahoma's scenic rivers. Additional plans are in the works for future regionally based studies.

References

Helsel, D.R. and Hirsch, R.M. 1995. Statistical Methods in Water Resources. 443pp.

North American Commission for Environmental Cooperation. 1997. *Ecoregions of North America (contains Omernik Level I, II, and III)*. GIS map files. North American Commission for Environmental Cooperation, Montreal, Quebec, Canada.

Oklahoma Conservation Commission. 2005a. *Analysis of Oklahoma Conservation Commission Physiochemical and Biological Data Toward Determination of High Quality Sites*". Oklahoma City, OK.

Oklahoma Conservation Commission. 2005b. *Small Watershed Rotating Basin Monitoring Program*
Year 1: Neosho-Grand and Upper Canadian Basins. Oklahoma City, OK.

Oklahoma Conservation Commission. 2006a. *Small Watershed Rotating Basin Monitoring Program*
Year 2: Upper North Canadian, Cimarron, and Upper Arkansas Basins. Oklahoma City, OK.

Oklahoma Conservation Commission. 2006b. *Small Watershed Rotating Basin Monitoring Program*
Year 3: Lower Arkansas, Lower Canadian, and Lower North Canadian Basins. Oklahoma City, OK.

Oklahoma Conservation Commission. 2007. *Small Watershed Rotating Basin Monitoring Program Year 4: Washita and Upper Red Basins*. Oklahoma City, OK.

Oklahoma Conservation Commission. 2008. *Small Watershed Rotating Basin Monitoring Program Year 5: Lower Red Basin*. Oklahoma City, OK.

Oklahoma Conservation Commission. 2009. Personal Communication. Oklahoma City, OK.

Oklahoma Department of Environmental Quality. 2006. *Continuing Planning Process*. Oklahoma City, OK.

Oklahoma Department of Environmental Quality. 2007. *Quality Management Plan*. QMP Track No. 00-182. Oklahoma City, OK.

Oklahoma Department of Environmental Quality. 2008. *The State of Oklahoma 2008 Water Quality Assessment Integrated Report*. Oklahoma City, OK.

Oklahoma Water Resources Board. 1999. *Technical Report 99-3: Standard Operating Procedures for Stream Assessments and Biological Collections Related to Biological Criteria and Development*. Oklahoma City, OK.

Oklahoma Water Resources Board. 2004a. *Standard Operating Procedure for the Collection of Fish in Streams.* Oklahoma City, OK.

Oklahoma Water Resources Board. 2004b. *Standard Operating Procedure for the Use of Floats to Determine Stream Discharge.* Oklahoma City, OK.

Oklahoma Water Resources Board. 2005a. *Implementation of a Stream/River Probabilistic Sampling Network for the State of Oklahoma:* FY04-05 Regional Environmental Monitoring and Assessment Program *Research Plan.* State of Oklahoma, U.S. Environmental Protection Agency Region 6, Dallas, TX.

Oklahoma Water Resources Board. 2005b. *Standard Operating Procedure for the Collection of Habitat in Streams.* Oklahoma City, OK.

Oklahoma Water Resources Board. 2005c. *Standard Operating Procedure for the Measurement of Stream Discharge.* Oklahoma City, OK.

Oklahoma Water Resources Board. 2005d. *Water Information Management System.* Oklahoma City, OK.

Oklahoma Water Resources Board. 2006a. *Development of a Stream/River Probabilistic Sampling Network for the State of Oklahoma: FY-2003 Section 104(b)3 Project 2, USEPA Region 6.* Oklahoma City, OK.

Oklahoma Water Resources Board. 2006b. *Standard Operating Procedure for the Collection, Filtration, and Extraction of Benthic and Sestonic Chlorophyll-a Samples in Streams.* Oklahoma City, OK.

Oklahoma Water Resources Board. 2006c. *Standard Operating Procedure for the Collection of Macroinvertebrates in Streams.* Oklahoma City, OK.

Oklahoma Water Resources Board. 2006d. *Standard Operating Procedure for the Collection of Water Quality Samples in Streams*. Oklahoma City, OK.

Oklahoma Water Resources Board. 2007a. *Oklahoma Water Quality Standards*. OAC 785:45. Oklahoma City, OK.

Oklahoma Water Resources Board. 2007b. *Water Quality Assessment Workbook v.2*. OKC, OK.

Oklahoma Water Resources Board. 2008a. *Fish and Macroinvertebrate Assessment Workbook v.3*. Oklahoma City, OK.

Oklahoma Water Resource Board. 2008b. *Implementation of Oklahoma's Water Quality Standards, Chapter 46, Subchapter 15: Use Support Assessment Protocols (USAP).* OAC 785:46-15. Oklahoma City, OK.

Oklahoma Water Resources Board. 2008c. *Oklahoma's Beneficial Use Monitoring Program Annual Report*. Oklahoma City, OK.

Oklahoma Water Resources Board. 2009a. *Monitoring in Support of TMDL Development in the Upper Kiamichi, Upper Little, and Lower Mountain Fork Watersheds: FY-2003 Section 104(b)3 Supplemental, Project 2*. Oklahoma City, OK.

Oklahoma Water Resources Board. 2009b. *Oklahoma's Water Quality Monitoring Strategy*. Oklahoma City, OK.

Olsen A. R. 2001. *Oklahoma Planning Basin Stream/River Sample – 2001*. USEPA, Office of Research and Development, Western Ecology Division, Corvallis, OR.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. *Annals of the Association of American Geographers 77*:118–125.

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, R. M. Hughes. 1989. *Rapid Bioassessment Protocols for Use in Streams and Rivers*. USEPA/444/4-89-001. U. S. E.P.A, Assessment and Watershed Protection Division, Washington, D. C.

Stevens, Jr., D.L. 1997. Variable density grid-based sampling designs for continuous spatial Populations. *Environmetrics.* 8:167-195.

Stevens, Jr., D. L., and A. R. Olsen. 2004. Spatially-balanced sampling of natural resources. Journal of American Statistical Association 99(465): 262-278.

United States Environmental Protection Agency. 2000. *Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion IX: Southeastern Temperate Forested Plains and Hills*. USEPA. Office of Water, Office of Science and Technology, Health and Ecological Criteria Division, Washington, D.C.

United States Environmental Protection Agency. 2000. *Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion XI: Central and Eastern Forested Uplands*. Office of Water, Office of Science and Technology, Health and Ecological Criteria Division, Washington, D.C.

United States Environmental Protection Agency. 2001. *Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion IV: Great Plains Grass and Shrublands*. Office of Water, Office of Science and Technology, Health and Ecological Criteria Division, Washington, D.C.

United States Environmental Protection Agency. 2001. *Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion V: South Central Cultivated Great Plains*. Office of Water, Office of Science and Technology, Health and Ecological Criteria Division, Washington, D.C.

United States Environmental Protection Agency. 2005. *The Recommended Elements of a State Monitoring Program*. http://www.epa.gov/owow/monitoring/elements/elements.html Office of Water, Office of Wetlands, Oceans, and Watersheds, Washington, D.C.

United States Environmental Protection Agency. 2006. *Wadeable Streams Assessment: A Collaborative Survey of the Nation's Streams*. USEPA 841-B-06-002. Office of Research and Development, Office of Water, Office of Science and Technology, Health and Ecological Criteria Division, Washington, D.C.

Van Sickle, J. 2004. Regional Assessment of Stressor Severity: A Relative Risk Approach. National Health and Environmental Effects Research Laboratory, Western Ecology Division, Corvallis, OR. Presented at the NW Biological Assessment Workgroup 15th Annual Meeting.

Van Sickle, J., J.L. Stoddard, S.G. Paulsen, and A.R. Olsen. 2006. Using relative risk to compare the effects of aquatic stressors at a regional scale. *Environmental Management 38*(6):1020–1030

Woods, A.J., Omernik, J.M., Butler, D.R., Ford, J.G., Henley, J.E., Hoagland, B.W., Arndt, D.S., and Moran, B.C. 2005. Ecoregions of Oklahoma (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,250,000).

Table 15. Appendix A—Metadata for All Sites.

Station ID	Waterbody Name	Yr Eval	S.O.	COUNTY	Ecoregion	Ecoregion Combined	Planning Basin	Drainage Area (m2)	Lat Field	Long Field	final.wgt	Mgmt Segment	Aquatic Tier
OKPB01-003	North Fork of the Red River	2005	7	KIOWA	Central Great Plains	Western Plains	Upper Red	2684.19	35.1032	-99.3973	202.328	311510	WWAC
OKPB01-005	Bird Creek	2005	3	OSAGE	Flint Hills	Forested Plains	Grand Neosho	162.99	36.6708	-96.306	83.919	121300	WWAC
OKPB01-008	Grayson Creek	2005	1	PONTOTOC	Cross Timbers	Forested Plains	Lower Canadian	1.93	34.8526	-96.7574	117.691	520600	WWAC
OKPB01-009	North Fork of Walnut Creek	2005	3	MCCLAIN	Central Great Plains	Western Plains	Upper Canadian	50.20	35.1619	-97.6086	79.394	520610	WWAC
OKPB01-010	Red River	2005	8	LOVE	Cross Timbers	Forested Plains	Upper Red	29295.77	33.9195	-97.4927	202.328	311100	WWAC
OKPB01-011	Lyon Creek	2005	4	KINGFISHER	Central Great Plains	Western Plains	Cimarron	33.86	36.1325	-97.7438	103.691	620910	WWAC
OKPB01-013	Sweetwater Creek	2005	4	BECKHAM	Central Great Plains	Western Plains	Upper Red	541.84	35.3071	-99.9547	263.026	311510	WWAC
OKPB01-015	Haystack Creek	2005	3	GREER	Central Great Plains	Western Plains	Upper Red	43.52	35.1029	-99.6376	404.660	311800	WWAC
OKPB01-017	Turkey Creek	2005	4	KINGFISHER	Central Great Plains	Western Plains	Cimarron	407.99	36.007	-97.9337	103.691	620910	WWAC
OKPB01-019	Coal Creek	2005	2	TULSA	Cross Timbers	Forested Plains	Lower Arkansas	13.19	36.0067	-95.9927	339.297	120420	WWAC
OKPB01-021	Canadian River	2005	3	CANADIAN	Central Great Plains	Western Plains	Upper Canadian	5262.99	35.3463	-97.8566	79.394	520610	HLAC
OKPB01-022	Mud Creek	2005	4	JEFFERSON	Cross Timbers	Forested Plains	Upper Red	294.58	34.1052	-97.6641	263.026	311100	WWAC
OKPB01-024	Baron Fork River	2005	4	ADAIR	Ozark Highlands	Temperate Forests	Lower Arkansas	191.18	35.951	-94.658	203.577	121700	CWAC
OKPB01-026	Holly Creek	2005	1	PUSHMATAHA	Ouachita Mountains	Temperate Forests	Lower Red	1.41	34.3518	-95.113	155.176	410210	WWAC
OKPB01-027	Bitter Creek	2006	4	JACKSON	Central Great Plains	Western Plains	Upper Red	18.84	34.7808	-99.3919	263.026	311600	HLAC
OKPB01-028	Clear Boggy Creek	2005	5	CHOCTAW	South Central Plains	Temperate Forests	Lower Red	998.88	34.0681	-95.8144	47.023	410400	WWAC
OKPB01-029	Red Rock Creek	2006	3	GARFIELD	Central Great Plains	Western Plains	Upper Arkansas	63.83	36.5185	-97.6146	118.396	621200	WWAC
OKPB01-031	Opossum Creek	2006	3	OKLAHOMA	Cross Timbers	Forested Plains	Lower North Canadian	23.52	35.7202	-97.1826	465.146	520700	WWAC

Station ID	Waterbody Name	Yr Eval	S.O.	COUNTY	Ecoregion	Ecoregion Combined	Planning_Basin	Drainage Area (m2)	Lat_Field	Long_Field	final.wgt	Mgmt Segment	Aquatic Tier
OKPB01-032	Neosho River	2006	7	OTTAWA	Central Irregular Plains	Forested Plains	Grand Neosho	5982.71	36.8783	-94.8928	41.959	121600	WWAC
OKPB01-033	Polecat Creek	2006	4	CREEK	Cross Timbers	Forested Plains	Lower Arkansas	51.20	35.9648	-96.4018	203.577	120420	WWAC
OKPB01-034	Crooked Creek	2005	2	MCCURTAIN	Ouachita Mountains	Temperate Forests	Lower Red	4.05	34.0852	-94.7231	129.313	410200	WWAC
OKPB01-035	Unnamed Creek	2006	1	ALFALFA	Central Great Plains	Western Plains	Upper Arkansas	1.92	36.7534	-98.248	153.914	621010	WWAC
OKPB01-036	Caston Creek	2006	4	LE FLORE	Arkansas Valley	Temperate Forests	Lower Arkansas	33.58	34.9599	-94.7379	203.577	220100	WWAC
OKPB01-038	Mountain Fork River	2005	6	MCCURTAIN	Ouachita Mountains	Temperate Forests	Lower Red	322.03	34.4613	-94.6344	47.023	410210	CWAC
OKPB01-043	Chikaskia River	2006	6	KAY	Central Great Plains	Western Plains	Upper Arkansas	1694.85	36.9098	-97.3649	46.641	621100	WWAC
OKPB01-044	Kiamichi River	2005	6	PUSHMATAHA	Ouachita Mountains	Temperate Forests	Lower Red	1133.15	34.2393	-95.5818	47.023	410300	WWAC
OKPB01-046	Unnamed Tributary	2005	1	LE FLORE	Ouachita Mountains	Temperate Forests	Lower Red	0.54	34.5826	-94.6989	155.176	410210	WWAC
OKPB01-050	Sand Creek	2006	2	OSAGE	Flint Hills	Forested Plains	Grand Neosho	39.60	36.7868	-96.3393	90.911	121400	WWAC
OKPB01-051	Greenleaf Creek	2006	2	WOODS	Central Great Plains	Western Plains	Upper Arkansas	15.98	36.9334	-98.8725	128.262	621010	WWAC
OKPB01-052	Fourche Maline	2006	5	LE FLORE	Arkansas Valley	Temperate Forests	Lower Arkansas	265.49	34.9165	-94.9483	123.382	220100	WWAC
OKPB01-054	South Fork of Dirty Creek	2006	4	MUSKOGEE	Central Irregular Plains	Forested Plains	Lower Arkansas	46.14	35.4528	-95.2143	203.577	120400	WWAC
OKPB01-056	Little Sandy Creek	2005	1	JOHNSTON	Cross Timbers	Forested Plains	Lower Red	2.40	34.3041	-96.5545	155.176	410600	WWAC
OKPB01-059	Deep Fork of the Canadian River	2007	6	OKMULGEE	Cross Timbers	Forested Plains	Lower North Canadian	2164.07	35.5694	-95.9386	183.239	520700	WWAC
OKPB01-060	Bird Creek	2007	1	HUGHES	Cross Timbers	Forested Plains	Lower Canadian	13.18	35.0399	-96.4654	117.691	520800	HLAC
OKPB01-064	Caney River	2007	6	WASHINGTON	Cross Timbers	Forested Plains	Grand Neosho	1708.04	36.6841	-95.9796	33.059	121400	WWAC
OKPB01-072	Big Cabin Creek	2007	3	CRAIG	Central Irregular Plains	Forested Plains	Grand Neosho	71.51	36.7939	-95.1727	83.919	121600	WWAC
OKPB01-073	Wolf Creek	2007	7	ELLIS	Southwestern Tablelands	Western Plains	Upper North Canadian	1179.45	36.287	-99.9496	42.171	720500	WWAC
OKPB01-076	Shady Grove Creek	2007	4	MCINTOSH	Central Irregular Plains	Forested Plains	Lower Arkansas	15.48	35.4706	-95.4584	203.577	120400	WWAC

Station ID	Waterbody Name	Yr Eval	S.O.	COUNTY	Ecoregion	Ecoregion Combined	Planning_Basin	Drainage Area (m2)	Lat_Field	Long_Field	final.wgt	Mgmt Segment	Aquatic Tier
OKPB01-078	Glover River	2005	5	MCCURTAIN	Ouachita Mountains	Temperate Forests	Lower Red	300.40	34.1362	-94.9147	47.023	410210	CWAC
OKPB01-081	Jim Creek	2007	1	POTTAWATOMIE	Cross Timbers	Forested Plains	Lower Canadian	7.73	35.2192	-97.0665	117.691	520800	WWAC
OKPB01-084	Peterson Creek	2005	1	PUSHMATAHA	Ouachita Mountains	Temperate Forests	Lower Red	2.22	34.5405	-95.3897	155.176	410300	WWAC
OKPB01-085	Deep Fork of the Canadian River	2007	5	LINCOLN	Cross Timbers	Forested Plains	Lower North Canadian	588.62	35.6401	-96.9079	183.239	520700	WWAC
OKPB01-092	Big Creek	2007	3	LE FLORE	Ouachita Mountains	Temperate Forests	Lower Arkansas	21.15	34.7073	-94.5338	313.200	220100	CWAC
OKPB01-098	Norwood Creek	2005	2	MCCURTAIN	South Central Plains	Temperate Forests	Lower Red	7.88	33.8276	-94.6621	129.313	410100	WWAC
OKPB01-099	North Fork of the Red River	2007	8	KIOWA	Central Great Plains	Western Plains	Upper Red	3708.99	34.8671	-99.3119	202.328	311510	WWAC
OKPB01-118	Caney Creek	2005	3	ATOKA	South Central Plains	Temperate Forests	Lower Red	42.70	34.2253	-96.2489	119.367	410400	WWAC
OKPB01-130	Blue River	2005	4	BRYAN	South Central Plains	Temperate Forests	Lower Red	671.00	33.8829	-95.9645	77.588	410600	WWAC
OKPB01-134	Buck Creek	2005	4	PUSHMATAHA	Ouachita Mountains	Temperate Forests	Lower Red	81.29	34.3942	-95.6783	77.588	410300	WWAC
OKPB01-136	Sand Springs Branch	2005	2	MCCURTAIN	South Central Plains	Temperate Forests	Lower Red	4.08	34.0206	-95.0469	129.313	410210	WWAC
OKPB01-138	Unnamed Tributary	2005	2	MCCURTAIN	Ouachita Mountains	Temperate Forests	Lower Red	10.29	34.2474	-94.8462	129.313	410210	WWAC
OKPB01-144	Boktuklo Creek	2005	1	MCCURTAIN	Ouachita Mountains	Temperate Forests	Lower Red	12.74	34.3909	-94.7378	155.176	410210	CWAC
OKPB01-148	Kiamichi River	2005	4	LE FLORE	Ouachita Mountains	Temperate Forests	Lower Red	36.67	34.6405	-94.6094	77.588	410310	WWAC
OKPB01-154	Blue River	2005	4	BRYAN	Cross Timbers	Forested Plains	Lower Red	367.17	34.0866	-96.361	77.588	410600	WWAC
OKPB01-156	Beck Creek	2005	2	ATOKA	Arkansas Valley	Temperate Forests	Lower Red	3.70	34.5808	-96.02	129.313	410400	WWAC
OKPB01-170	Clear Boggy Creek	2005	5	COAL	Arkansas Valley	Temperate Forests	Lower Red	367.59	34.49	-96.3484	47.023	410400	WWAC
OKPB01-196	Buffalo Creek	2005	3	MCCURTAIN	Ouachita Mountains	Temperate Forests	Lower Red	110.38	34.3626	-94.6418	119.367	410210	CWAC
OKPB01-210	Big Cedar Creek	2005	2	LE FLORE	Ouachita Mountains	Temperate Forests	Lower Red	4.77	34.6822	-94.6476	129.313	410310	WWAC
OKPB01-212	Cimarron River	2007	5	CIMARRON	Southwestern Tablelands	Western Plains	Cimarron	1197.08	36.906	-102.9753	62.844	720900	WWAC

Station ID	Waterbody Name	Yr Eval	S.O.	COUNTY	Ecoregion	Ecoregion Combined	Planning_Basin	Drainage Area (m2)	Lat_Field	Long_Field	final.wgt	Mgmt Segment	Aquatic Tier
OKPB01-213	Wolf Creek	2006	7	ELLIS	Southwestern Tablelands	Western Plains	Upper North Canadian	1611.98	36.3504	-99.6978	42.171	720500	WWAC
OKPB01-216	Muddy Boggy Creek	2005	6	COAL	Arkansas Valley	Temperate Forests	Lower Red	339.61	34.6016	-96.1695	47.023	410400	WWAC
OKPB01-220	Curl Creek	2006	2	WASHINGTON	Central Irregular Plains	Forested Plains	Grand Neosho	47.75	36.5975	-95.8608	90.911	121400	WWAC
OKPB01-223	Gar Creek	2006	3	WAGONER	Central Irregular Plains	Forested Plains	Grand Neosho	15.49	35.9588	-95.5495	83.919	121500	WWAC
OKPB01-224	Carnasaw Creek	2005	1	MCCURTAIN	Ouachita Mountains	Temperate Forests	Lower Red	3.05	34.1243	-94.6546	155.176	410210	WWAC
OKPB01-227	Unnamed Tributary	2007	1	OKLAHOMA	Central Great Plains	Western Plains	Cimarron	0.63	35.5983	-97.5663	207.384	620910	WWAC
OKPB01-229	Cimarron River	2007	7	WOODS	Central Great Plains	Western Plains	Cimarron	10203.28	36.8746	-99.3596	79.763	620920	WWAC
OKPB01-232	Julian Creek	2007	2	POTTAWATOMIE	Cross Timbers	Forested Plains	Lower Canadian	5.36	34.9696	-96.9737	98.075	520600	WWAC
OKPB01-235	Turkey Creek	2007	2	PAWNEE	Central Great Plains	Western Plains	Upper Arkansas	10.47	36.359	-96.9242	128.262	621200	WWAC
OKPB01-236	California Creek	2006	1	NOWATA	Central Irregular Plains	Forested Plains	Grand Neosho	7.86	36.8983	-95.7366	109.094	121510	WWAC
OKPB01-239	Crooked Creek	2007	5	BEAVER	Southwestern Tablelands	Western Plains	Cimarron	1437.68	36.9827	-100.134	62.844	620930	WWAC
OKPB01-247	Tyner Creek	2006	2	WASHINGTON	Central Irregular Plains	Forested Plains	Grand Neosho	8.79	36.4379	-95.9961	90.911	121300	WWAC
OKPB01-251	Cooper Creek	2007	3	KINGFISHER	Central Great Plains	Western Plains	Cimarron	60.17	35.9733	-98.1311	159.527	620910	WWAC
OKPB01-255	Turkey Creek	2007	2	LINCOLN	Central Great Plains	Western Plains	Cimarron	4.25	35.903	-96.7257	172.820	620900	WWAC
OKPB01-256	Carpenter Branch	2005	1	MCCURTAIN	Ouachita Mountains	Temperate Forests	Lower Red	2.42	34.3874	-94.8576	155.176	410210	WWAC
OKPB01-260	Madden Creek	2006	1	CRAIG	Central Irregular Plains	Forested Plains	Grand Neosho	6.81	36.703	-95.4179	109.094	121510	WWAC
OKPB01-266	Mayhew Creek	2005	1	CHOCTAW	South Central Plains	Temperate Forests	Lower Red	4.51	34.0555	-95.9209	155.176	410400	WWAC
OKPB01-267	Arkansas River	2007	7	OSAGE	Central Great Plains	Western Plains	Upper Arkansas	18055.04	36.6752	-97.0639	59.198	621200	WWAC
OKPB01-282	Tomike Creek	2007	2	MCCLAIN	Central Great Plains	Western Plains	Lower Canadian	5.42	34.9252	-97.1582	98.075	520610	WWAC
OKPB01-283	Skeleton Creek	2007	4	GARFIELD	Central Great Plains	Western Plains	Cimarron	157.40	36.2347	-97.7575	103.691	620910	HLAC
OKPB01-284	Rock Creek	2006	1	MAYES	Central Irregular Plains	Forested Plains	Grand Neosho	5.55	36.5021	-95.2672	109.094	121600	WWAC
OKPB01-	Little Cabin	2006	2	CRAIG	Central Irregular Plains	Forested Plains	Grand Neosho	14.26	36.8256	-95.0763	90.911	121600	WWAC

Station ID	Waterbody Name	Yr Eval	S.O.	COUNTY	Ecoregion	Ecoregion Combined	Planning_Basin	Drainage Area (m2)	Lat_Field	Long_Field	final.wgt	Mgmt Segment	Aquatic Tier
292	Creek												
OKPB01-293	Driftwood Creek	2007	5	ALFALFA	Central Great Plains	Western Plains	Upper Arkansas	225.78	36.8961	-98.4374	46.641	621010	WWAC
OKPB01-298	Mineral Bayou	2005	2	BRYAN	Cross Timbers	Forested Plains	Lower Red	21.15	34.0058	-96.3646	129.313	410600	WWAC
OKPB01-299	Doga Creek	2007	2	OSAGE	Flint Hills	Forested Plains	Upper Arkansas	14.07	36.6074	-96.8196	128.262	621200	WWAC
OKPB01-302	Kiamichi River	2005	4	LE FLORE	Ouachita Mountains	Temperate Forests	Lower Red	68.80	34.6431	-94.7142	77.588	410310	WWAC
OKPB01-311	Ranch creek	2006	1	TULSA	Central Irregular Plains	Forested Plains	Grand Neosho	2.57	36.3017	-95.8742	109.094	121300	WWAC
OKPB01-317	Unnamed Creek	2006	2	ELLIS	Central Great Plains	Western Plains	Upper Canadian	4.29	35.9847	-99.7932	86.009	520620	WWAC
OKPB01-323	Skeleton Creek	2007	5	LOGAN	Central Great Plains	Western Plains	Cimarron	553.52	36.0506	-97.5419	62.844	620910	WWAC
OKPB01-327	Verdigris River	2006	7	ROGERS	Central Irregular Plains	Forested Plains	Grand Neosho	7653.28	36.1981	-95.7008	41.959	121500	WWAC
OKPB01-328	Glover River	2006	5	MCCURTAIN	Ouachita Mountains	Temperate Forests	Lower Red	208.20	34.2806	-94.9079	47.023	410210	CWAC
OKPB01-330	Clear Boggy Creek	2006	5	ATOKA	South Central Plains	Temperate Forests	Lower Red	813.48	34.1683	-96.0575	47.023	410400	WWAC
OKPB01-335	Beaver River	2006	7	BEAVER	Southwestern Tablelands	Western Plains	Upper North Canadian	8610.00	36.8001	-100.0195	42.171	720500	WWAC
OKPB01-336	Beaverdam Creek	2006	2	CHOCTAW	South Central Plains	Temperate Forests	Lower Red	10.44	34.0918	-95.7549	129.313	410400	WWAC
OKPB01-342	Cedar Creek	2006	4	PUSHMATAHA	Ouachita Mountains	Temperate Forests	Lower Red	173.89	34.2578	-95.5377	77.588	410300	CWAC
OKPB01-343	Bitter Creek	2007	4	KAY	Central Great Plains	Western Plains	Upper Arkansas	136.77	36.8228	-97.2685	76.957	621100	WWAC
OKPB01-344	Muddy Boggy Creek	2007	6	COAL	Arkansas Valley	Temperate Forests	Lower Red	505.94	34.4567	-96.1734	47.023	410400	WWAC
OKPB01-347	Black Bear Creek	2007	3	GARFIELD	Central Great Plains	Western Plains	Upper Arkansas	93.18	36.3685	-97.5052	118.396	621200	WWAC
OKPB01-348	Fish Creek	2006	1	WASHINGTON	Central Irregular Plains	Forested Plains	Grand Neosho	3.90	36.7092	-95.8843	109.094	121400	WWAC
OKPB01-355	Cottonwood Creek	2007	4	LOGAN	Central Great Plains	Western Plains	Cimarron	67.54	35.7684	-97.6302	103.691	620910	WWAC
OKPB01-357	Eagle Chief Creek	2007	3	WOODS	Central Great Plains	Western Plains	Cimarron	83.28	36.6972	-98.6977	159.527	620920	WWAC
OKPB01-360	Little River	2007	4	SEMINOLE	Cross Timbers	Forested Plains	Lower Canadian	600.64	35.0219	-96.6106	58.845	520800	WWAC
OKPB01-363	Black Bear Creek	2007	4	NOBLE	Central Great Plains	Western Plains	Upper Arkansas	289.47	36.3451	-97.1902	76.957	621200	WWAC

Station ID	Waterbody Name	Yr Eval	S.O.	COUNTY	Ecoregion	Ecoregion Combined	Planning_Basin	Drainage Area (m2)	Lat_Field	Long_Field	final.wgt	Mgmt Segment	Aquatic Tier
OKPB01-369	Canadian River	2006	4	CLEVELAND	Central Great Plains	Western Plains	Upper Canadian	5599.86	35.0354	-97.3565	51.605	520610	HLAC
OKPB01-372	Beaty Creek	2006	3	DELAWARE	Ozark Highlands	Temperate Forests	Grand Neosho	51.30	36.3668	-94.7314	83.919	121600	CWAC
OKPB01-376	Peaceable Creek	2007	4	PITTSBURG	Arkansas Valley	Temperate Forests	Lower Canadian	98.26	34.8233	-95.7716	58.845	220600	WWAC
OKPB01-389	Salt Fork of Arkansas River	2007	5	WOODS	Central Great Plains	Western Plains	Upper Arkansas	835.65	36.9435	-98.7739	46.641	621010	WWAC
OKPB01-391	Verdigris River	2006	7	ROGERS	Central Irregular Plains	Forested Plains	Grand Neosho	6485.49	36.2337	-95.7227	41.959	121500	WWAC
OKPB01-395	Dugout Creek	2007	1	OSAGE	Flint Hills	Forested Plains	Upper Arkansas	8.59	36.8452	-96.5764	153.914	621200	WWAC
OKPB01-399	Duck Pond Creek	2006	3	BEAVER	Southwestern Tablelands	Western Plains	Upper North Canadian	83.12	36.7011	-100.3118	84.343	720500	WWAC
OKPB01-404	Chouteau Creek	2006	2	MAYES	Central Irregular Plains	Forested Plains	Grand Neosho	42.38	36.2071	-95.3676	90.911	121600	WWAC
OKPB01-405	Bitter Creek	2007	4	KAY	Central Great Plains	Western Plains	Upper Arkansas	80.85	36.9211	-97.2646	76.957	621100	WWAC
OKPB01-424	Scipio Creek	2007	4	PITTSBURG	Arkansas Valley	Temperate Forests	Lower Canadian	33.18	35.0975	-95.9297	58.845	220600	WWAC
OKPB01-429	Unnamed Creek (Lariat Creek)	2006	1	BLAINE	Central Great Plains	Western Plains	Upper Canadian	6.93	35.6274	-98.4294	103.211	520620	WWAC
OKPB01-431	Clear Creek	2006	4	ELLIS	Southwestern Tablelands	Western Plains	Upper North Canadian	39.60	36.5487	-99.9417	54.822	720500	WWAC
OKPB01-453	Canadian River	2006	7	DEWEY	Central Great Plains	Western Plains	Upper Canadian	3694.55	36.0037	-99.2974	39.696	520620	WWAC
OKPB01-469	North Canadian River	2006	7	WOODWARD	Central Great Plains	Western Plains	Upper North Canadian	11705.62	36.4617	-99.4388	42.171	720500	WWAC
OKPB01-495	Beaver River	2006	7	BEAVER	Southwestern Tablelands	Western Plains	Upper North Canadian	8006.11	36.814	-100.4762	42.171	720500	WWAC
OKPB01-504	Bull Creek	2007	3	PITTSBURG	Arkansas Valley	Temperate Forests	Lower Canadian	25.03	34.8597	-95.8285	90.532	220600	WWAC
OKPB01-519	Bird Creek	2006	5	ROGERS	Central Irregular Plains	Forested Plains	Grand Neosho	1131.11	36.2169	-95.768	33.059	121300	WWAC
OKPB01-527	Beaver River	2006	7	BEAVER	Southwestern Tablelands	Western Plains	Upper North Canadian	8574.92	36.7683	-100.1072	42.171	720500	WWAC
OKPB01-548	Windy Creek	2006	1	OTTAWA	Central Irregular Plains	Forested Plains	Grand Neosho	7.33	36.8755	-94.9496	109.094	121600	WWAC
OKPB01-552	Mill Creek	2007	4	MCINTOSH	Arkansas Valley	Temperate Forests	Lower Canadian	31.49	35.2082	-95.9038	58.845	220600	WWAC

Station ID	Waterbody Name	Yr Eval	S.O.	COUNTY	Ecoregion	Ecoregion Combined	Planning_Basin	Drainage Area (m2)	Lat_Field	Long_Field	final.wgt	Mgmt Segment	Aquatic Tier
OKPB01-567	Bull Creek	2006	3	OSAGE	Cross Timbers	Forested Plains	Grand Neosho	12.94	36.4693	-96.1052	83.919	121300	WWAC
OKPB01-581	Canadian River	2006	7	DEWEY	Central Great Plains	Western Plains	Upper Canadian	3903.82	35.9693	-99.0263	39.696	520620	WWAC
OKPB01-583	Adams Creek	2006	1	WAGONER	Central Irregular Plains	Forested Plains	Grand Neosho	14.67	36.0683	-95.7128	109.094	121500	WWAC
OKPB01-616	Canadian River	2007	7	HUGHES	Arkansas Valley	Temperate Forests	Lower Canadian	7753.06	35.0692	-96.0653	45.265	220600	WWAC
OKPB01-619	Sand Creek	2006	2	OSAGE	Flint Hills	Forested Plains	Grand Neosho	51.87	36.7589	-96.3143	90.911	121400	WWAC

Table 16. Appendix B—Water Quality Data for All Sites.

Sample ID	Station ID	Sample Date	Sample Time	NH_3 (mg/L)	TKN (mg/L)	NO_3 (mg/L)	NO2 (mg/L)	TN (mg/L)	AN (mg/L)	P-Ortho (mg/L)	P-Total (mg/L)	DO (mg/L)	pH (std units)	Turb. (NTU)	Water Temp. (^oC)	Cond. (us/cm)	Cl (mg/L)	TDS (mg/L)	Su (mg/L)
377939	OKPB01-003	07/05/2005	16:30	0.050	0.650	0.050	0.050	0.750	0.150	0.016	0.053	6.10	8.25		33.97	2470.0	469.0	1970.0	601.0
378141	OKPB01-005	07/11/2005	14:30	0.050	0.400	0.050	0.050	0.500	0.150	0.025	0.067	7.20	7.83	32.0	29.11	247.4	10.0	170.0	21.8
376904	OKPB01-008	06/20/2005	15:55	0.050	0.150	0.050	0.050	0.250	0.150	0.039	0.060	5.70	7.25		26.08	676.0	42.0	413.0	19.4
378659	OKPB01-009	07/19/2005	10:45	0.050	0.790	0.050	0.050	0.890	0.150	0.088	0.173	2.52	7.71		26.73	529.0	14.6	357.0	20.7
378306	OKPB01-010	07/12/2005	12:00	0.930	2.250	1.840	0.150	4.240	2.920	0.045	0.452	7.12	7.93	55.0	32.36	2065.0	982.0	2510.0	552.0
378535	OKPB01-011	07/18/2005	10:46	0.140	1.280	0.720	0.050	2.050	0.910	0.103	0.199	4.74	8.06		25.60	1535.0	261.0	999.0	178.0
377938	OKPB01-013	07/25/2005	13:00	0.070	0.940	0.490	0.050	1.480	0.610	0.036	0.137	8.37	8.67	10.0	23.62	2090.0	366.0	1600.0	499.0
379181	OKPB01-013	07/05/2005	10:30	0.050	1.460	0.310	0.050	1.820	0.410	0.006	0.036	8.80	8.50		29.54	9079.0	2000.0	5930.0	1200.0
379180	OKPB01-015	07/25/2005	15:06	0.290	2.450	0.050	0.050	2.550	0.390	0.103	0.189	8.88	8.07	55.0	30.35	13254.0	2200.0	10800.0	4500.0
378536	OKPB01-017	07/18/2005	13:31	0.050	0.920	0.810	0.050	1.780	0.910	0.429	0.496	10.68	8.34	20.0	29.94	1029.0	181.0	675.0	90.2
377407	OKPB01-019	07/11/2005	10:30	0.050	0.550	0.060	0.050	0.660	0.160	0.020	0.054	4.06	7.42	17.0	28.37	1043.0	277.0	690.0	10.0
378140	OKPB01-019	06/28/2005	16:25	0.050	0.440	0.080	0.050	0.570	0.180	0.029	0.058	9.00	7.25	16.0	26.72	674.4	160.0	412.0	24.5
378757	OKPB01-021	07/20/2005	10:31	0.050	1.830	0.810	0.050	2.690	0.910	0.013	0.082	7.21	8.12	14.0	26.92	946.4	0.0	670.0	0.0
378305	OKPB01-022	07/12/2005	15:00	1.180	2.720	0.140	0.400	3.260	1.720	0.132	0.565	1.33	7.21	55.0	29.22	335.4	33.2	300.0	93.8
377406	OKPB01-024	06/28/2005	18:00	0.070	0.060	0.530	0.050	0.640	0.650	0.030	0.041	9.90	7.25	5.0	28.25	192.0	10.0	135.0	10.0
377046	OKPB01-026	06/22/2005	17:31	0.050	0.050	0.080	0.050	0.180	0.180	0.009	0.019	4.10	5.91	14.3	21.60	45.3	10.0	46.0	11.8
377225	OKPB01-026	06/27/2005	16:33	0.050	0.050	0.060	0.050	0.160	0.160	0.009	0.020			5.0	23.00		10.0	43.0	12.4
400503	OKPB01-027	09/20/2006	13:00	0.120	2.520	0.340	0.050	2.910	0.510	0.056	0.520	13.51	7.98	25.0	21.93	3164.0	480.0	1970.0	797.0

Sample ID	Station ID	Sample Date	Sample Time	NH_3 (mg/L)	TKN (mg/L)	NO_3 (mg/L)	NO2 (mg/L)	TN (mg/L)	AN (mg/L)	P-Ortho (mg/L)	P-Total (mg/L)	DO (mg/L)	pH (std units)	Turb. (NTU)	Water Temp. (^oC)	Cond. (us/cm)	Cl (mg/L)	TDS (mg/L)	Su (mg/L)
405721	OKPB01-027	07/05/2006	11:45	0.050	0.840	1.880	0.080	2.800	2.010	0.005	0.060	12.29	7.75	316.0	28.57	5200.0	920.0	3290.0	1320.0
377425	OKPB01-028	06/29/2005	10:00	0.070	0.510	0.050	0.050	0.610	0.170	0.053	0.095	6.84	8.08	31.2	27.20	719.0	88.8	395.0	23.8
400627	OKPB01-029	07/10/2006	14:30	0.050	0.580	0.050	0.050	0.680	0.150	0.299	0.352	6.26	8.31	12.0	30.34	1031.0	172.0	778.0	155.0
401943	OKPB01-031	08/02/2006	13:45	0.050	1.420	0.050	0.050	1.520	0.150	0.037	0.176	6.12	8.13	46.0	31.11	922.8	79.9	483.0	17.2
401507	OKPB01-032	07/25/2006	10:45	0.050	0.580	0.050	0.050	0.680	0.150	0.066	0.119	5.50	8.05	13.0	30.21	414.0	10.3	500.0	40.5
401194	OKPB01-033	07/19/2000	09:45	0.070	0.880	0.050	0.050	0.980	0.170	0.009	0.129	6.67	8.16	213.0	30.15	341.2	74.1	242.0	10.0
376983	OKPB01-034	06/21/2005	12:30	0.050	0.070	0.050	0.050	0.170	0.150	0.005	0.012	6.71	6.99	1.3	25.70	135.0	10.0	77.0	11.5
401884	OKPB01-035	08/01/2006	10:30	0.050	4.870	0.050	0.050	4.970	0.150	0.113	0.329	4.25	8.01	19.0	25.72	104960.0	43400.0	63000.0	6810.0
400990	OKPB01-036	07/17/2006	19:30	0.050	0.360	0.050	0.050	0.460	0.150	0.008	0.036	5.33	7.38	4.0	34.50	95.8	10.0	74.0	11.0
376980	OKPB01-038	06/21/2005	18:30	0.050	0.230	0.050	0.050	0.330	0.150	0.008	0.038	9.10	7.00	5.0	30.45	30.0	10.0	80.0	10.0
400626	OKPB01-043	07/10/2006	11:30	0.050	0.650	0.050	0.050	0.750	0.150	0.119	0.186	6.86	8.28	35.0	26.65	577.3	44.3	366.0	72.4
381694	OKPB01-044	08/23/2005	14:45	0.050	0.800	0.050	0.050	0.900	0.150	0.007	0.074	3.06	6.36	5.0	30.05	70.4	10.0	61.0	10.0
376906	OKPB01-046	06/20/2005	12:46	0.050	0.050	0.160	0.050	0.260	0.260	0.010	0.019	7.58	6.15	11.9	26.30	31.2	10.0	40.0	10.0
401600	OKPB01-050	07/26/2006	12:45	0.050	0.490	0.050	0.050	0.590	0.150	0.011	0.051	4.44	7.64	17.0	27.88	341.9	10.0	207.0	10.6
400718	OKPB01-051	07/11/2006	09:30	0.050	0.940	1.010	0.050	2.000	1.110	0.008	0.019	5.76	7.81	9.0	23.55	3084.0	51.1	3150.0	1960.0
400989	OKPB01-052	07/17/2006	13:30	0.050	0.670	0.080	0.050	0.800	0.180	0.026	0.113	3.61	7.04	58.0	30.08	70.5	10.0	92.0	26.5
404506	OKPB01-054	09/06/2006	15:45	0.090	1.240	0.050	0.050	1.340	0.190	0.025	0.104	3.36	7.21	160.0	23.68	276.0	10.0	86.0	27.1
377370	OKPB01-056	06/28/2005	16:35	0.050	0.920	0.050	0.050	1.020	0.150	0.011	0.085	13.52	7.57	7.0	30.90	201.0	10.9	127.0	10.0
427911	OKPB01-059	10/03/2007	15:00	0.170	1.270	0.240	0.100	1.610	0.510	0.199	0.364	6.34	8.37	154.0	23.89	363.0	53.4	276.0	48.4
419687	OKPB01-060	06/12/2007	13:30	0.050	0.460	0.050	0.050	0.560	0.150	0.017	0.025	7.65	7.90	7.6	34.90	3781.0	1220.0	2210.0	36.0
428679	OKPB01-064	10/16/2007	14:00	0.180	1.280	1.600	0.130	3.010	1.910	0.271	0.385	7.55	7.96	40.8	17.96	421.0	45.5	217.0	22.1

Sample ID	Station ID	Sample Date	Sample Time	NH_3 (mg/L)	TKN (mg/L)	NO_3 (mg/L)	NO2 (mg/L)	TN (mg/L)	AN (mg/L)	P-Ortho (mg/L)	P-Total (mg/L)	DO (mg/L)	pH (std units)	Turb. (NTU)	Water Temp. (^oC)	Cond. (us/cm)	Cl (mg/L)	TDS (mg/L)	Su (mg/L)
422988	OKPB01-072	08/06/2007	10:00	0.050	0.490	0.050	0.050	0.590	0.150	0.009	0.039	4.59	7.34	5.3	28.60	801.0	10.0	554.0	296.0
423522	OKPB01-073	08/14/2007	13:00	0.050	1.820	1.400	0.090	3.310	1.540	0.009	0.051	9.15	8.00	16.0	25.45	1382.0	222.0	771.0	128.0
423008	OKPB01-076	08/06/2007	12:31	0.100	0.430	0.110	0.050	0.590	0.260	0.005	0.000	5.38	6.53	11.0	28.10	1626.0	10.0	1310.0	912.0
376977	OKPB01-078	06/21/2005	11:30	0.050	0.170	0.050	0.050	0.270	0.150	0.007	0.025	7.00	7.00	5.0	28.62	0.0	10.0	45.0	10.0
419805	OKPB01-081	06/13/2007	10:00	0.050	0.280	0.050	0.050	0.380	0.150	0.011	0.036	8.47	8.11	27.0	23.86	502.0	37.7	310.0	14.2
424913	OKPB01-081	09/04/2007	11:00	0.070	0.160	0.050	0.050	0.260	0.170	0.010	0.023	2.98	7.86	26.0	22.29	539.0	33.6	287.0	18.0
376907	OKPB01-084	06/20/2005	16:30	0.050	0.050	0.050	0.050	0.150	0.150	0.007	0.020	6.84	6.26	8.3	25.90	50.5	10.0	45.0	10.0
424988	OKPB01-085	09/05/2007	10:31	0.050	0.410	0.050	0.050	0.510	0.150	0.031	0.064	12.90	8.40	5.5	25.45	945.0	147.0	588.0	60.4
422061	OKPB01-092	07/25/2007	12:15	0.050	0.140	0.050	0.050	0.240	0.150	0.005	0.005	9.11	7.46	2.4	23.44	26.0	10.0	24.0	10.0
377044	OKPB01-098	06/22/2005	10:01	0.050	1.030	0.050	0.050	1.130	0.150	0.025	0.200	0.43	6.86	14.2	22.20	184.6	10.0	124.0	27.9
423524	OKPB01-099	08/14/2007	19:00	0.050	0.610	0.050	0.050	0.710	0.150	0.005	0.020	11.13	7.96	3.0	34.70	18146.0	5550.0	10200.0	1470.0
377368	OKPB01-118	06/28/2005	11:39	0.070	0.350	0.050	0.050	0.450	0.170	0.012	0.033	4.67	7.49	5.2	24.60	956.0	170.0	566.0	18.4
381841	OKPB01-130	08/24/2005	16:30	0.050	0.360	0.050	0.050	0.460	0.150	0.026	0.071						10.0	212.0	10.0
377047	OKPB01-134	06/22/2005	15:00	0.050	0.340	0.050	0.050	0.440	0.150	0.008	0.041	8.10	7.00	5.0	30.00	66.0	10.0	57.0	17.2
377045	OKPB01-136	06/22/2005	13:31	0.080	0.520	0.160	0.050	0.730	0.290	0.012	0.043	4.36	7.38	15.1	22.80	153.5	10.0	105.0	16.0
376984	OKPB01-138	06/21/2005	15:00	0.050	0.130	0.060	0.050	0.240	0.160	0.006	0.012	4.92	6.69	4.0	25.50	43.6	10.0	39.0	10.0
376981	OKPB01-144	06/21/2005	07:30	0.050	0.050	0.050	0.050	0.150	0.150	0.005	0.012	9.24	6.98	5.1	21.60	27.5	10.0	81.0	10.0
377223	OKPB01-144	06/27/2005	11:00	0.050	0.080	0.050	0.050	0.180	0.150	0.005	0.014	3.11	5.45	8.2	22.00	41.1	10.0	25.0	10.0
376978	OKPB01-148	06/21/2005	15:00	0.050	0.090	0.050	0.050	0.190	0.150	0.006	0.016	9.00	7.25	2.8	28.05	20.0	10.0	32.0	10.0
377369	OKPB01-154	06/28/2005	14:31	0.050	0.250	0.050	0.050	0.350	0.150	0.037	0.051	5.88	8.16	8.1	31.40	456.0	10.0	249.0	11.9
376903	OKPB01-156	06/20/2005	12:40	0.080	0.710	0.050	0.050	0.810	0.180	0.026	0.092	2.20	7.00		22.42	263.0	17.4	187.0	54.0

Sample ID	Station ID	Sample Date	Sample Time	NH_3 (mg/L)	TKN (mg/L)	NO_3 (mg/L)	NO2 (mg/L)	TN (mg/L)	AN (mg/L)	P-Ortho (mg/L)	P-Total (mg/L)	DO (mg/L)	pH (std units)	Turb. (NTU)	Water Temp. (^oC)	Cond. (us/cm)	Cl (mg/L)	TDS (mg/L)	Su (mg/L)
377426	OKPB01-170	06/29/2005	15:01	0.050	0.390	0.120	0.050	0.560	0.220	0.089	0.123	5.33	7.17	50.6	27.90	630.0	44.5	343.0	16.5
376982	OKPB01-196	06/21/2005	10:00	0.050	0.180	0.050	0.050	0.280	0.150	0.007	0.028	10.92	8.63	3.8	30.30	48.0	10.0	41.0	10.0
376905	OKPB01-210	06/20/2005	10:09	0.050	0.050	0.050	0.050	0.150	0.150	0.010	0.023	4.85	5.46	14.9	22.50	38.3	10.0	48.0	13.2
419686	OKPB01-212	06/12/2007	09:01	0.050	0.860	0.050	0.050	0.960	0.150	0.043	0.094	4.55	8.18	71.0	22.90	2411.0	61.2	1610.0	705.0
400229	OKPB01-213	06/28/2006	10:00	0.050	0.520	0.050	0.050	0.620	0.150	0.012	0.070	8.41	8.02	26.3	24.00	1222.0	181.0	728.0	156.0
378424	OKPB01-216	07/13/2005	15:16	0.210	1.300	0.700	0.380	2.380	1.290	0.042	0.134	7.59	7.58	54.7	28.80	482.0	70.1	291.0	45.2
400994	OKPB01-220	07/17/2006	13:00	0.050	0.610	0.050	0.050	0.710	0.150	0.022	0.078	6.40	7.61	27.5	30.80	300.9	12.5	171.0	13.9
400122	OKPB01-223	06/27/2006	10:00	0.220	0.790	0.050	0.050	0.890	0.320	0.013	0.075	4.43	7.14	18.6	23.60	324.3	12.4	232.0	65.9
378324	OKPB01-224	07/12/2005	14:30	0.050	0.270	0.080	0.050	0.400	0.180	0.005	0.012	8.60	8.14	1.3	27.90	109.8	10.0	62.0	10.0
419231	OKPB01-227	6/4/2007	0905	0.160	1.660	1.360	0.100	3.120	1.620	0.088	0.121	10.61	8.60	2.3	21.29	513.0	145.0	665.0	213.0
423520	OKPB01-229	08/14/2007	10:16	0.050	0.540	0.050	0.050	0.640	0.150	0.019	0.039	16.02	8.19	3.0	22.61	7138.0	1550.0	3970.0	608.0
419688	OKPB01-232	06/12/2007	16:00	0.050	0.270	0.050	0.050	0.370	0.150	0.010	0.022	6.75	7.82	4.9	23.29	1358.0	390.0	1030.0	42.3
423077	OKPB01-235	08/15/2007	15:15	0.050	0.390	0.050	0.050	0.490	0.150	0.035	0.045	8.31	7.59	2.5	30.20	732.0	24.4	428.0	46.9
423631	OKPB01-235	08/07/2007	15:00	0.050	0.330	0.050	0.050	0.430	0.150	0.026	0.046	7.32	7.80	3.4	31.70	742.0	29.4	439.0	54.0
399032	OKPB01-236	06/13/2006	15:31	0.050	0.540	0.050	0.050	0.640	0.150	0.009	0.038	9.31	7.92	6.1	28.10	418.4	41.1	240.0	18.8
419834	OKPB01-239	06/13/2007	10:00	0.050	0.330	0.100	0.050	0.480	0.200	0.036	0.058	7.53	7.94	1.5	23.60	4542.0	1270.0	2440.0	201.0
399029	OKPB01-247	06/13/2006	10:15	0.370	1.440	0.050	0.050	1.540	0.470	0.047	0.199	1.79	7.51	8.7	22.40	562.0	24.4	316.0	10.0
419497	OKPB01-251	08/08/2007	09:41	0.110	1.030	1.080	0.050	2.160	1.240	0.265	0.322	5.96	7.61	9.8	25.30	2484.0	262.0	1700.0	780.0
423146	OKPB01-251	08/15/2007	10:00	0.050	0.750	1.110	0.050	1.910	1.210	0.069	0.097	6.28	7.43	24.0	25.30	3028.0	326.0	2130.0	952.0
423630	OKPB01-251	06/06/2007	10:00	0.090	0.790	1.120	0.050	1.960	1.260	0.078	0.112	6.84	7.80	50.1	27.20	2928.0	385.0	2090.0	848.0
423148	OKPB01-255	08/08/2007	14:30	0.050	0.890	0.050	0.050	0.990	0.150	0.009	0.037	6.50	7.81	11.2	28.20	403.8	10.0	223.0	24.4

Sample ID	Station ID	Sample Date	Sample Time	NH_3 (mg/L)	TKN (mg/L)	NO_3 (mg/L)	NO2 (mg/L)	TN (mg/L)	AN (mg/L)	P-Ortho (mg/L)	P-Total (mg/L)	DO (mg/L)	pH (std units)	Turb. (NTU)	Water Temp. (^oC)	Cond. (us/cm)	Cl (mg/L)	TDS (mg/L)	Su (mg/L)
377224	OKPB01-256	06/27/2005	13:31	0.050	0.210	0.050	0.050	0.310	0.150	0.014	0.044	2.40	5.75	8.7	24.00	67.7	10.0	49.0	10.0
399143	OKPB01-260	06/14/2006	09:31	0.050	0.410	0.050	0.050	0.510	0.150	0.020	0.038	7.94	7.83	1.7	21.30	3939.0	10.0	4300.0	2390.0
378422	OKPB01-266	07/13/2005	10:31	0.050	0.450	0.050	0.050	0.550	0.150	0.005	0.030	3.65	7.40	3.4	28.20	410.0	10.0	200.0	16.2
428678	OKPB01-267	10/15/2007	17:00	0.050	0.320	0.230	0.050	0.600	0.330	0.075	0.082	10.65	8.31	3.5	18.94	766.0	113.0	398.0	56.7
419409	OKPB01-282	06/06/2007		0.050	0.360	0.740	0.050	1.150	0.840	0.059	0.073	10.52	7.96	9.0	20.60	597.0	18.3	409.0	31.2
423075	OKPB01-283	08/07/2007	10:00	0.050	1.190	3.380	0.090	4.660	3.520	0.401	0.487	6.62	7.77	19.7	26.10	1911.0	288.0	1150.0	258.0
398400	OKPB01-284	06/05/2006	12:30	0.690	2.710	0.190	0.230	3.130	1.110	0.033	0.250	5.15	7.37	77.8	24.40	398.9	14.7	242.0	74.0
399144	OKPB01-292	06/14/2006	12:31	0.870	3.710	0.070	0.190	3.970	1.130	0.040	0.236	1.92	6.85	93.3	30.10	314.8	142.0	489.0	87.9
423920	OKPB01-293	08/21/2007	11:15	0.050	1.360	0.500	0.050	1.910	0.600	0.058	0.191	4.74	7.92	70.1	26.00	1939.0	89.0	1470.0	822.0
378423	OKPB01-298	07/13/2005	12:01	2.640	4.380	0.130	0.130	4.640	2.900	0.235	0.344	2.42	7.25	10.8	25.90	401.0	19.4	245.0	29.6
423410	OKPB01-299	08/13/2007	11:30	0.050	0.480	0.050	0.050	0.580	0.150	0.012	0.037	3.94	7.21	8.3	27.00	539.0	15.1	304.0	21.4
378323	OKPB01-302	07/12/2005	10:31	0.050	0.350	0.050	0.050	0.450	0.150	0.005	0.043	4.34	6.34	5.4	26.50	41.2	10.0	34.0	10.0
400124	OKPB01-311	06/27/2006	13:45	0.320	0.880	0.050	0.050	0.980	0.420	0.016	0.088	9.36	8.16	23.1	24.50	347.7	10.0	207.0	47.8
398742	OKPB01-317	06/07/2006	10:46	0.050	0.330	0.110	0.050	0.490	0.210	0.016	0.024	6.79	7.71	4.2	22.40	1900.0	29.8	1620.0	225.0
427729	OKPB01-323	10/01/2007	14:30	0.050	2.140	1.170	0.050	3.360	1.270	0.289	0.555	14.90	8.72	17.0	23.23	173.0	271.0	1020.0	200.0
404083	OKPB01-327	08/29/2006	12:30	0.110	1.040	1.020	0.080	2.140	1.210	0.215	0.294	5.71	7.67	29.0	28.33	332.2	29.6	209.0	49.9
399113	OKPB01-328	06/14/2006	10:45	0.050	0.420	0.060	0.050	0.530	0.160	0.007	0.036	6.36	7.62	10.0	28.09	126.1	10.0	49.0	10.0
400115	OKPB01-330	06/27/2006	09:00	0.190	0.440	0.050	0.050	0.540	0.290	0.043	0.102	2.65	7.67	18.0	27.51	552.0	40.7	308.0	21.0
398405	OKPB01-335	06/05/2006	12:31	0.050	0.700	0.050	0.050	0.800	0.150	0.011	0.070	6.80	7.36	6.8	29.34	3303.0	815.0	1990.0	366.0
398989	OKPB01-336	06/13/2006	09:15	0.050	0.230	0.370	0.050	0.650	0.470	0.010	0.032	6.70	7.79	4.0	23.22	291.7	14.1	220.0	16.4
398987	OKPB01-342	06/12/2006	19:00	0.050	0.430	0.050	0.050	0.530	0.150	0.006	0.042	5.30	7.19	6.4	30.74	124.9	10.0	61.0	10.0

Sample ID	Station ID	Sample Date	Sample Time	NH_3 (mg/L)	TKN (mg/L)	NO_3 (mg/L)	NO2 (mg/L)	TN (mg/L)	AN (mg/L)	P-Ortho (mg/L)	P-Total (mg/L)	DO (mg/L)	pH (std units)	Turb. (NTU)	Water Temp. (^oC)	Cond. (us/cm)	Cl (mg/L)	TDS (mg/L)	Su (mg/L)
423489	OKPB01-343	08/14/2007	14:45	0.050	0.870	0.130	0.050	1.050	0.230	0.054	0.093	8.54	7.59	18.6	29.80	2884.0	992.0	2910.0	1020.0
426010	OKPB01-344	09/17/2007	14:30	0.050	0.790	0.160	0.050	1.000	0.260	0.038	0.087	6.63	7.88	69.0	31.60	201.0	12.5	170.0	40.8
423076	OKPB01-347	08/07/2007	12:50	0.050	0.550	0.050	0.050	0.650	0.150	0.035	0.097	11.55	8.03	2.8	32.00	3897.0	1190.0	2130.0	82.2
399031	OKPB01-348	06/13/2006	13:50	0.050	0.610	0.050	0.050	0.710	0.150	0.012	0.051	7.64	7.65	19.4	28.10	484.0	30.1	281.0	23.4
423147	OKPB01-355	08/08/2007	12:00	0.050	0.490	0.500	0.050	1.040	0.600	0.111	0.125	7.34	7.83	12.1	27.20	1096.0	61.7	776.0	273.0
423921	OKPB01-357	08/21/2007	13:30	0.050	0.700	0.050	0.050	0.800	0.150	0.006	0.047	7.70	7.77	42.6	26.60	3232.0	97.9	2950.0	845.0
426397	OKPB01-360	09/19/2007	16:00	0.050	0.780	0.070	0.050	0.900	0.170	0.042	0.096	7.40	8.10	72.3	25.18	362.0	22.4	234.0	13.8
423487	OKPB01-363	08/14/2007	10:00	0.070	1.480	0.200	0.060	1.740	0.330	0.160	0.279	6.35	7.88	104.0	29.30	553.0	88.3	308.0	35.2
401079	OKPB01-369	07/18/2006	11:00	0.050	2.580	4.280	0.340	7.200	4.670	0.677	0.950	10.38	9.18	16.0	36.73	719.4	71.0	443.0	91.4
402552	OKPB01-369	08/09/2006	13:30	0.050	3.330	3.560	0.920	7.810	4.530	1.070	1.260	9.97	9.21	14.0	27.41	578.9	86.3	543.0	130.0
401164	OKPB01-372	07/18/2006	15:00	0.050	0.130	1.240	0.050	1.420	1.340	0.038	0.048	8.81	7.19	0.9	23.90	302.8	10.0	171.0	10.0
401901	OKPB01-372	08/01/2006	14:00	0.050	0.130	0.930	0.050	1.110	1.030	0.033	0.048	4.30	7.45	1.9	24.30	319.1	10.0	169.0	10.0
419233	OKPB01-376	06/04/2007		0.080	0.980	0.170	0.050	1.200	0.300	0.061	0.104	5.46	7.17	33.3	25.50	1475.0	10.0	344.0	51.3
423769	OKPB01-389	08/20/2007	14:00	0.050	0.290	0.050	0.050	0.390	0.150	0.005	0.016	7.29	7.64	3.7	35.40	2615.0	486.0	2200.0	1180.0
404084	OKPB01-391	08/29/2006	14:40	0.220	0.910	0.510	0.070	1.490	0.800	0.111	0.167	5.45	7.73	15.0	29.86	349.6	23.9	219.0	55.7
422987	OKPB01-395	08/06/2007	14:30	0.050	0.720	0.050	0.050	0.820	0.150	0.007	0.040	8.63	7.71	18.2	35.80	245.4	10.0	167.0	15.7
399981	OKPB01-399	06/26/2006	10:00	0.210	0.990	0.050	0.050	1.090	0.310	0.017	0.096	6.12	7.40	9.7	23.40	1017.0	212.0	556.0	37.9
398399	OKPB01-404	06/05/2006	10:00	0.150	1.920	0.050	0.050	2.020	0.250	0.016	0.173	2.38	6.70	1.9	23.20	0.2	10.0	168.0	30.5
423488	OKPB01-405	08/14/2007	13:00	0.070	0.750	0.430	0.050	1.230	0.550	0.044	0.073	6.70	7.36	76.0	26.30	3707.0	656.0	2620.0	1130.0
419234	OKPB01-424	6/4/2007		0.050	0.460	0.050	0.050	0.560	0.150	0.010	0.018	6.50	7.12	16.6	27.10	133.8	10.0	89.0	21.4
398514	OKPB01-429	06/06/2006	10:41	0.110	0.700	0.090	0.050	0.840	0.250	0.259	0.316	7.03	7.63	7.6	23.90	692.0	13.9	386.0	13.5

Sample ID	Station ID	Sample Date	Sample Time	NH_3 (mg/L)	TKN (mg/L)	NO_3 (mg/L)	NO2 (mg/L)	TN (mg/L)	AN (mg/L)	P-Ortho (mg/L)	P-Total (mg/L)	DO (mg/L)	pH (std units)	Turb. (NTU)	Water Temp. (^oC)	Cond. (us/cm)	Cl (mg/L)	TDS (mg/L)	Su (mg/L)
399982	OKPB01-431	06/26/2006	13:15	0.210	1.160	0.050	0.050	1.260	0.310	0.000	0.093	4.64	8.10	7.5	25.50	408.9	14.6	239.0	23.7
398743	OKPB01-453	06/07/2006	13:46	0.050	0.390	0.050	0.050	0.490	0.150	0.007	0.015	7.46	8.17	1.6	33.20	2686.0	640.0	1660.0	188.0
400230	OKPB01-469	06/28/2006	12:15	0.050	0.480	0.050	0.050	0.580	0.150	0.006	0.022	9.06	8.17	2.6	28.60	1861.0	268.0	1200.0	405.0
398740	OKPB01-495	06/07/2006	09:01	0.050	2.810	0.050	0.050	2.910	0.150	0.012	0.206	1.25	7.53	18.0	23.53	10310.0	2590.0	6270.0	240.0
422417	OKPB01-504	07/30/2007	11:45	0.050	0.590	0.110	0.100	0.800	0.260	0.005	0.035	5.28	7.32	7.5	28.13	266.0	15.1	151.0	31.4
400993	OKPB01-519	07/17/2006	10:15	0.050	1.080	1.730	0.050	2.860	1.830	0.353	0.446	5.77	7.44	47.3	31.50	374.4	34.8	203.0	31.6
398406	OKPB01-527	06/05/2006	14:01	0.050	0.990	0.050	0.050	1.090	0.150	0.009	0.110	3.83	7.36	9.5	29.07	1776.0	309.0	1060.0	195.0
399145	OKPB01-548	06/14/2006	15:01	0.050	1.600	0.050	0.050	1.700	0.150	0.020	0.138	10.00	6.60	26.5	32.00	291.3	10.0	175.0	29.3
422668	OKPB01-552	08/01/2007	11:20	0.050	0.720	0.060	0.050	0.830	0.160	0.010	0.065	2.69	7.23	20.0	25.98	276.0	11.0	175.0	20.4
398771	OKPB01-567	06/07/2006	14:31	0.050	0.720	0.050	0.050	0.820	0.150	0.005	0.030	7.13	6.96	5.0	29.50	226.1	18.4	131.0	18.7
398515	OKPB01-581	06/06/2006	13:51	0.050	0.630	0.050	0.050	0.730	0.150	0.005	0.024	6.28	8.29	3.5	34.10	2785.0	565.0	1790.0	265.0
398401	OKPB01-583	06/05/2006	14:55	0.050	0.340	0.080	0.050	0.470	0.180	0.009	0.030	7.14	7.60	7.3	25.20	1161.0	39.1	819.0	413.0
400123	OKPB01-583	06/27/2006	11:30	0.050	0.260	0.050	0.050	0.360	0.150	0.018	0.036	5.70	7.52	10.2	22.50	1344.0	30.9	1040.0	545.0
426396	OKPB01-616	09/18/2007	19:00	0.050	1.030	0.050	0.050	1.130	0.150	0.048	0.173	9.71	8.22	67.4	26.18	721.0	66.7	470.0	145.0
398770	OKPB01-619	06/07/2006	10:45	0.050	0.430	0.050	0.050	0.530	0.150	0.005	0.025	10.76	8.30	2.7	27.50	309.6	10.0	185.0	15.8

Table 17. Appendix C—Habitat Data for All Sites.

SITE ID	Final Habitat Score	% Loose Bed Material	% Embeddedness	% Deep Pools	% Point Bars	Sed USAP- 1 Parameter	Sed USAP- 2 Parameter
OKPB01-003	78.5	99%	NC	0%	91%	impaired	Unimpaired
OKPB01-005	96.5	10%	5%	40%	61%	impaired	Unimpaired
OKPB01-008	90.2	36%	1%	16%	87%	impaired	Impaired
OKPB01-009	53.2	85%	NC	28%	87%	impaired	impaired
OKPB01-010	86.6	100%	100%	16%	87%	impaired	impaired
OKPB01-011	85.1	61%	20%	8%	70%	impaired	impaired
OKPB01-013	64.2	98%	NC	0%	87%	impaired	impaired
OKPB01-013	65.7	97%	NC	8%	87%	impaired	impaired
OKPB01-015	44.5	100%	NC	0%	87%	impaired	impaired
OKPB01-019	88.7	16%	9%	28%	87%	impaired	impaired
OKPB01-021	78.2	100%	NC	4%	87%	impaired	impaired
OKPB01-022	74.2	99%	NC	48%	87%	impaired	impaired
OKPB01-024	90.0	29%	10%	28%	48%	impaired	unimpaired
OKPB01-027	48.3	85%	89%	0%	87%	impaired	impaired
OKPB01-027	85.1	100%	100%	0%	0%	impaired	impaired
OKPB01-028	104.2	88%	96%	36%	0%	impaired	impaired
OKPB01-029	88.7	16%	NC	28%	87%	impaired	unimpaired
OKPB01-031	63.7	86%	NC	12%	87%	impaired	impaired
OKPB01-032	67.3	54%	100%	0%	87%	impaired	impaired

SITE ID	Final Habitat Score	% Loose Bed Material	% Embeddedness	% Deep Pools	% Point Bars	Sed USAP- 1 Parameter	Sed USAP- 2 Parameter
OKPB01-033	77.4	97%	88%	12%	87%	impaired	impaired
OKPB01-034	100.2	6%	3%	16%	26%	impaired	impaired
OKPB01-034	92.2	6%	NC	12%	26%	impaired	impaired
OKPB01-035	45.9	65%	NC	0%	87%	impaired	impaired
OKPB01-036	80.9	26%	8%	20%	65%	impaired	impaired
OKPB01-038	83.5	3%	5%	44%	57%	impaired	impaired
OKPB01-043	83.5	41%	97%	40%	87%	impaired	impaired
OKPB01-044	81.9	27%	5%	32%	48%	impaired	impaired
OKPB01-046	97.8	2%	9%	0%	0%	impaired	impaired
OKPB01-050	73.3	33%	NC	80%		impaired	unimpaired
OKPB01-051	57.9	62%	25%	0%	87%	impaired	impaired
OKPB01-052	77.6	26%	10%	28%	87%	impaired	impaired
OKPB01-054	86.2	52%	NC	64%	87%	impaired	impaired
OKPB01-056	67.0	62%	0%	4%	13%	impaired	impaired
OKPB01-059	75.2	90%	NC	0%	48%	impaired	impaired
OKPB01-060	61.7	96%	62%	4%	87%	impaired	impaired
OKPB01-064	77.7	97%	100%	8%	4%	impaired	impaired
OKPB01-072	95.3	22%	40%	60%	26%	impaired	unimpaired
OKPB01-073	84.7	87%	100%	4%	87%	impaired	impaired
OKPB01-076	99.1	77%	50%	68%	61%	impaired	impaired
OKPB01-078	83.6	5%	0%	32%	65%	impaired	impaired
OKPB01-081	53.3	83%	61%	0%	87%	impaired	impaired
OKPB01-081	60.5	60%	93%	0%	48%	impaired	impaired
OKPB01-	87.9	95%	NC	20%	48%	impaired	impaired

SITE_ID	Final Habitat Score	% Loose Bed Material	% Embeddedness	% Deep Pools	% Point Bars	Sed USAP- 1 Parameter	Sed USAP- 2 Parameter
085							
OKPB01-092	99.8	10%	5%	12%	87%	impaired	impaired
OKPB01-098	100.6	68%	NC	72%	0%	impaired	unimpaired
OKPB01-099	82.9	83%	100%	0%	87%	impaired	impaired
OKPB01-118	86.3	82%	NC	12%	48%	impaired	impaired
OKPB01-118	90.2	81%	NC	20%	48%	impaired	impaired
OKPB01-130	95.7	82%	100%	64%	87%	impaired	impaired
OKPB01-134	92.9	13%	9%	32%	87%	impaired	impaired
OKPB01-136	108.3	93%	0%	52%	0%	impaired	unimpaired
OKPB01-138	87.4	10%	0%	0%	13%	impaired	unimpaired
OKPB01-144	79.0	0%	NC	8%	0%	unimpaired	unimpaired
OKPB01-148	114.1	13%	5%	60%	22%	impaired	impaired
OKPB01-154	92.9	94%	17%	80%	0%	impaired	impaired
OKPB01-156	84.1	34%	0%	48%	87%	impaired	impaired
OKPB01-170	109.0	70%	NC	76%	0%	impaired	unimpaired
OKPB01-196	101.7	3%	5%	32%	0%	impaired	unimpaired
OKPB01-210	108.2	2%	5%	12%	0%	impaired	impaired
OKPB01-212	69.1	100%	NC	80%	0%	impaired	unimpaired
OKPB01-213	79.9	93%	NC	0%	87%	impaired	unimpaired
OKPB01-216	97.0	50%	23%	60%	0%	impaired	impaired
OKPB01-220	99.6	26%	NC	40%	9%	unimpaired	unimpaired
OKPB01-223	100.4	67%	NC	56%	4%	impaired	unimpaired
OKPB01-224	88.0	0%	NC	0%	0%	impaired	unimpaired
OKPB01-227	66.1	0%	0%	0%	9%	impaired	unimpaired

SITE ID	Final Habitat Score	% Loose Bed Material	% Embeddedness	% Deep Pools	% Point Bars	Sed USAP- 1 Parameter	Sed USAP- 2 Parameter
OKPB01-229	71.2	98%	NC	0%	87%	impaired	unimpaired
OKPB01-232	84.3	99%	NC	48%	57%	impaired	impaired
OKPB01-235	69.8	73%	NC	12%	39%	impaired	impaired
OKPB01-235	85.5	73%	NC	20%	43%	impaired	impaired
OKPB01-236	89.3	24%	0%	36%	57%	impaired	impaired
OKPB01-239	95.4	100%	NC	0%	0%	impaired	impaired
OKPB01-247	75.0	80%	NC	64%	22%	impaired	unimpaired
OKPB01-251	96.6	84%	NC	20%	35%	impaired	impaired
OKPB01-251	94.8	84%	NC	16%	22%	impaired	unimpaired
OKPB01-256	99.9	7%	10%	24%	0%	impaired	impaired
OKPB01-260	96.2	94%	NC	28%	0%	impaired	unimpaired
OKPB01-266	81.8	48%	0%	28%	87%	impaired	impaired
OKPB01-267	75.5	88%	NC	0%	87%	impaired	impaired
OKPB01-282	91.4	98%	NC	32%	61%	impaired	impaired
OKPB01-283	90.7	85%	NC	16%	35%	impaired	unimpaired
OKPB01-284	69.3	77%	NC	0%	35%	impaired	impaired
OKPB01-292	64.5	74%	NC	24%	22%	impaired	unimpaired
OKPB01-293	114.4	72%	NC	56%	17%	unimpaired	unimpaired
OKPB01-298	86.2	46%	43%	36%	74%	impaired	impaired
OKPB01-299	95.4	41%	NC	80%	0%	impaired	unimpaired
OKPB01-302	93.7	6%	0%	0%	0%	impaired	unimpaired
OKPB01-311	83.4	34%	NC	4%	22%	impaired	unimpaired
OKPB01-317	86.6	84%	NC	8%	13%	impaired	unimpaired
OKPB01-	69.7	91%	70%	36%	87%	impaired	impaired

SITE_ID	Final Habitat Score	% Loose Bed Material	% Embeddedness	% Deep Pools	% Point Bars	Sed USAP- 1 Parameter	Sed USAP- 2 Parameter
323							
OKPB01-327	56.3	100%	NC	80%	87%	impaired	impaired
OKPB01-328	77.5	1%	7%	64%	87%	impaired	unimpaired
OKPB01-330	74.0	90%	NC	80%	87%	impaired	impaired
OKPB01-335	63.0	72%	NC	0%	87%	impaired	impaired
OKPB01-336	80.8	90%	100%	4%	87%	impaired	impaired
OKPB01-342	97.0	25%	15%	64%	87%	impaired	unimpaired
OKPB01-343	111.2	88%	NC	64%	39%	impaired	unimpaired
OKPB01-344	88.7	66%	20%	76%	61%	impaired	impaired
OKPB01-347	90.3	54%	NC	0%	70%	impaired	impaired
OKPB01-348	63.0	31%	0%	12%	39%	impaired	impaired
OKPB01-355	96.7	99%	NC	0%	22%	impaired	impaired
OKPB01-357	94.2	89%	NC	48%	26%	impaired	unimpaired
OKPB01-360	90.6	100%	NC	0%	17%	impaired	impaired
OKPB01-363	89.9	78%	NC	32%	74%	impaired	impaired
OKPB01-369	70.7	75%	NC	0%	87%	impaired	impaired
OKPB01-369	68.9	98%	NC	0%	87%	impaired	impaired
OKPB01-372	92.4	3%	13%	32%	61%	unimpaired	unimpaired
OKPB01-372	98.0	4%	13%	40%	61%	unimpaired	unimpaired
OKPB01-376	97.7	48%	15%	60%	57%	impaired	impaired
OKPB01-389	72.4	98%	NC	0%	87%	impaired	impaired
OKPB01-391	73.0	100%	NC	80%	87%	impaired	impaired
OKPB01-395	51.9	0%	NC	0%	0%	impaired	unimpaired
OKPB01-399	88.0	98%	NC	20%	0%	impaired	unimpaired

SITE_ID	Final Habitat Score	% Loose Bed Material	% Embeddedness	% Deep Pools	% Point Bars	Sed USAP- 1 Parameter	Sed USAP- 2 Parameter
OKPB01-404	74.2	53%	NC	20%	39%	impaired	impaired
OKPB01-405	100.7	82%	NC	40%	30%	impaired	unimpaired
OKPB01-429	58.5	100%	NC	0%	78%	impaired	impaired
OKPB01-429	67.0	99%	NC	4%	43%	impaired	impaired
OKPB01-431	80.9	100%	NC	8%	9%	impaired	impaired
OKPB01-453	68.8	96%	NC	12%	87%	impaired	impaired
OKPB01-469	70.1	93%	NC	0%	87%	impaired	unimpaired
OKPB01-495	53.5	74%	NC	0%	87%	impaired	impaired
OKPB01-504	87.9	63%	100%	44%	87%	impaired	impaired
OKPB01-519	97.3	25%	0%	76%	4%	unimpaired	unimpaired
OKPB01-527	73.4	63%	NC	16%	87%	impaired	impaired
OKPB01-548	64.7	83%	NC	16%	4%	impaired	unimpaired
OKPB01-552	98.3	98%	NC	40%	87%	impaired	impaired
OKPB01-567	93.1	11%	0%	40%	0%	unimpaired	unimpaired
OKPB01-581	59.2	95%	0%	4%	87%	impaired	impaired
OKPB01-583	90.8	25%	25%	44%	52%	impaired	impaired
OKPB01-616	63.9	100%	NC	0%	87%	impaired	impaired
OKPB01-619	71.5	27%	NC	16%	0%	impaired	impaired

Table 18. Appendix C—Fish and Macroinvertebrate Scores and Classifications for All Sites.

Station ID	OKFIBI Score	OKFIBI Support Stat.	OCCIBI % of Ref.	OCCIBI Integ. Class.	FIBI Binomial	BIBI_._of_Reference	BIBI Binomial	BIBI Binomial
OKPB01-003	18	Undetermined	84	Good	Good	112	Non-impaired	Good
OKPB01-005	33	No Biocriteria	85	Good	Good	113	Non-impaired	Good
OKPB01-008	35	Supporting	92	Excellent	Good	92	Non-impaired	Good
OKPB01-009	26	Supporting	92	Excellent	Good	81	Non-impaired	Good
OKPB01-010	25	Undetermined	No ref	No Reference	Good	88	Non-impaired	Good
OKPB01-011	27	Supporting	92	Excellent	Good	113	Non-impaired	Good
OKPB01-013	23	Supporting	100	Excellent	Good	106	Non-impaired	Good
OKPB01-015	23	Supporting	74	Fair	Good	58	Slightly Impaired	Poor
OKPB01-017	20	Undetermined	92	Excellent	Good	124	Non-impaired	Good
OKPB01-019	31	Supporting	78	Good	Good	74	Slightly Impaired	Poor
OKPB01-021	20	Undetermined	63	Fair	Poor	92	Non-impaired	Good
OKPB01-022	20	Undetermined	57	Poor	Poor	140	Non-impaired	Good
OKPB01-024	39	Supporting	100	Excellent	Good	118	Non-impaired	Good
OKPB01-026	No Collection	No Score	No Collection	No Score	No Score	108	Non-impaired	Good
OKPB01-027	21	Undetermined	61	Poor	Poor	75	Slightly Impaired	Poor
OKPB01-028	33	No Biocriteria	92	Excellent	Good	112	Non-impaired	Good
OKPB01-029	23	Supporting	91	Excellent	Good	69	Slightly Impaired	Poor
OKPB01-031	26	Supporting	70	Fair	Good	73	Slightly Impaired	Poor
OKPB01-	24	Undetermined	52	Poor	Poor	42	Moderately Impaired	Poor

Station ID	OKFIBI Score	OKFIBI Support Stat.	OCCIBI % of Ref.	OCCIBI Integ. Class.	FIBI Binomial	BIBI_._of_Reference	BIBI Binomial	BIBI Binomial
032								
OKPB01-033	26	Supporting	70	Fair	Good	88	Non-impaired	Good
OKPB01-034	45	Supporting	126	Excellent	Good	123	Non-impaired	Good
OKPB01-035	12	Not Supporting	26	Very Poor	Poor	25	Moderately Impaired	Poor
OKPB01-036	37	Supporting	78	Good	Good	100	Non-impaired	Good
OKPB01-038	35	Supporting	85	Good	Good	84	Non-impaired	Good
OKPB01-043	27	Supporting	100	Excellent	Good	112	Non-impaired	Good
OKPB01-044	41	Supporting	100	Excellent	Good	103	Non-impaired	Good
OKPB01-046	25	Undetermined	63	Fair	Poor	85	Non-impaired	Good
OKPB01-050	33	No Biocriteria	85	Good	Good	63	Slightly Impaired	Poor
OKPB01-051	25	Supporting	91	Excellent	Good	124	Non-impaired	Good
OKPB01-052	39	Supporting	79	Good	Good	108	Non-impaired	Good
OKPB01-054	27	Undetermined	74	Fair	Good	77	Slightly Impaired	Good
OKPB01-056	27	Supporting	60	Poor	Poor	54	Slightly Impaired	Poor
OKPB01-059	24	Undetermined	65	Fair	Poor	No Collection	No Score	No Score
OKPB01-060	24	Undetermined	76	Fair	Good	93	Non-impaired	Good
OKPB01-064	27	Supporting	74	Fair	Good	No Collection	No Score	No Score
OKPB01-072	33	Supporting	76	Fair	Good	100	Non-impaired	Good
OKPB01-073	29	No Biocriteria	92	Excellent	Good	108	Non-impaired	Good
OKPB01-076	31	Supporting	68	Fair	Good	55	Slightly Impaired	Poor

Station ID	OKFIBI Score	OKFIBI Support Stat.	OCCIBI % of Ref.	OCCIBI Integ. Class.	FIBI Binomial	BIBI_._of_Reference	BIBI Binomial	BIBI Binomial
OKPB01-078	37	Supporting	100	Excellent	Good	118	Non-impaired	Good
OKPB01-081	25	Undetermined	68	Fair	Poor	87	Non-impaired	Good
OKPB01-084	No Collection	No Score	No Collection	No Score	No Score	No Collection	No Score	No Score
OKPB01-085	26	Supporting	74	Fair	Good	62	Slightly Impaired	Poor
OKPB01-092	33	Undetermined	100	Excellent	Good	100	Non-impaired	Good
OKPB01-098	27	No Biocriteria	60	Poor	Poor	50	Moderately Impaired	Poor
OKPB01-099	21	Undetermined	78	Good	Good	58	Slightly Impaired	Poor
OKPB01-118	35	No Biocriteria	92	Excellent	Good	69	Slightly Impaired	Poor
OKPB01-130	31	No Biocriteria	84	Good	Good	112	Non-impaired	Good
OKPB01-134	27	Undetermined	78	Good	Good	117	Non-impaired	Good
OKPB01-136	27	No Biocriteria	74	Fair	Good	85	Non-impaired	Good
OKPB01-138	33	Undetermined	93	Excellent	Good	96	Non-impaired	Good
OKPB01-144	33	Undetermined	115	Excellent	Good	112	Non-impaired	Good
OKPB01-148	29	Undetermined	78	Good	Good	122	Non-impaired	Good
OKPB01-154	31	Supporting	109	Excellent	Good	115	Non-impaired	Good
OKPB01-156	35	Supporting	78	Good	Good	54	Slightly Impaired	Poor
OKPB01-170	29	Supporting	91	Excellent	Good	85	Non-impaired	Good
OKPB01-196	39	Supporting	100	Excellent	Good	123	Non-impaired	Good
OKPB01-210	37	Supporting	107	Excellent	Good	85	Non-impaired	Good
OKPB01-	18	No Biocriteria	57	Poor	Poor	62	Slightly Impaired	Poor

Station ID	OKFIBI Score	OKFIBI Support Stat.	OCCIBI % of Ref.	OCCIBI Integ. Class.	FIBI Binomial	BIBI_._of_Reference	BIBI Binomial	BIBI Binomial
212								
OKPB01-213	24	No Biocriteria	76	Fair	Good	123	Non-impaired	Good
OKPB01-216	39	Supporting	79	Good	Good	100	Non-impaired	Good
OKPB01-220	32	Supporting	70	Fair	Good	85	Non-impaired	Good
OKPB01-223	35	Supporting	83	Good	Good	54	Slightly Impaired	Poor
OKPB01-224	33	Undetermined	85	Good	Good	100	Non-impaired	Good
OKPB01-227	No Fish Obs	Not Supporting	0	Very Poor	Poor	33	Moderately Impaired	Poor
OKPB01-229	19	Undetermined	56	Poor	Poor	50	Moderately Impaired	Poor
OKPB01-232	24	Undetermined	60	Poor	Poor	82	Non-impaired	Good
OKPB01-235	22	Supporting	70	Fair	Good	108	Non-impaired	Good
OKPB01-236	33	Supporting	70	Fair	Good	92	Non-impaired	Good
OKPB01-239	22	No Biocriteria	76	Fair	Good	108	Non-impaired	Good
OKPB01-247	25	Undetermined	70	Fair	Good	67	Slightly Impaired	Poor
OKPB01-251	26	Supporting	100	Excellent	Good	68	Slightly Impaired	Poor
OKPB01-255	20	Undetermined	48	Poor	Poor	100	Non-impaired	Good
OKPB01-256	37	Supporting	93	Excellent	Good	54	Slightly Impaired	Poor
OKPB01-260	21	Not Supporting	63	Fair	Poor	92	Non-impaired	Good
OKPB01-266	27	No Biocriteria	76	Fair	Good	50	Moderately Impaired	Poor
OKPB01-267	31	Supporting	92	Excellent	Good	No Collection	No Score	No Score
OKPB01-282	26	Supporting	65	Fair	Good	62	Slightly Impaired	Poor

Station ID	OKFIBI Score	OKFIBI Support Stat.	OCCIBI % of Ref.	OCCIBI Integ. Class.	FIBI Binomial	BIBI_._of_Reference	BIBI Binomial	BIBI Binomial
OKPB01-283	24	Supporting	92	Excellent	Good	97	Non-impaired	Good
OKPB01-284	16	Not Supporting	33	Very Poor	Poor	46	Moderately Impaired	Poor
OKPB01-292	35	Supporting	78	Good	Good	54	Slightly Impaired	Poor
OKPB01-293	20	Undetermined	92	Excellent	Good	60	Slightly Impaired	Poor
OKPB01-298	33	Supporting	100	Excellent	Good	69	Slightly Impaired	Poor
OKPB01-299	29	Supporting	100	Excellent	Good	92	Non-impaired	Good
OKPB01-302	35	Supporting	92	Excellent	Good	123	Non-impaired	Good
OKPB01-311	20	Not Supporting	63	Fair	Poor	46	Moderately Impaired	Poor
OKPB01-317	14	Not Supporting	41	Very Poor	Poor	75	Slightly Impaired	Poor
OKPB01-323	24	Supporting	100	Excellent	Good	No Collection	No Score	No Score
OKPB01-327	28	Undetermined	76	Fair	Good	60	Slightly Impaired	Poor
OKPB01-328	33	Undetermined	85	Good	Good	108	Non-impaired	Good
OKPB01-330	22	No Biocriteria	44	Poor	Poor	54	Slightly Impaired	Poor
OKPB01-335	14	No Biocriteria	28	Very Poor	Poor	83	Non-impaired	Good
OKPB01-336	33	No Biocriteria	84	Good	Good	77	Slightly Impaired	Good
OKPB01-342	31	Undetermined	70	Fair	Good	104	Non-impaired	Good
OKPB01-343	26	Supporting	91	Excellent	Good	62	Slightly Impaired	Poor
OKPB01-344	35	Supporting	79		Good	No Collection	No Score	No Score
OKPB01-347	25	Supporting	84	Good	Good	108	Non-impaired	Good
OKPB01-	37	Supporting	85	Good	Good	23	Moderately Impaired	Poor

Station ID	OKFIBI Score	OKFIBI Support Stat.	OCCIBI % of Ref.	OCCIBI Integ. Class.	FIBI Binomial	BIBI_._of_Reference	BIBI Binomial	BIBI Binomial
348								
OKPB01-355	26	Supporting	100	Excellent	Good	123	Non-impaired	Good
OKPB01-357	18	Undetermined	48	Poor	Poor	100	Non-impaired	Good
OKPB01-360	24	Undetermined	91	Excellent	Good	No Collection	No Score	No Score
OKPB01-363	29	Supporting	91	Excellent	Good	123	Non-impaired	Good
OKPB01-369	21	Undetermined	82	Good	Good	48	Moderately Impaired	Poor
OKPB01-372	42	Supporting	94	Excellent	Good	115	Non-impaired	Good
OKPB01-376	33	Undetermined	66	Fair	Poor	123	Non-impaired	Good
OKPB01-389	16	Not Supporting	84	Good	Good	92	Non-impaired	Good
OKPB01-391	24	Undetermined	76	Fair	Good	56	Slightly Impaired	Poor
OKPB01-395	No Fish Obs	Not Supporting	0	Very Poor	Poor	77	Slightly Impaired	Good
OKPB01-399	22	No Biocriteria	60	Poor	Poor	77	Slightly Impaired	Good
OKPB01-404	30	Supporting	70	Fair	Good	46	Moderately Impaired	Poor
OKPB01-405	26	Supporting	91	Excellent	Good	92	Non-impaired	Good
OKPB01-424	No Collection	No Score	No Collection	No Score	No Score	46	Moderately Impaired	Poor
OKPB01-429	23	Supporting	74	Fair	Good	92	Non-impaired	Good
OKPB01-431	20	No Biocriteria	52	Poor	Poor	46	Moderately Impaired	Poor
OKPB01-453	27	Supporting	85	Good	Good	77	Slightly Impaired	Good
OKPB01-469	18	Undetermined	84	Good	Good	108	Non-impaired	Good
OKPB01-495	18	No Biocriteria	65	Fair	Poor	46	Moderately Impaired	Poor

Station ID	OKFIBI Score	OKFIBI Support Stat.	OCCIBI % of Ref.	OCCIBI Integ. Class.	FIBI Binomial	BIBI_._of_Reference	BIBI Binomial	BIBI Binomial
OKPB01-504	35	Supporting	86	Good	Good	82	Non-impaired	Good
OKPB01-519	35	Supporting	76	Fair	Good	62	Slightly Impaired	Poor
OKPB01-527	16	No Biocriteria	68	Fair	Poor	46	Moderately Impaired	Poor
OKPB01-548	24	Undetermined	63	Fair	Poor	54	Slightly Impaired	Poor
OKPB01-552	29	Undetermined	78	Good	Good	69	Slightly Impaired	Poor
OKPB01-567	29	Supporting	56	Poor	Poor	23	Moderately Impaired	Poor
OKPB01-581	29	Supporting	85	Good	Good	69	Slightly Impaired	Poor
OKPB01-583	35	Supporting	85	Good	Good	77	Slightly Impaired	Good
OKPB01-616	20	Not Supporting	83	Good	Poor	No Collection	No Score	No Score
OKPB01-619	35	No Biocriteria	85	Good	Good	117	Non-impaired	Good

Table 19. Appendix C—Benthic and Sestonic Algal Data for All Sites.

Sample ID	Station ID	Sample Date	Benthic Chlorophyll-a (mg/m2)		Sample ID	Station ID	Sample Date	Sestonic Chlorophyl A (mg/m3)
378143	OKPB01-003	07/05/2005	31.81		380465	OKPB01-003	07/05/2005	24.200
378977	OKPB01-005	07/11/2005	38.04		380467	OKPB01-005	07/11/2005	7.500
377813	OKPB01-008	06/20/2005	3.66		378335	OKPB01-008	06/20/2005	0.840
379183	OKPB01-009	07/19/2005	4.93		380478	OKPB01-009	07/19/2005	2.820
378985	OKPB01-010	07/12/2005	3.24		380470	OKPB01-010	07/12/2005	45.900
378979	OKPB01-011	07/18/2005	25.36		380484	OKPB01-011	07/18/2005	7.140
379185	OKPB01-013	07/26/2005	9.70		380464	OKPB01-013	07/20/2005	7.400
379184	OKPB01-015	07/25/2005	9.08		380480	OKPB01-015	07/25/2005	33.800
378980	OKPB01-017	07/18/2005	10.12		380483	OKPB01-017	07/18/2005	9.250
378978	OKPB01-019	07/11/2005	3.58		380463	OKPB01-019	06/28/2005	4.170
379182	OKPB01-021	07/20/2005	7.21		380482	OKPB01-021	07/20/2005	47.600
378986	OKPB01-022	07/12/2005	2.20		380471	OKPB01-022	07/12/2005	18.700
377814	OKPB01-024	06/28/2005	8.07		378351	OKPB01-024	06/28/2005	1.070
377815	OKPB01-026	06/22/2005	9.02		378349	OKPB01-026	06/27/2005	0.600
408579	OKPB01-027	09/20/2006	126.28		408575	OKPB01-027	09/20/2006	55.800

Sample ID	Station ID	Sample Date	Benthic Chlorophyll-a (mg/m2)		Sample ID	Station ID	Sample Date	Sestonic Chlorophyl A (mg/m3)
402791	OKPB01-029	07/10/2006	123.48		402816	OKPB01-029	07/10/2006	3.250
408577	OKPB01-031	08/02/2006	96.66		408574	OKPB01-031	08/02/2006	61.400
402800	OKPB01-032	07/25/2006	84.61		402828	OKPB01-032	07/25/2006	10.300
402798	OKPB01-033	07/19/2006	40.12		402825	OKPB01-033	07/19/2006	6.720
	OKPB01-034	06/21/2005	NS		378332	OKPB01-034	06/21/2005	525.000
402803	OKPB01-035	8/1/2006	98.12		407538	OKPB01-035	8/1/2006	69.900
402794	OKPB01-036	07/17/2006	64.86		402824	OKPB01-036	07/17/2006	1.370
378330	OKPB01-038	7/21/2005	54.67		378343	OKPB01-038	06/21/2005	2.140
402790	OKPB01-043	07/10/2006	104.77		402815	OKPB01-043	07/10/2006	16.000
384855	OKPB01-044	10/18/2005	2.91		384857	OKPB01-044	8/23/2005	0.900
377817	OKPB01-046	06/20/2005	7.05		378329	OKPB01-046	06/20/2005	0.100
402826	OKPB01-050	07/26/2006	31.60		402826	OKPB01-050	07/26/2006	8.740
402789	OKPB01-051	07/11/2006	41.58		402814	OKPB01-051	07/11/2006	2.910
402796	OKPB01-052	07/17/2006	59.24		408576	OKPB01-052	07/17/2006	5.140
408578	OKPB01-054	09/06/2006	74.42		408573	OKPB01-054	09/06/2006	16.800
377818	OKPB01-056	06/28/2005	39.23		378346	OKPB01-056	06/28/2005	12.800

Sample ID	Station ID	Sample Date	Benthic Chlorophyll-a (mg/m2)		Sample ID	Station ID	Sample Date	Sestonic Chlorophyl A (mg/m3)
433235	OKPB01-059	10/03/2007	3.99		431563	OKPB01-059	10/03/2007	5.680
425929	OKPB01-060	06/13/2007	13.55		425273	OKPB01-060	06/12/2007	4.700
433233	OKPB01-064	10/16/2007	4.97		431557	OKPB01-064	10/16/2007	16.900
425956	OKPB01-072	8/6/2007	6.26		425294	OKPB01-072	08/14/2007	4.260
425940	OKPB01-073	08/14/2007	66.10		425279	OKPB01-073	06/12/2007	38.790
425936	OKPB01-076	08/06/2007	16.01		429262	OKPB01-076	08/06/2007	4.000
377820	OKPB01-078	06/21/2005	10.21		378339	OKPB01-078	06/21/2005	1.840
425928	OKPB01-081	06/13/2007	14.58		425274	OKPB01-081	06/12/2007	1.550
377821	OKPB01-084	06/21/2005	5.16		378328	OKPB01-084	06/20/2005	1.990
425930	OKPB01-085	09/05/2007	13.05		429261	OKPB01-085	09/05/2007	11.800
425932	OKPB01-092	07/25/2007	12.62		425277	OKPB01-092	06/12/2007	0.360
377822	OKPB01-098	06/22/2005	3.70		380459	OKPB01-098	06/22/2005	8.500
425938	OKPB01-099	08/14/2007	17.90		425281	OKPB01-099	08/14/2007	5.300
377823	OKPB01-118	06/28/2005	12.56		378347	OKPB01-118	06/28/2005	2.620
384859	OKPB01-130	8/24/2005	60.70		384860	OKPB01-130	8/24/2005	15.300
377824	OKPB01-134	06/22/2005	17.34		380460	OKPB01-134	06/22/2005	0.800

Sample ID	Station ID	Sample Date	Benthic Chlorophyll-a (mg/m2)		Sample ID	Station ID	Sample Date	Sestonic Chlorophyl A (mg/m3)
377826	OKPB01-136	06/22/2005	1.48		380458	OKPB01-136	06/22/2005	0.360
377827	OKPB01-138	06/21/2005	6.34		380456	OKPB01-138	06/21/2005	0.750
377828	OKPB01-144	06/21/2005	28.06		380461	OKPB01-144	06/27/2005	0.520
378334	OKPB01-148	06/21/2005	92.71		378341	OKPB01-148	06/21/2005	5.050
	OKPB01-154		NS		378344	OKPB01-154	06/28/2005	4.700
377830	OKPB01-156	06/20/2005	22.03		378337	OKPB01-156	06/20/2005	12.300
377831	OKPB01-170	06/29/2005	33.26		378345	OKPB01-170	06/29/2005	7.070
377832	OKPB01-196	06/21/2005	12.74		378340	OKPB01-196	06/21/2005	0.910
377833	OKPB01-210	06/20/2005	3.95		378336	OKPB01-210	06/20/2005	1.010
425958	OKPB01-212	08/14/2007	4.68		425291	OKPB01-212	08/14/2007	9.790
402781	OKPB01-213	6/28/2006	205.17		402812	OKPB01-213	6/28/2006	7.610
378984	OKPB01-216	07/13/2005	16.78		380479	OKPB01-216	07/13/2005	2.300
402793	OKPB01-220	07/17/2006	37.83		402819	OKPB01-220	07/17/2006	24.200
402787	OKPB01-223	06/27/2006	28.27		402808	OKPB01-223	06/27/2006	10.500
378989	OKPB01-224	07/12/2005	4.99		380473	OKPB01-224	07/12/2005	0.980
425925	OKPB01-227	06/04/2007	NS		425272	OKPB01-227	06/04/2007	10.180

Sample ID	Station ID	Sample Date	Benthic Chlorophyll-a (mg/m2)		Sample ID	Station ID	Sample Date	Sestonic Chlorophyl A (mg/m3)
425935	OKPB01-229	08/14/2007	9.89		425283	OKPB01-229	08/14/2007	9.320
425927	OKPB01-232	06/12/2007	10.17		425275	OKPB01-232	06/12/2007	2.770
425955	OKPB01-235	08/07/2007	10.52		425284	OKPB01-235	08/14/2007	3.760
399748	OKPB01-236	06/13/2006	58.00		399730	OKPB01-236	06/13/2006	12.000
425957	OKPB01-239	06/04/2007	22.45		425301	OKPB01-239	06/04/2007	2.000
399749	OKPB01-247	06/13/2006	11.14		399724	OKPB01-247	06/13/2006	20.410
425945	OKPB01-251	08/15/2007	59.45		425285	OKPB01-251	08/15/2007	4.900
425950	OKPB01-255	08/08/2007	NS		425304	OKPB01-255	08/08/2007	12.250
377834	OKPB01-256	06/27/2005	3.24		378348	OKPB01-256	06/27/2005	0.210
399755	OKPB01-260	06/14/2006	107.89		399723	OKPB01-260	06/14/2006	2.240
378982	OKPB01-266	07/13/2005	3.70		380475	OKPB01-266	07/13/2005	5.000
433236	OKPB01-267	10/15/2007	40.12		431558	OKPB01-267	10/15/2007	4.480
425959	OKPB01-282	08/08/2007	1.03		425298	OKPB01-282	08/08/2007	2.670
425953	OKPB01-283	08/07/2007	83.15		425297	OKPB01-283	08/08/2007	20.390
399738	OKPB01-284	06/05/2006	8.61		399717	OKPB01-284	06/05/2006	81.300
399754	OKPB01-292	06/14/2006	32.22		399733	OKPB01-292	06/14/2006	48.440

Sample ID	Station ID	Sample Date	Benthic Chlorophyll-a (mg/m2)		Sample ID	Station ID	Sample Date	Sestonic Chlorophyl A (mg/m3)
425941	OKPB01-293	08/21/2007	13.16		425288	OKPB01-293	08/21/2007	57.300
378981	OKPB01-298	07/13/2005	19.23		380476	OKPB01-298	07/13/2005	2.110
425949	OKPB01-299	08/13/2007	8.48		425292	OKPB01-299	08/14/2007	7.940
378988	OKPB01-302	07/12/2005	6.88		380472	OKPB01-302	07/12/2005	4.220
402785	OKPB01-311	06/27/2006	17.00		402806	OKPB01-311	06/27/2006	15.500
399740	OKPB01-317	06/07/2006	65.27		399714	OKPB01-317	06/07/2006	0.480
433234	OKPB01-323	10/01/2007	161.73		431559	OKPB01-323	10/01/2007	195.000
407533	OKPB01-327	08/29/2006	NS		407534	OKPB01-327	08/29/2006	14.700
399758	OKPB01-328	06/14/2006	70.78		399727	OKPB01-328	06/14/2006	1.910
402782	OKPB01-330	06/27/2006	17.05		402811	OKPB01-330	06/27/2006	6.650
399745	OKPB01-335	06/05/2006	1153.71		399719	OKPB01-335	06/05/2006	3.330
399751	OKPB01-336	06/13/2006	35.55		399732	OKPB01-336	06/13/2006	0.290
399753	OKPB01-342	06/12/2006	30.97		399734	OKPB01-342	06/12/2006	9.040
425947	OKPB01-343	08/14/2007	37.83		425293	OKPB01-343	08/14/2007	11.720
425926	OKPB01-344	08/20/2007	6.53		431560	OKPB01-344	09/17/2007	12.500
425954	OKPB01-347	08/07/2007	16.26		425295	OKPB01-347	08/14/2007	2.590

Sample ID	Station ID	Sample Date	Benthic Chlorophyll-a (mg/m2)		Sample ID	Station ID	Sample Date	Sestonic Chlorophyl A (mg/m3)
399747	OKPB01-348	06/13/2006	33.68		399729	OKPB01-348	06/13/2006	7.690
425952	OKPB01-355	08/08/2007	63.61		425303	OKPB01-355	06/04/2007	1.580
425942	OKPB01-357	08/21/2007	6.19		425287	OKPB01-357	08/21/2007	5.040
433237	OKPB01-360	09/19/2007	5.76		431561	OKPB01-360	09/19/2007	25.000
425946	OKPB01-363	08/14/2007	7.32		425290	OKPB01-363	08/14/2007	43.230
402799	OKPB01-369	07/18/2006	161.31		407536	OKPB01-369	08/09/2006	33.700
402804	OKPB01-372	08/01/2006	122.54		402821	OKPB01-372	07/18/2006	0.470
425960	OKPB01-376	06/04/2007	0.02		425300	OKPB01-376	06/04/2007	1.410
425943	OKPB01-389	08/20/2007	33.88		425286	OKPB01-389	08/20/2007	2.730
No Sample	OKPB01-391	08/29/2007	0.00		407535	OKPB01-391	08/29/2007	14.100
425924	OKPB01-395	08/06/2007	16.90		429285	OKPB01-395	08/06/2007	1.340
402783	OKPB01-399	06/26/2006	47.60		402810	OKPB01-399	06/26/2006	36.700
399737	OKPB01-404	06/05/2006	18.65		399716	OKPB01-404	06/05/2006	104.360
425948	OKPB01-405	08/14/2007	117.87		425289	OKPB01-405	08/14/2007	7.870
425961	OKPB01-424	6/4/2007	1.69		425299	OKPB01-424	06/04/2007	2.590
399743	OKPB01-429	06/06/2006	91.67		399715	OKPB01-429	06/06/2006	4.400

Sample ID	Station ID	Sample Date	Benthic Chlorophyll-a (mg/m2)		Sample ID	Station ID	Sample Date	Sestonic Chlorophyl A (mg/m3)
402784	OKPB01-431	06/26/2006	111.42		402809	OKPB01-431	06/26/2006	16.500
399741	OKPB01-453	06/07/2006	70.89		399721	OKPB01-453	06/07/2006	3.270
402780	OKPB01-469	06/28/2006	153.41		402813	OKPB01-469	06/28/2006	1.440
399746	OKPB01-495	06/07/2006	118.70		399720	OKPB01-495	06/07/2006	38.190
425933	OKPB01-504	07/30/2007	NS		425276	OKPB01-504	06/12/2007	0.820
402732	OKPB01-519	7/17/2006	135.54		402818	OKPB01-519	7/17/2006	12.700
399744	OKPB01-527	06/05/2006	131.79		399722	OKPB01-527	06/05/2006	5.210
399756	OKPB01-548	06/14/2006	120.36		399725	OKPB01-548	06/14/2006	41.010
425934	OKPB01-552	08/01/2007	16.71		425278	OKPB01-552	06/12/2007	4.520
399757	OKPB01-567	06/07/2006	135.33		399736	OKPB01-567	06/07/2006	4.700
399742	OKPB01-581	06/06/2006	30.97		399713	OKPB01-581	06/06/2006	9.240
399739	OKPB01-583	06/05/2006	17.69		399718	OKPB01-583	06/05/2006	5.620
433238	OKPB01-616	09/18/2007	52.38		431562	OKPB01-616	09/18/2007	40.300
399760	OKPB01-619	06/07/2006	41.99		399735	OKPB01-619	06/07/2006	1.370

Table 20. Appendix C—Microbiological Data for All Sites.

Sample ID	Station ID	Sample Date	Eschericia Coli (cfu/mL)	Fecal Coliform (cfu/mL)	Enterococci (cfu/mL)
377939	OKPB01-003	07/05/2005	118.0	430.0	108.0
378141	OKPB01-005	07/11/2005	74.0	60.0	10.0
376904	OKPB01-008	06/20/2005	63.0	110.0	108.0
378659	OKPB01-009	07/19/2005	98.0	640.0	10.0
378306	OKPB01-010	07/12/2005	10.0	50.0	31.0
378535	OKPB01-011	07/18/2005	63.0	240.0	288.0
377938	OKPB01-013	07/05/2005	382.0	1800.0	313.0
ND	OKPB01-015		ND	ND	ND
378536	OKPB01-017	07/18/2005	9.0	100.0	41.0
377407	OKPB01-019	06/28/2005	20.0	10.0	20.0
378757	OKPB01-021	07/20/2005	74.0	730.0	41.0
378305	OKPB01-022	07/12/2005	359.0	2770.0	309.0
377406	OKPB01-024	06/28/2005	9.0	10.0	9.0
377046	OKPB01-026	06/22/2005	63.0	20.0	31.0
693272	OKPB01-027	7/5/2006	314.0	12400.0	496.0

Sample ID	Station ID	Sample Date	Eschericia Coli (cfu/mL)	Fecal Coliform (cfu/mL)	Enterococci (cfu/mL)
377425	OKPB01-028	06/29/2005	20.0	140.0	41.0
400627	OKPB01-029	07/10/2006	20.0	270.0	203.0
401943	OKPB01-031	08/02/2006	20.0	90.0	31.0
A01397	OKPB01-032	07/25/2006	10.0	10.0	10.0
401194	OKPB01-033	07/19/2000	74.0	60.0	63.0
376983	OKPB01-034	06/21/2005	9.0	9.0	9.0
A01237	OKPB01-035	08/01/2006	298.0	10.0	63.0
400990	OKPB01-036	07/17/2006	9.0	9.0	9.0
376980	OKPB01-038	06/21/2005	10.0	60.0	10.0
693704	OKPB01-043	7/10/2006	10.0	50.0	41.0
381694	OKPB01-044	08/23/2005	9.0	70.0	9.0
376906	OKPB01-046	06/20/2005	9.0	10.0	209.0
A01404	OKPB01-050	07/26/2006	20.0	50.0	41.0
400718	OKPB01-051	07/11/2006	145.0	290.0	246.0
400989	OKPB01-052	07/17/2006	63.0	140.0	
A01685	OKPB01-054	09/06/2006	20.0	180.0	97.0

Sample ID	Station ID	Sample Date	Eschericia Coli (cfu/mL)	Fecal Coliform (cfu/mL)	Enterococci (cfu/mL)
377370	OKPB01-056	06/28/2005	10.0	10.0	9.0
723809	OKPB01-059	10/3/2007	24192.0	8664.0	10462.0
419687	OKPB01-060	06/12/2007	355.0	500.0	52.0
724691	OKPB01-064	10/15/2007	201.0	170.0	62.0
422988	OKPB01-072	08/06/2007	31.0	50.0	108.0
719810	OKPB01-073	8/14/2007	10.0	160.0	20.0
423008	OKPB01-076	08/06/2007	10.0	150.0	10.0
376977	OKPB01-078	06/21/2005	10.0	20.0	9.0
419805	OKPB01-081	06/13/2007	10	810.0	324.0
376907	OKPB01-084	06/20/2005	10.0	9.0	31.0
721298	OKPB01-085	9/5/2007	30.0	90.0	10.0
422061	OKPB01-092	07/25/2007	9.0	9.0	9.0
377044	OKPB01-098	06/22/2005	10.0	20.0	10.0
719811	OKPB01-099	8/14/2007	86.0	10.0	20.0
377368	OKPB01-118	06/28/2005	74.0	70.0	74.0
381841	OKPB01-130	08/24/2005	9.0	500.0	9.0

Sample ID	Station ID	Sample Date	Eschericia Coli (cfu/mL)	Fecal Coliform (cfu/mL)	Enterococci (cfu/mL)
377047	OKPB01-134	06/22/2005	10.0	9.0	20.0
377045	OKPB01-136	06/22/2005	135.0	70.0	121.0
376984	OKPB01-138	06/21/2005	20.0	30.0	9.0
376981	OKPB01-144	06/21/2005	410.0	30.0	62.0
376978	OKPB01-148	06/21/2005	9.0	9.0	9.0
377369	OKPB01-154	06/28/2005	85.0	160.0	31.0
376903	OKPB01-156	06/20/2005	97.0	260.0	41.0
377426	OKPB01-170	06/29/2005	107.0	70.0	20.0
376982	OKPB01-196	06/21/2005	63.0	40.0	30.0
376905	OKPB01-210	06/20/2005	20.0	30.0	10.0
419686	OKPB01-212	06/12/2007	9.0	10.0	20.0
400229	OKPB01-213	06/28/2006	278.0	720.0	31.0
378424	OKPB01-216	07/13/2005	9.0	110.0	10.0
400994	OKPB01-220	07/17/2006	20.0	50.0	98.0
692851	OKPB01-223	6/27/2006	109.0	100.0	74.0
378324	OKPB01-224	07/12/2005	247.0	240.0	275.0

Sample ID	Station ID	Sample Date	Eschericia Coli (cfu/mL)	Fecal Coliform (cfu/mL)	Enterococci (cfu/mL)
714265	OKPB01-227	6/4/2007	441.0	770.0	62.0
719808	OKPB01-229	8/14/2007	84.0	100.0	41.0
419688	OKPB01-232	06/12/2007	31.0	20.0	10.0
423077	OKPB01-235	08/07/2007	31.0	10.0	10.0
399032	OKPB01-236	06/13/2006	20.0	40.0	10.0
419834	OKPB01-239	06/13/2007	9.0	20.0	31.0
399029	OKPB01-247	06/13/2006	9.0	9.0	10.0
419497	OKPB01-251	06/06/2007	354.0	520.0	143.0
423148	OKPB01-255	08/08/2007	41.0	9.0	9.0
377224	OKPB01-256	06/27/2005	31.0	20.0	135.0
691990	OKPB01-260	6/14/06	63.0	110.0	275.0
378422	OKPB01-266	07/13/2005	262.0	390.0	41.0
720228	OKPB01-267	8/21/2007	717.0	1020.0	703.0
714562	OKPB01-282	6/5/2007	645.0	580.0	471.0
423075	OKPB01-283	08/07/2007	160.0	310.0	41.0
398400	OKPB01-284	06/05/2006	31.0	50.0	98.0

Sample ID	Station ID	Sample Date	Eschericia Coli (cfu/mL)	Fecal Coliform (cfu/mL)	Enterococci (cfu/mL)
691991	OKPB01-292	6/14/2006	86.0	260.0	52.0
720228	OKPB01-293	8/21/2007	717.0	1020.0	703.0
378423	OKPB01-298	07/13/2005	2143.0	5400.0	278.0
423410	OKPB01-299	08/13/2007	408.0	470.0	10.0
378323	OKPB01-302	07/12/2005	10.0	20.0	9.0
692853	OKPB01-311	6/27/2006	20.0	40.0	63.0
398742	OKPB01-317	06/07/2006	789.0	420.0	1067.0
ND	OKPB01-323		ND	ND	ND
404083	OKPB01-327	08/29/2006	74.0	150.0	41.0
399113	OKPB01-328	06/14/2006	20.0	9.0	9.0
692840	OKPB01-330	6/27/2006	52.0	90.0	31.0
398405	OKPB01-335	06/05/2006	364.0	310.0	1178.0
398989	OKPB01-336	06/13/2006	265.0	230.0	135.0
398987	OKPB01-342	06/12/2006	9.0	20.0	84.0
ND	OKPB01-343		ND	ND	ND
722392	OKPB01-344	9/18/2007	74.0	60.0	20.0

Sample ID	Station ID	Sample Date	Eschericia Coli (cfu/mL)	Fecal Coliform (cfu/mL)	Enterococci (cfu/mL)
423076	OKPB01-347	08/07/2007	9.0	50.0	9.0
399031	OKPB01-348	06/13/2006	9.0	9.0	9.0
423147	OKPB01-355	08/08/2007	41.0	130.0	86.0
720229	OKPB01-357	8/21/2007	86.0	190.0	51.0
722611	OKPB01-360	9/19/2007	62.0	70.0	31.0
719805	OKPB01-363	8/14/2007	96.0	370.0	171.0
402552	OKPB01-369	08/09/2006	175.0	1300.0	122.0
401901	OKPB01-372	08/01/2006	10.0	10.0	40.0
714417	OKPB01-376	6/4/2007	98.0	220.0	20.0
720191	OKPB01-389	8/20/2007	52.0	80.0	10.0
404084	OKPB01-391	08/29/2006	233.0	470.0	52.0
422987	OKPB01-395	08/06/2007	20.0	100.0	9.0
692718	OKPB01-399	6/26/2006	10.0	240.0	228.0
398399	OKPB01-404	06/05/2006	309.0	280.0	122.0
719806	OKPB01-405	8/14/2007	52.0	130.0	52.0
714418	OKPB01-424	6/4/2007	187.0	240.0	10.0

Sample ID	Station ID	Sample Date	Eschericia Coli (cfu/mL)	Fecal Coliform (cfu/mL)	Enterococci (cfu/mL)
398514	OKPB01-429	06/06/2006	706.0	2300.0	121.0
692719	OKPB01-431	6/26/2006	84.0	70.0	97.0
398743	OKPB01-453	06/07/2006	591.0	380.0	1153.0
692972	OKPB01-469	6/28/06	10.0	60.0	10.0
398740	OKPB01-495	06/07/2006	31.0	90.0	134.0
422417	OKPB01-504	07/30/2007	10.0	30.0	9.0
400993	OKPB01-519	07/17/2006	9.0	180.0	51.0
398406	OKPB01-527	06/05/2006	74.0	240.0	52.0
691992	OKPB01-548	6/14/2006	20.0	10.0	10.0
422668	OKPB01-552	08/01/2007	262.0	220.0	74.0
398771	OKPB01-567	06/07/2006	9.0	10.0	86.0
398515	OKPB01-581	06/06/2006	41.0	80.0	63.0
398401	OKPB01-583	06/05/2006	318.0	340.0	20.0
ND	OKPB01-616		ND	ND	ND
398770	OKPB01-619	06/07/2006	9.0	9.0	9.0