In cooperation with the Houston-Galveston Area Council

Comparison of Dissolved Oxygen and Aquatic Biota Between a State 303(d)-Listed Stream Segment and USGS Biological Reference Sites in the San Jacinto River Basin, Texas, 2000

About 30 percent of the 238 water bodies on the 2000 State of Texas 303(d) list of impaired or threatened waters are included for not meeting optimum conditions for aquatic life (Texas Natural Resource Conservation Commission, 2000). Most of the water bodies on the list were assessed using water-column measures such as concentrations of dissolved oxygen (DO) and total metals as surrogates for aquatic biological data. Many water bodies were listed because of low concentrations of DO or potentially toxic dissolved metals such as lead; ambient toxicity to nonresident (laboratory) aquatic organisms also could have been a reason for listing. The Texas Natural Resource Conservation Commission (TNRCC) has emphasized the use of aquatic biological data to determine if a water body should be included or removed from the 303(d) list.

The standards used to determine whether a water body should be on the State 303(d) list generally are statewide standards that have not been adjusted for regional or watershed-scale differences that reflect variability across Texas. Such is the case for DO, which is one of the more common surrogate measures used in the listing of stream segments that do not meet optimum conditions for aquatic life. The statewide minimum concentration of DO to

The State 303(d) List comprises surface-water bodies in Texas identified by the TNRCC as impaired (do not meet applicable water-quality standards) or threatened (are not expected to meet applicable standards in the near future). The name comes from Section 303(d) of the Federal Clean Water Act. Section 303(d) (and related regulations) require each State to assess the quality of its surface waters and to develop water-quality improvement strategies for impaired and threatened waters. The TNRCC submits its list of impaired and threatened stream segments, lakes, and estuaries to the U.S. Environmental Protection Agency for review in April each year.

This Fact Sheet summarizes the results of a study by the USGS, in cooperation with the Houston-Galveston Area Council (H–GAC), to compare dissolved oxygen concentrations between a site on a State 303(d)-listed stream segment and a USGS biological reference site and to compare selected aquatic-life measures for the 303(d) site with those for seven USGS biological reference sites. All sites are in the San Jacinto River Basin. Comparison graphics show dissolved oxygen concentrations at the 303(d) site and the reference site during mid-May through mid-July and also show biological integrity scores, number of fish species, and aquatic-habitat characteristics at the 303(d) site and the seven reference sites.

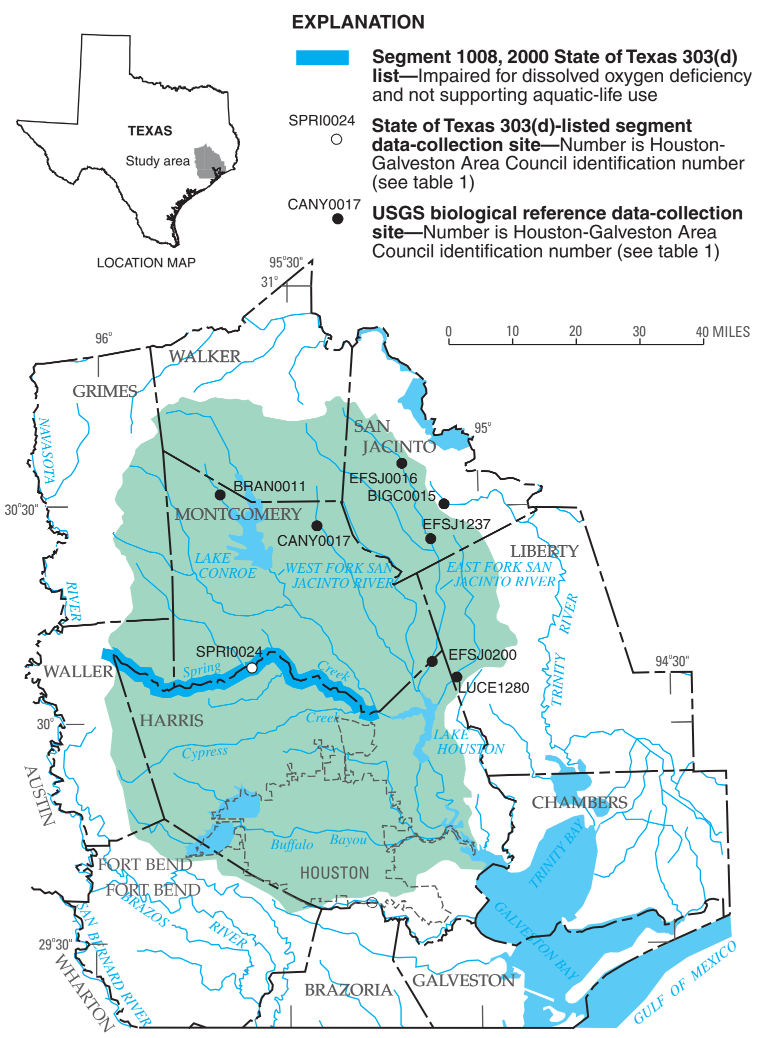

Figure 1. San Jacinto River Basin and data-collection sites.

meet optimal conditions for aquatic life is 5.0 milligrams per liter. Many water bodies in Texas with few, if any, anthropogenic influences might have DO concentrations below 5.0 milligrams per liter, especially in the late summer when water temperatures peak and streamflows are at minimums for the year.

A Previous Study Laid the Foundation for This Study

The U.S. Geological Survey (USGS) and the Houston-Galveston Area Council (H–GAC) recognized a lack of data and information on aquatic biota in the 303(d)-listed above-tidal streams in the H–GAC service area. Primarily in response to this data gap, the USGS, in cooperation with the H–GAC, did a study during 1997–98 to assess the status of aquatic biota in above-tidal streams of the San Jacinto River Basin (Moring, 2001). The first objective of the 1997–98 study was to assess the status of instream biological resources (fish and benthic macroinvertebrates) for sites with variable channel conditions and variable land uses in the watershed upstream of each site. To determine the status of aquatic life at these sites in a meaningful way, a set of reference sites that represent optimal or least-affected locations across a range of channel conditions and land uses had to be selected. Seven reference sites were selected by screening for sites with higher scores for an index of biological integrity, with higher scores for measures of channel structure and complexity, and with a higher percentage of the watershed as forested rather than urbanized land use. With information on the status of aquatic life at 32 sites in the San Jacinto River Basin and with seven sites selected as reference sites, the USGS and the H–GAC had the baseline data and information to pursue several lines of inquiry.

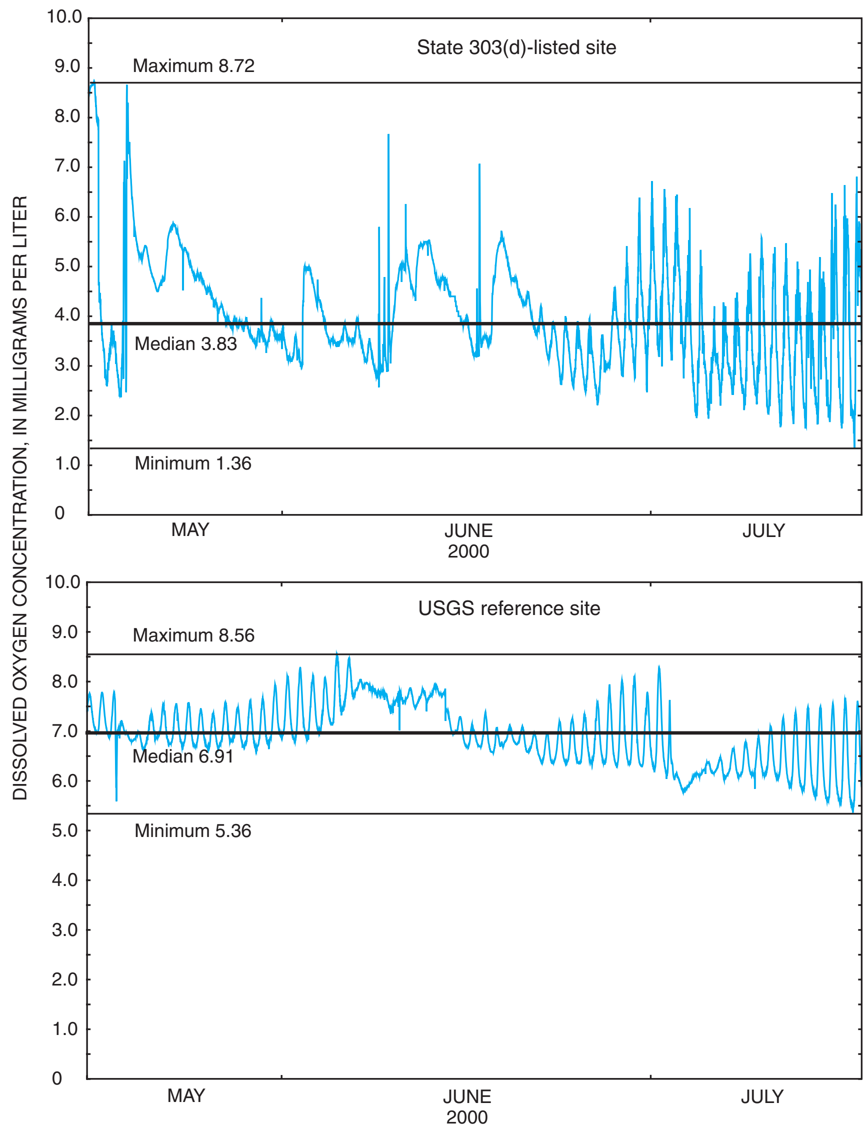

Figure 2. Dissolved oxygen concentrations at State 303(d)-listed site Spring Creek near Tomball and at USGS biological reference site East Fork San Jacinto River near New Caney, May 17–July 18, 2000.

What This Study Involved

In fall 2000, the USGS, in cooperation with the H–GAC, proposed to compare DO concentrations between a site (Spring Creek near Tomball [SPRI0024]) on a 303(d)-listed segment of Spring Creek (State segment 1008) and one of seven USGS biological reference sites (East Fork San Jacinto River near New Caney [EFSJ0020]) (fig. 1, table 1). The Spring Creek segment was on the 2000 list in part because "…DO concentrations are sometimes lower than the criterion established to assure optimum conditions for aquatic life." The TNRCC gave this segment a "medium" ranking in overall priority for the development of a total maximum daily load (TMDL) for the segment. Prioritizing impaired or threatened water bodies for development of a TMDL is a requirement of Section 303(d).

Multiparameter meters were deployed on the downstream side of the bridge at each site. DO concentration was recorded at 1-hour intervals and water temperature at 15-minute intervals during May 17–July 18, 2000. The installation and maintenance of these meters followed established USGS methods (U.S. Geological Survey, 1997–present), and the meters were serviced every 2 weeks or more frequently as needed over the period of deployment.

The TNRCC also indicated in the 303(d) list that the Spring Creek segment was "not supporting" (NS) its designated use as defined in the Texas Surface Water Quality Standards. The standards define aquatic-life use as "high" for Spring Creek segment 1008 (Texas Natural Resource Conservation Commission, 2002). Accordingly, the USGS and the H–GAC also proposed to compare selected aquatic-life measures for the Spring Creek near Tomball site with the same measures for seven USGS biological reference sites.

Benthic macroinvertebrates and fish were collected at the Spring Creek near Tomball site and the seven USGS biological reference sites. At each site, a sampling reach was selected that included one full stream-channel meander that was at least

20 times the wetted channel width (Cuffney and others, 1993; Moring, 2001). In each sampling reach, benthic macroinvertebrates were collected from five woody snag habitats using a modified Surber sampler with a 425-micron mesh. The five samples from each reach were composited, and the sample was submitted to a contract laboratory for identification and enumeration of the benthic macroinvertebrate taxa contained in the sample. The laboratory identified a minimum of 500 organisms per sample, or all of the organisms, if the sample contained fewer than 500 organisms.

Fish were collected in each reach using a barge electrofishing unit and a 7.6 by 1.8 meter, 0.006-meter-mesh bag seine. The entire reach was electrofished, and three to five seine hauls were made per reach depending on accessibility. Debris in the channel and depths greater than 2 meters often prevented optimum seining.

How Does Dissolved Oxygen Compare?

DO concentrations were lower at the 303(d) site Spring Creek near Tomball than at the reference site East Fork San Jacinto River near New Caney (fig. 2). The median DO concentration during the May–July period was 3.83 milligrams per liter for the 303(d) site and 6.91 milligrams per liter for the reference site. In addition to lower DO concentrations, diurnal fluctuations in concentration were greater at the 303(d) site than at the reference site. DO fluctuates diurnally primarily because of aquatic-plant photosynthesis, respiration, and decomposition. Photosynthesis (oxygen production) requires light and thus occurs only during daylight hours; respiration and decomposition (oxygen consumption) occur 24 hours a day. The diurnal fluctuations thus result from differences in the daily balance between rates of oxygen production and consumption. Investigation of the causes of lower DO concentrations and greater diurnal fluctuations at the 303(d) site were beyond the scope of this study.

Daily minimum DO concentrations at both sites generally decreased beginning in early July; and the lowest minimum daily concentrations at both sites occurred in mid-July, probably as a result of increasing water temperatures. Warmer water cannot retain as much DO as cooler water, hence oxygen solubility decreases as water temperature increases.

Water temperatures were similar from mid-May through mid-July for the 303(d) site and the reference site (fig. 3). Minimum temperatures of 21.4 degrees Celsius at the Spring Creek 303(d) site and 23.0 degrees Celsius at the East Fork near New Caney reference site were recorded in mid-May. With the exception of a brief period in early July, maximum and

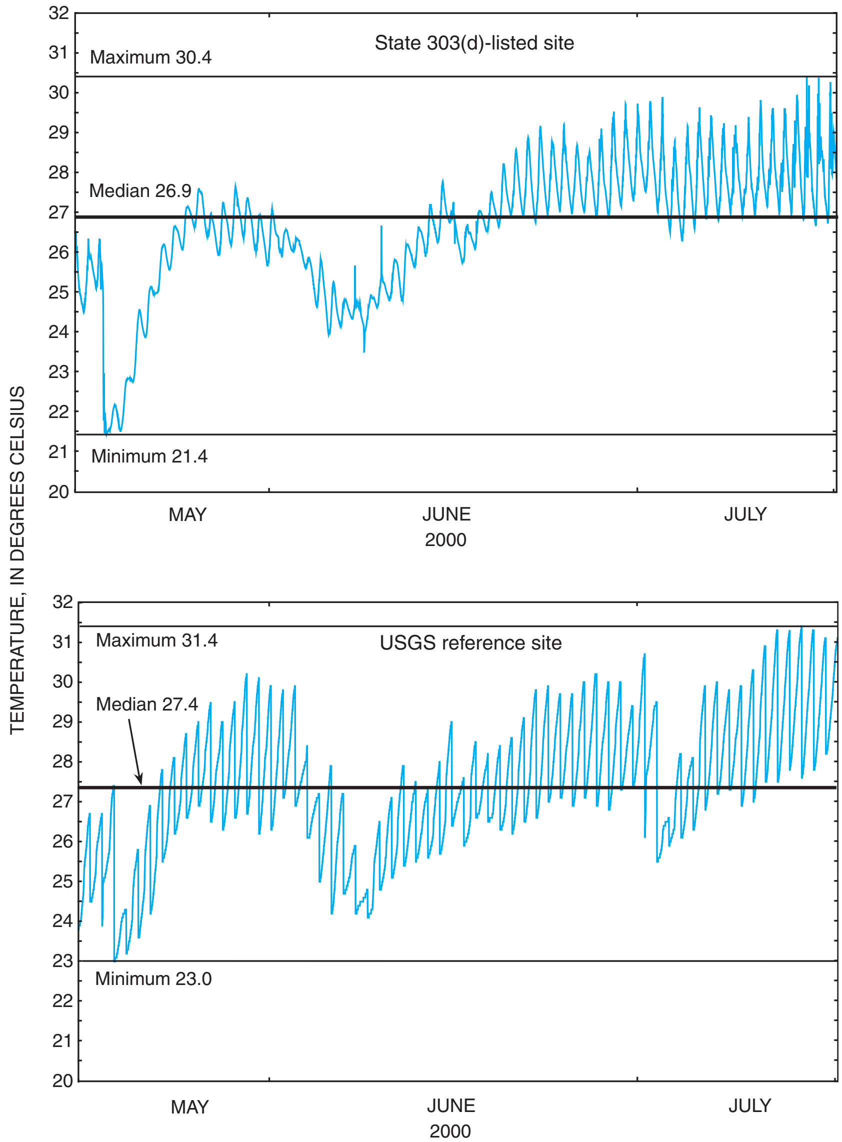

Figure 3. Water temperature at State 303(d)-listed site Spring Creek near Tomball and at USGS biological reference site East Fork San Jacinto River near New Caney, May 17–July 18, 2000.

Table 1. Benthic macroinvertebrate, fish, and habitat data-collection sites in the Houston-Galveston Area Council service area

[H–GAC ID, Houston-Galveston Area Council identification number; FM, farm road]

Site name	H–GAC ID	Downstream reach boundary coordinates	
		Latitude	Longitude
Big Creek in Big Creek Scenic Area/Sam Houston National Forest	BIGC0015	30°30'13"	95°05'21"
Branch Creek at FM 1375 bridge	BRAN0011	30°31'38"	95°40'45"
Caney Creek near Willis	CANY0017	30°27'21"	95°25'28"
East Fork San Jacinto River at FM 945	EFSJ0016	30°35'48"	95°11'58"
East Fork San Jacinto River near New Caney	EFSJ0200	30°08'43"	95°07'27"
East Fork San Jacinto River on FM 2025	EFSJ1237	30°25'29"	95°07'30"
Luce Bayou above Lake Houston near Huffman	LUCE1280	30°06'34"	95°03'35"
Spring Creek near Tomball	SPRI0024	30°08'00"	95°35'50"

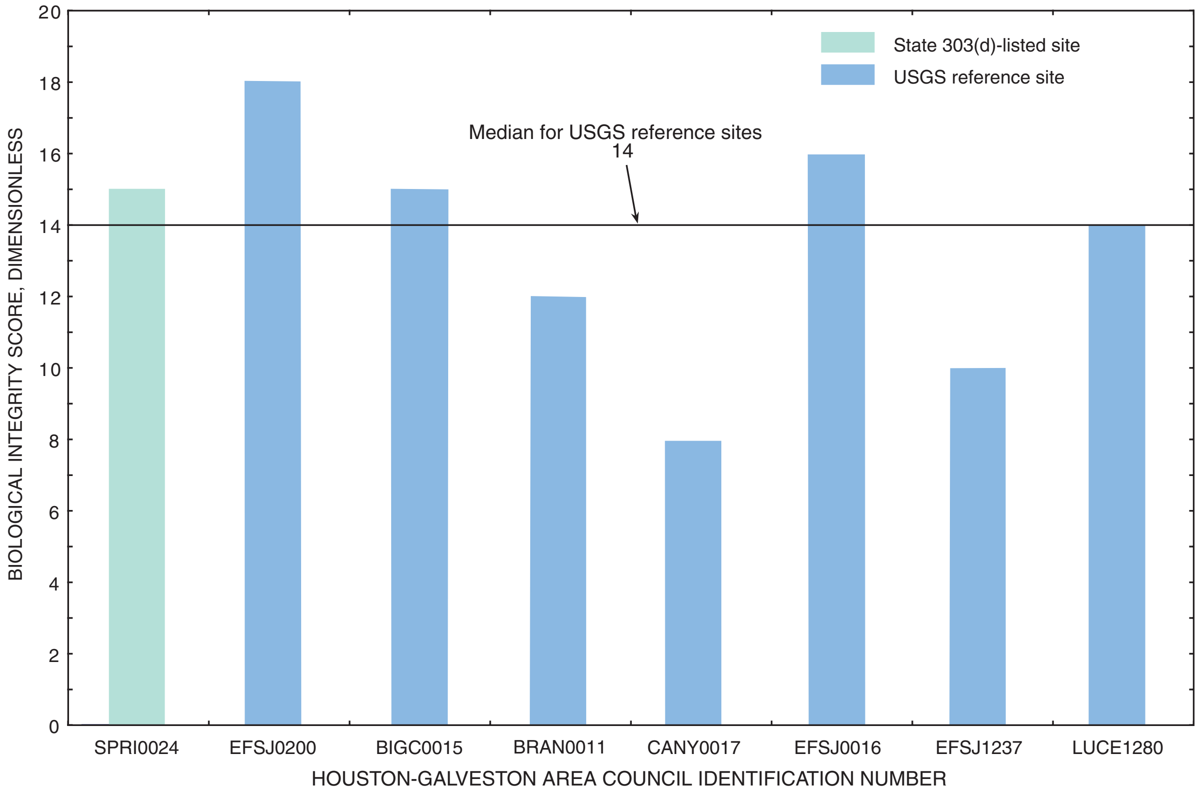

Figure 4. Biological integrity scores at State 303(d)-listed site Spring Creek near Tomball and at the seven USGS biological reference sites, San Jacinto River Basin.

minimum temperatures steadily increased from mid-June to mid-July at both sites.

How Do the Aquatic Biota Compare?

Human activities can cause a decline in biological condition, which can be quantified (scored) by an index of biological integrity. Four benthic macroinvertebrate measures were used to compute a biological integrity score for the Spring Creek 303(d) site and the USGS reference sites (Moring, 2001)—the Hilsenhoff Biotic Index (Hilsenhoff, 1987), the percent Chironomidae, the sum of the percent ephemeroptera, plecoptera, and trichoptera (known as the EPT index), and the number of benthic macroinvertebrate taxa. Each measure was assigned a score, and the scores for all measures were summed to yield the biological integrity score for each site. The biological integrity score for the Spring Creek 303(d) site was 15; the biological integrity score for the East Fork near New Caney reference site, where DO concentrations were compared for this study, was 18; and the median score of all seven USGS reference sites was 14 (fig. 4). The difference in biological integrity scores for the Spring Creek site and the East Fork near New Caney site is largely accounted for by the Hilsenhoff Biotic Index value for the Spring Creek site and the larger number of taxa at the East Fork near New Caney site. The Hilsenhoff Biotic Index is a community metric that incorporates characteristics of taxonomic diversity with tolerance values of individual taxa; the higher the index value, generally the more altered the community is. In this study, a higher Hilsenhoff Biotic Index value translated to a lower biological integrity score for the East Fork near New Caney site.

These results are different from those of the previous (Moring, 2001) study. In the previous study, the biological integrity score was 17 for both the Spring Creek 303(d) site and the East Fork near New Caney reference site; and the median score for the seven USGS reference sites also was 17. The differences in scores between 1997–98 and 2000 data probably reflect inherent variability related to seasonal and annual differences in the abundance of individual taxa.

Sixteen and seventeen species of fish, respectively, were collected at the Spring Creek and East Fork near New Caney sites (fig. 5). The number of fish species at both sites exceeded the median number of species (12) for the seven reference sites. The number of fish species was not positively correlated with the channel widths of the reaches, indicating that the difference in stream size between the sites did not influence fish species richness.

Many factors can influence the structure of aquatic communities including biological competition, predation, food resource availability, and the composition and availability of aquatic habitat. Two measures of aquatic-habitat integrity that varied between the Spring Creek 303(d) site and the USGS reference sites were the riparian, channel, and environmental (RCE) index and the reach structure index (fig. 6). The RCE and reach structure indexes were computed from data collected at the sites during 1997–98 (Moring, 2001). The RCE index consists of 16 scored metrics that include land use, continuity and vegetative composition of the riparian and floodplain zones, channel structure, channel sediments, bank undercutting, aquatic vegetation, and type and frequency of geomorphic channel units (Petersen, 1992). The RCE score, computed as the sum of the 16 metrics, is

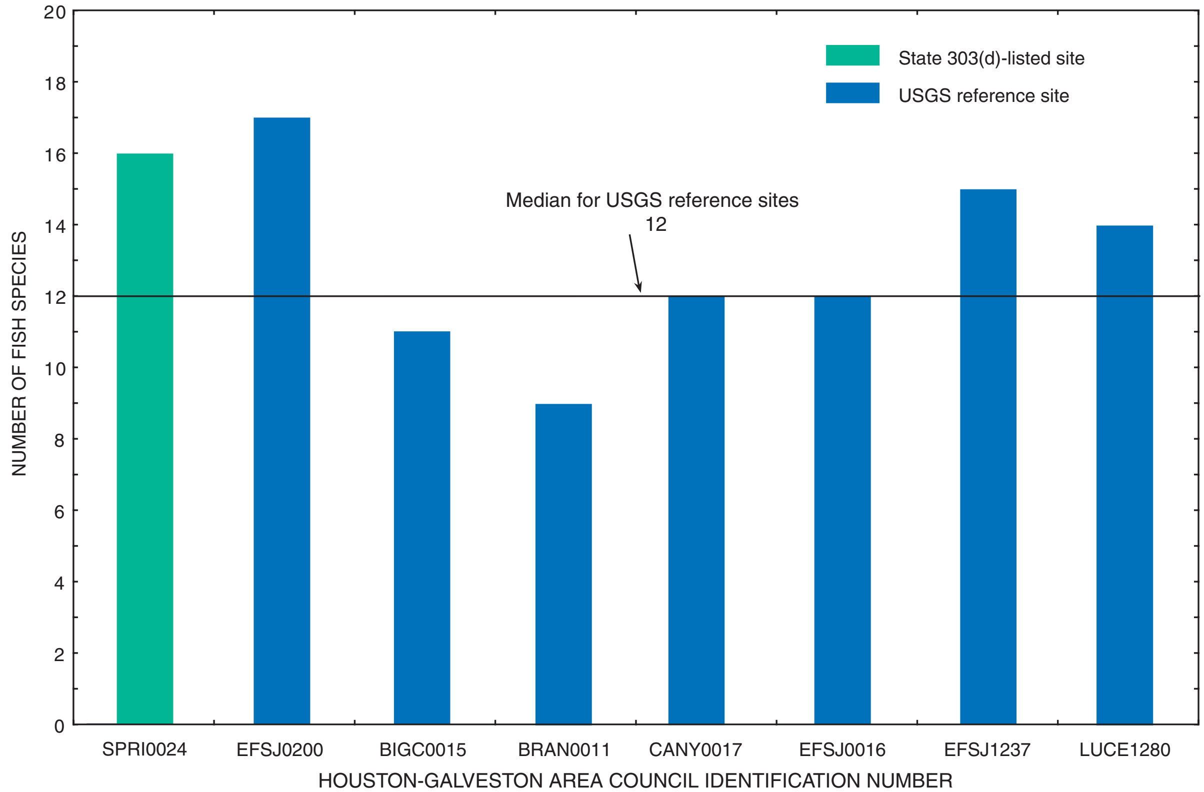

Figure 5. Number of fish species at State 303(d)-listed site Spring Creek near Tomball and at the seven USGS biological reference sites, San Jacinto River Basin.

inversely proportional to the degree of alteration of the channel and adjacent features. The higher the score, generally the less altered are the channel and adjacent land use features in the riparian and floodplain zones.

The RCE scores for the Spring Creek 303(d) site and the seven USGS reference sites were standardized by dividing each RCE score by the maximum RCE score of the reference sites and multiplying by 100 to yield the dimensionless variable, RCE maximum. The RCE maximum score for the Spring Creek site (83.1) was lower than the RCE maximum score for the East Fork near New Caney site (99.3) and lower than the median RCE maximum score for the seven USGS reference sites (95.1). Most of the difference in RCE scores can be attributed to differences in development and the clearing of vegetation along the riparian and floodplain corridor.

The reach structure index is a reach-based measure of available habitat and habitat complexity for the aquatic biota in a stream reach (Moring, 2001). The reach structure index is computed as the ratio of the sum of in-channel structures (such as woody snags, stumps, and undercut banks) in the reach to the curvilinear length of the reach at each site. By dividing the total number of in-channel structures by reach length, the structure of reaches of different size can be compared. The reach structure index among the sites varied over a wide range (fig. 6). The reach structure index value for the Spring Creek 303(d) site (140) was lower than the index value for the East Fork near New Caney reference site (165) and lower than the median index value for the seven reference sites (184). Higher reach structure index values can indicate an increase of in-channel structures such as woody snags and debris that could be the result of increased rates of bank erosion from the higher flow events that often are associated with increased urban or agricultural development in a watershed. However, the stability of woody structures in a channel might be greater in reaches that are not influenced by development.

The higher biological integrity scores and reach structure indexes reflected higher structural complexity. This higher structural complexity resulted from a higher frequency of woody snags in the channel that provide habitat for aquatic life.

Summary of Major Findings and Indication for Further Study

1. The median DO concentration during mid-May through mid-July 2000 at the 303(d)-listed Spring Creek near Tomball site (3.83 milligrams per liter) was lower than that for the USGS biological reference site East Fork San Jacinto River near New Caney (6.91 milligrams per liter). The range in diurnal fluctuations in concentration was greater at the 303(d) site than at the reference site. Daily minimum DO concentrations at both sites generally decreased beginning in early July, probably as a result of increasing water temperatures.

2. The biological integrity score for the 303(d) Spring Creek site (15) was lower than that for the East Fork near New Caney reference site (18); but the 303(d) site score was higher than the median score (14) for the seven USGS reference sites. These results are different from those of the previous (Moring, 2001) study, which probably reflects inherent

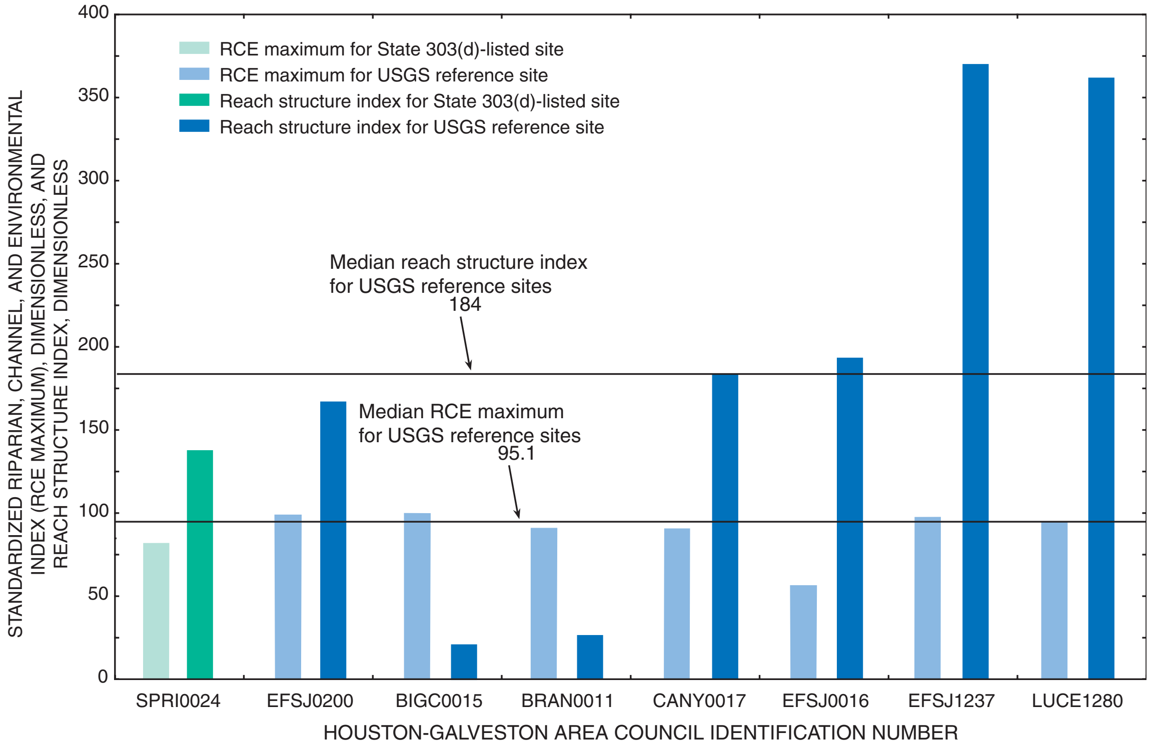

Figure 6. Aquatic-habitat characteristics at State 303(d)-listed site Spring Creek near Tomball and at the seven USGS biological reference sites, San Jacinto River Basin.

variability related to seasonal and annual differences in the abundance of individual taxa.

3. The aquatic-habitat integrity for the 303(d) Spring Creek site, as measured by the RCE index and the reach structure index, was lower than that for the East Fork near New Caney reference site and lower than the median RCE and reach structure indexes for the seven reference sites.

The biological integrity of the 303(d) Spring Creek site relative to the seven USGS reference sites (which were selected by screening for sites with higher biological integrity scores on the basis of 1997–98 data) was not definitively established by this study. In fact, the biological integrity of the 303(d) site increased, and the median biological integrity of the USGS reference sites decreased relative to those of a previous study. Because of the inherent variability in the data that compose the biological integrity index, seasonal sampling of the benthic macroinvertebrate and fish communities for several years would be needed for definitive comparison of the biological conditions at the 303(d) site relative to conditions at USGS reference sites.

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