Bioassessment of Lake Mexia

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Executive Summary

Lake Mexia (Segment 1210) was included on the 2002 Texas list of impaired water bodies ("303(d) list") as a concern due to depressed dissolved oxygen concentrations. In response to the concern, a dissolved oxygen monitoring project and concurrent bioassessment were conducted by the Texas Commission on Environmental Quality (TCEQ) and Texas Parks and Wildlife Department (TPWD) in 2002 and 2003. The bioassessment included fish, benthic macroinvertebrate, zooplankton, aquatic macrophyte and shoreline habitat surveys. The study objectives were to obtain additional data to determine if the reservoir was meeting the dissolved oxygen criteria for its designated high Aquatic Life Use (ALU), to determine if the designated ALU and oxygen criteria were appropriate and to generate data to allow possible modifications to the criteria if necessary, and to evaluate whether biological data from the reservoir has utility in assessing the ALU.

The results indicate the reservoir meets the dissolved oxygen criteria for high ALU and that no change to the criteria is needed. Lake Mexia was removed from the 303(d) list based on the data collected for this project. At a superficial level, the fish assemblage data, as well as a 2003 TPWD fishery survey of Lake Mexia, do not suggest impairment from depressed dissolved oxygen. The study found 30 species of fish, including two species classified as intolerant to anthropogenic effects. The TPWD fishery survey indicates the reservoir supports a healthy prey base and largemouth bass and white crappie populations provide excellent angling opportunities. The benthic macroinvertebrate data varied depending on the substrate sampled. Samples associated with vegetation had higher species richness than the sediment samples. There is not enough information regarding benthic macroinvertebrates in Texas reservoirs to make a determination of whether Lake Mexia is supporting a healthy benthic community. For similar reasons the zooplankton survey was also inconclusive. The shoreline habitat surveys characterized shoreline uses and available aquatic habitat. However, the approach to assessing human influence on the shoreline was based on presence/absence and did not assess the severity of a given human influence type. The aquatic macrophyte community was dominated by native emergent vegetation. Very little invasive vegetation was observed.

This was the first study in Texas to collect biological data in a reservoir for the purpose of assessing aquatic life use attainment. There are no biological indices developed for Texas reservoirs and similar data are not available from any other reservoirs in Texas. As such, it's not possible to draw any strong conclusions about whether this type of data will be useful in determining support of an ALU designation. At present, it appears that TPWD survey data alone is not adequate for determining whether a reservoir is meeting its designated ALU. If the state pursues development of ecological indices or metrics prove to assess reservoirs, the TPWD survey level of effort for electrofishing with the addition of seining may be adequate if all species and individuals collected are recorded. Other natural resource agencies outside of Texas have found success in using biological data to assess reservoirs and the metrics used by other states may have some applicability in Texas.

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List of Acronyms

ALU	Aquatic Life Use
CPUE	Catch Per Unit Effort
DO	Dissolved Oxygen
USEPA	United States Environmental Protection Agency
QAP	Quality Assurance Plan
RFAI	Reservoir Fish Assemblage Index
SWQM	Surface Water Quality Monitoring
TCEQ	Texas Commission on Environmental Quality, formerly Texas Natural Resource Conservation Commission
TPWD	Texas Parks and Wildlife Department
TSI	Trophic State Index
TVA	Tennessee Valley Authority
TWDB	Texas Water Development Board
UAA	Use Attainability Analysis

Introduction

Lake Mexia is assigned a high ALU with 5.0 mg/L mean and 3.0 mg/L minimum dissolved oxygen criteria in the Texas Surface Water Quality Standards (TCEQ 2000). This study was prompted by instantaneous surface water quality monitoring data from 1998 to 2001 which indicated that the reservoir was not meeting the dissolved oxygen criteria.

The study objectives were to obtain additional data to determine if the reservoir was meeting the dissolved oxygen criteria for its designated high Aquatic Life Use (ALU), to determine if the designated ALU and oxygen criteria were appropriate and to generate data to allow possible modifications to the criteria if necessary, and to evaluate whether biological data from the reservoir has utility in assessing the ALU.

Study Area

Lake Mexia, Segment 1210, and Bistone Dam are located in the upper watershed of the Navasota River in Limestone County, approximately 11 km southwest of Mexia, Texas, adjacent to and south of US Highway 84. The reservoir and dam are owned by the Bistone Municipal Water Supply District (Sullivan *et al.* 1996). Inflows to the reservoir originate over a 513 km^2 drainage area. At the conservation capacity pool elevation of 135.3 m (443.8 ft) above sea level, the reservoir is approximately 3.2 km long and 1.0 km wide at the widest point. The reservoir was first filled in June 1961. The maximum height of the dam is 15 m above the original riverbed at an elevation of 140.9 m (462.3 ft). The spillway is a concrete ogee (over the crest) type located at the east end of the dam. The original surface area of the reservoir was 486 ha (1200 acres) with a corresponding capacity of 10,000 acre-feet. A volumetric survey conducted by the Texas Water Development Board in 1996 (Sullivan *et al.* 1996) indicated that the reservoir storage volume was 52% filled with sediment.

The watershed is primarily pasture/hay, with deciduous forest bordering the streams. Some quarries are located northeast and southwest of the reservoir. Row crops and low intensity residential areas are a small percentage of the watershed. Much of the reservoir perimeter has home sites served by on-site sewage facilities. The reservoir was created primarily as a public water supply for the City of Mexia and the Mexia State School. The reservoir has a sport fishery managed by the Texas Parks and Wildlife Department and provides opportunities for contact recreation including boating, skiing, and swimming. Bistone Municipal Water Supply District maintains a campground and boat ramp on the east shore of the reservoir.

Methods

This special study followed the TCEQ Quality Assurance Plan (QAP) titled *Bioassessment of Lake Mexia* as amended April 28, 2004 (TCEQ 2004).

Study Design

The study was conducted in accordance with data requirements and timing considerations specified in the TCEQ Surface Water Quality Monitoring (SWQM) Biological Monitoring Fact Sheet for Use Attainability Analysis (UAA Fact Sheet 2002). Three separate sampling events were performed during the index period (March 15 to October 15), one in 2002 and two in 2003.

Three areas on Lake Mexia representing the upper, middle**,** and lower areas of the reservoir were sampled. These locations are often referenced as “Upper Lake,” “Mid-Lake,” and “Dam,” respectively. The following TCEQ Surface Water Quality Monitoring Stations as shown on Figure 1 were the “hubs” for the chosen sampling areas:

TCEQ Station 17586 - Lake Mexia 330 m northwest of the dam.
TCEQ Station 17587 - Lake Mexia 130 m south-southeast of FM 3437.
TCEQ Station 17588 - Lake Mexia 680 m south-southeast of US Hwy 84.

Each sampling area had three assessment and sampling events that included instantaneous field measurements, routine water chemistry analysis, and characterization of benthic macroinvertebrate, fish, zooplankton, and aquatic macrophyte assemblages, as well as a shoreline habitat assessment. Two sampling events were conducted within the critical period (July 1 to September 30) of 2002 and 2003 and one in the early portion of the index period (March 15 to April 30) in 2003 (TCEQ 2005).

A dissolved oxygen monitoring project, comprised of twelve 24-hour dissolved oxygen measurements from each of the three stations, was conducted concurrently. These 24-hour measurements were conducted once per month from April through September for 2002 and 2003. Data were equally split between the critical and non-critical portions of the index period.

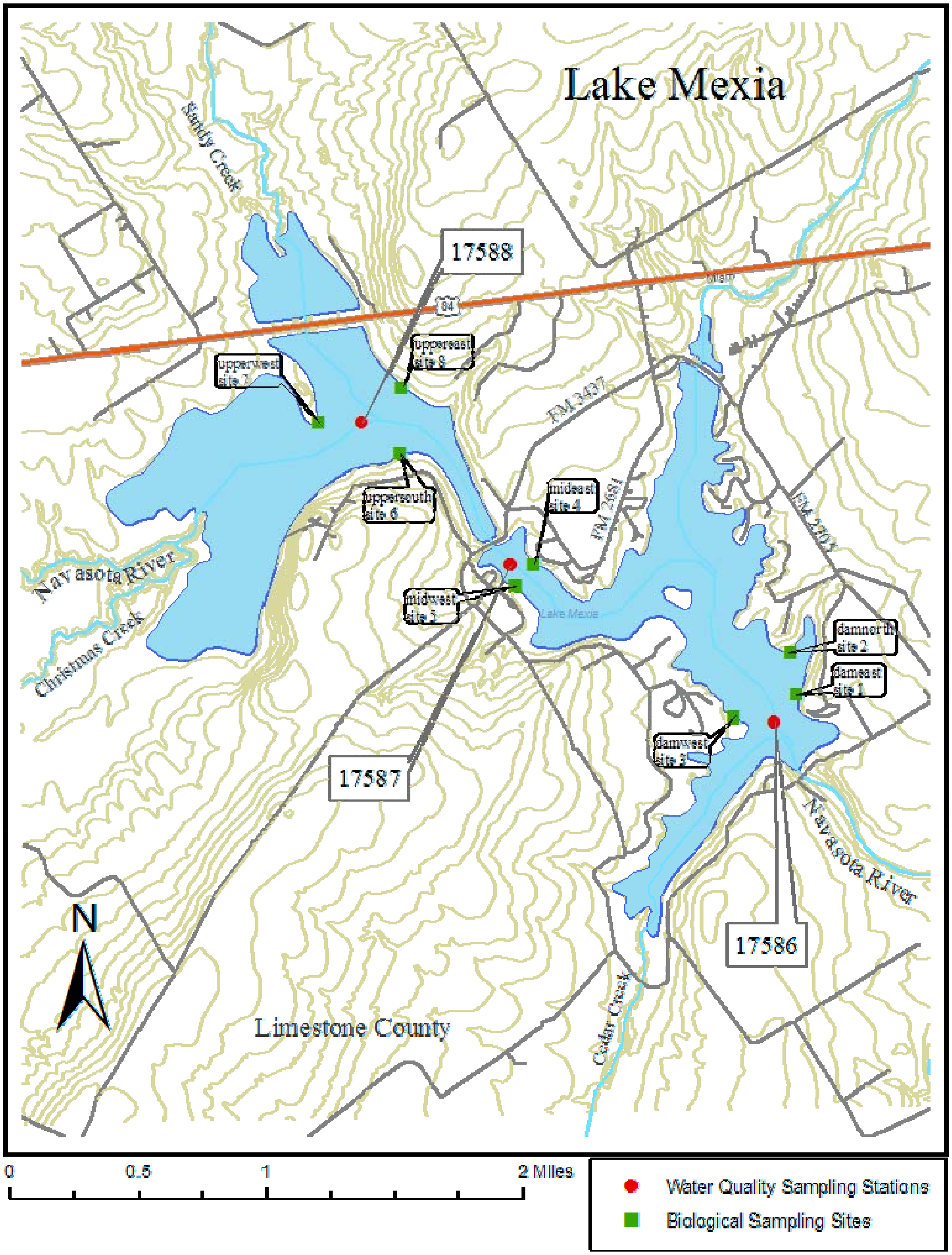

Figure 1. Lake Mexia water quality sampling stations and hub transect locations for biological sampling. Numbers are TCEQ Surface Water Quality Monitoring (SWQM) station numbers.

Chemical Parameters

Water samples were collected from TCEQ Surface Water Quality Monitoring Stations 17586, 17587, and 17588 (Figure 1) during each sampling event and analyzed at the TCEQ laboratory in Houston. Additional chemical data available from on-going water quality monitoring is included in the results and discussion section.

Physicochemical Parameters

Water temperature, pH, dissolved oxygen (DO), and specific conductivity were measured with YSI 600XLM multi-probe datasondes. Physicochemical profiles were conducted at the time of each 24-hour datasonde deployment and retrieval.

YSI 600 XLM multi-probe datasondes were deployed to obtain 24 hours of physicochemical data at 30 minute intervals. The sondes were suspended under Rolyan Buoys with the probes set at no greater than half the depth of the mixed surface layer. The mixed surface layer was considered to be the depth at which a greater than 0.5 degree ºC change from the 0.3 meter temperature occurred. The profile data was used to determine the mixed surface layer. Generally, on the deployed sondes, the first measurement was eliminated then the next 48 readings were utilized as the reportable data, reporting the maximum, minimum, and mean values.

Biological Parameters

Sampling dates were September 24-27, 2002, March 31-April 4, 2003, and September 8-12, 2003 with the last habitat assessment on September 29, 2003. Biological sampling sites were randomly selected, one from the east side and one from the west side of the river channel for each sampling area. Sampling effort was consistent at each of the selected biological sampling sites throughout the study unless otherwise noted. The Dam and Upper Lake sampling areas have an extra biological sampling site due to the fact that the seining effort in September 2002 included sampling outside the randomly selected sites.

Fish Assemblage Sampling

Multiple habitats were sampled using four collection methods: boat electrofishing, seining, gill netting, and trap netting. A combination of TCEQ and TPWD sampling protocols was used to establish a level of effort for each collection method. This was necessary to be consistent with TCEQ UAA guidelines while incorporating TPWD sampling gear for reservoirs. The level of effort for electrofishing, gill netting and trap netting in the study represents about 60% to 75% of TPWD's typical level of effort for reservoirs less than 2023 ha (5000 acres) in size (Table 22). Fish were identified, measured for total length, and weighed. Species such as shad that were collected in large numbers and cyprinid species were not always weighed. Voucher specimens are retained in the TCEQ Region 9 office. Voucher specimens that were too large to keep were photographed with a digital camera.

Seining was not listed as a collection method in the QAP (which was written prior to the 2007 TCEQ *SWQM Procedures, Volume 2*, which specifically lists sampling methods for reservoirs). However, seining effort was added in the study to be consistent with TCEQ stream sampling protocols that existed at the time in the TCEQ *Receiving Water Assessment Procedures Manual* (TNRCC 1999).

Electrofishing

Electrofishing was conducted by TPWD Inland Fisheries Division staff using a TPWD electrofishing boat. A Smith Root Model GPP 5.0, with a variable pulse DC output was used to sample mainly in the littoral zone using two netters. A second boat trailed the electrofishing boat to ensure all available fish were collected. Shocking time at each biological sampling site was a minimum of 7.5 minutes giving a total of 15 minutes (900 seconds) per sampling area at the Dam, Mid-Lake, and Upper Lake. Sampling continued beyond the minimum effort if new species were noted. Time was split to allow all available habitats to be sampled similar to sampling both sides of a stream. Sampling was conducted in the morning daylight hours (as opposed to TPWD guidance which recommends night electrofishing). Sampling at night was not possible due to TCEQ concerns regarding equipment, safety, and work-hours.

Seining

Seining was conducted using a 7.6 m by 1.2 m (25 ft by 4 ft) bag seine and a 6.1 m by 1.2 m (20 ft by 4 ft) straight seine. The bag seine had a delta weave with a mesh size of 0.64 cm (1/4 in). The straight seine had a delta weave with a mesh size of 0.32 cm (1/8 in). Seining was conducted at one site per sampling area running parallel with the shoreline. The seining effort was measured in combined length with a goal of six seine hauls per sampling area. Seining effort is listed in the fish data tables in the Results section. Seining effort was variable per site in September 2002, but was consistent between sites in April 2003 and September 2003. Sampling continued if new species were noted.

Gill Nets

One gill net was set at each of the Dam, Mid-Lake, and Upper Lake sampling areas. The gill nets were 38.1 m long by 2.4 m deep (125 ft by 8 ft) consisting of five 7.6 m (25 ft) panels of differing mesh size. Panels were constructed of monofilament webbing material. Bar measure and twine size for the five panels was as follows:

Table 1. Gill net parameters.

Panel	Bar measure (in)	Bar measure (cm)	Twine size
1	1.0	2.54	104
2	1.5	3.81	104
3	2.0	5.08	139
4	2.5	6.35	139
5	3.0	7.62	139

The nets were set in the daylight evening hours and retrieved the following morning. (This is a standard unit of one “net-night.”) The nets were set perpendicular to the shoreline with the small panels toward the shore.

Trap Nets

One trap net was set at each sampling area. The nets were set in the daylight hours, fished overnight, and retrieved the following day (one "net-night" per site). The nets were set oriented perpendicular to the shore. The trap nets were constructed of two 0.9 m high by 1.8 m (3 ft by 6 ft) wide frames and four 0.9 m (3 ft) diameter hoops made from 0.79 cm (5/16 in) steel. Frames are spaced 76 cm (30 in) apart with the first hoop 81 cm (32 in) from the second frame. Remaining hoops are spaced 76 cm (24 in) apart. The first frame has a slit throat and the first and third hoops have 15 cm (6 in) funnel throats. Frames are covered with 1.3 cm (1/2 in) bar-mesh, 105 knotless black nylon webbing. Leaders are 18 m (60 ft) long, 1.2 m (4 ft) high, and constructed of 1.3 cm (1/2 in) bar-mesh 105 knotless black nylon webbing.

Benthic Macroinvertebrates

Benthic macroinvertebrate sampling by Ekman dredge was conducted at each area. Three dredge samples were collected at the middle of the channel and near opposite shorelines and then combined into a single composite sample. In some cases additional samples were collected to obtain the desired number of organisms. (SWQM procedures currently target 175 organisms (+/- 20 percent) (TCEQ 2005).) The samples were preserved and retained for subsequent sorting and identification. Samples with heavy organic composition were preserved initially with formalin then transferred to alcohol. At the TCEQ Region 9 laboratory, the samples were distributed into a sorting pan. Organisms were to be retrieved from a circular isolating-ring placed at random until 100 organisms were retained. However, low number of organisms resulted in total retrieval of the organisms.

Due to the low numbers and diversity of organisms in the dredge samples, macroinvertebrates were also collected by washing and picking organisms from bundles of aquatic vegetation removed from the littoral zones. The samples were preserved and sorted in the laboratory as described above. The organisms were identified to the lowest practical taxonomic level (genus/species in many cases) in the TCEQ Region 9 laboratory. The entire collection is retained in the TCEQ Region 9 laboratory for reference in Waco, Texas.

Zooplankton

Zooplankton was collected using a Wildco plankton net with a throat diameter of 11.3 cm (4.5 in). At the Dam and Mid-Lake stations, three vertical tows from 2.5 m were composited into a single sample. Due to shallow water depths at the Upper Lake station, three horizontal tows of 2.5 m, each at 0.3 m depth, were composited into a single sample. All samples were preserved with Lugol's solution.

Shoreline Habitat and Aquatic Macrophyte Sampling

Three hundred meters of shoreline habitat were visually assessed at each of the biological sampling sites. Measurements were scored and documented according to Lakeshore Habitat Measurements and Metrics form, Figure 7-5 from the EPA *Lake and Reservoir Bioassessment and Biocriteria: Technical Guidance Document* (EPA 1998). The Texas Inland Fisheries Assessment Procedures' Habitat Assessment Table was also used on the April 2003 sampling event to estimate the relative abundance of available shoreline habitat (TPWD 1998). The biological sampling sites were also assessed to determine an estimate of area covered by macrophytes. Rakes, as described by the QAP, were used to retrieve submerged macrophytes to determine relative biomass. Aquatic macrophytes were identified to family or genus and relative abundance determined by visual inspection.

Results and Discussion

Water Quality

All routine chemical data from January 1999 to January 2005 for Segment 1210 was retrieved from the TCEQ SWQM database and reviewed to capture this project's data as well as a broader set of data centered around the time of this study. The nutrient data were compared to the 2004 TCEQ Texas Water Quality Standards guidelines for identifying secondary concerns and compared to nutrient levels of reservoirs in the Brazos Basin using the 85th percentile. Mean nitrate plus nitrite nitrogen was less than the basin 85th percentile and the screening level. Mean total phosphorus was 0.21 mg/L, exceeding the basin 85th percent level and the screening level, both 0.18 mg/L. Mean ortho-phosphorus was 0.08 mg/L, exceeding the basin 85th percent level of 0.02 mg/L, and the secondary concern screening level of 0.05 mg/L. Mean chlorophyll *a*, 22.4 μg/L, was less than the basin 85th percent level of 28.9 μg/L, but exceeded the screening level of 21.4 μg/L. The summary data is shown in Table 2. The italicized values exceeded the basin 85th percentile and/or the secondary screening level.

Table 2. Lake Mexia water chemistry data summary statistics (Jan 1, 1999 – Jan 1, 2005).

Parameter	Number of samples	Minimum	Maximum	Mean	Median	Standard deviation	Coefficient of variation	Brazos basin 85th percentile	TCEQ screening level
NO_2-N + NO_3-N total, mg/L	26	0	*1.01*	0.15	0.05	0.25	1.67	0.33	0.32
Total phosphorus, mg/L	47	0.12	*0.45*	*0.21*	*0.19*	0.06	0.29	0.18	0.18
Ortho-phosphorus dissolved, mg/L	46	0	*0.18*	*0.08*	*0.06*	0.03	0.38	0.02	0.05
Chlorophyll *a*, μg/L	50	3.2	*57.0*	*22.4*	19.8	14.9	0.66	28.9	21.4

Trophic State

The 2004 Texas Water Quality Inventory includes the trophic classification of reservoirs. TCEQ uses the most recent ten years of surface water quality measurements collected near the dam in the main pool of each reservoir where data is available. The Carlson's Trophic State Index (TSI) is calculated for each reservoir using secchi depth, total phosphorus or chlorophyll *a* data. The TCEQ uses chlorophyll *a* data to rank the reservoirs as it is the best indicator for algal biomass in most reservoirs. The chlorophyll *a* TSI value for Lake Mexia was 54.48, ranking 80th out of 94 reservoirs assessed. This places Lake Mexia in the upper end of the eutrophic class and the reservoir is borderline hypereutrophic. The TSI range and number of reservoirs assessed for each class are oligotrophic (0 to 35), one reservoir, mesotrophic (>35 to 45), 29 reservoirs, eutrophic (>45 to 55), 52 reservoirs, and hypereutrophic (>55), 12 reservoirs.

24-hour Physicochemical Data

Data from the thirty-six 24-hour deployments are shown in Table 3 - Table 5. The data indicate Lake Mexia is meeting the dissolved oxygen criteria for high ALU. The lowest dissolved oxygen concentration recorded was 3.7 mg/L at the Mid-Lake station in August 2003.

Table 3. 24-hour physicochemical parameters for Station 17586, Dam (2002-2003).

		Dissolved oxygen (mg/L)			Temperature (ºC)			pH		Specific conductivity (µS/cm)		
Date	Depth (m)	Min	Max	Mean	Min	Max	Mean	Min	Max	Min	Max	Mean
04/11/02	0.5	6.9	7.7	7.2	18.2	20	18.9	7.6	7.7	232	236	235
05/21/02	1	6.3	7.6	7	22.5	23.3	22.9	7.8	8.1	275	277	276
06/19/02	0.3	5.7	9.7	7.6	28	30.5	29.1	7.9	8.7	234	240	237
07/18/02	0.6	5.8	8.8	7.2	28.6	29.8	29.1	7.8	8.4	218	221	220
08/21/02	1	6	9	7.4	29.2	30.4	29.7	8.1	8.7	244	248	246
09/25/02	1	7.4	9.2	8.2	23.8	24.8	24.3	8.1	8.4	262	264	263
04/01/03	1	9.9	11.3	10.5	15.5	16.8	16	8.1	8.6	194	196	195
05/07/03	1	5.9	6.4	6.1	24.9	25.5	25.3	7.7	7.8	237	238	238
06/12/03	1	5.6	7.6	6.4	26.6	27.8	27.2	7.7	8.1	261	263	262
07/10/03	1	5.4	7.8	6.5	29	30.1	29.5	7.8	8.2	277	279	278
08/06/03	1	5.5	9.8	7	29.3	31	30	7.9	8.6	294	298	297
09/11/03	1	4.1	6.1	5	27.1	28.1	27.5	7.9	8.2	311	312	312
Overall		4.1	9.8	7.2	15.5	30.5	25.8	7.6	8.7	194	312	255

Table 4. 24-hour physicochemical parameters for Station 17587, Mid-Lake (2002-2003).

		Dissolved oxygen (mg/L)			Temperature (ºC)			pH		Specific conductivity (µS/cm)		
Date	Depth (m)	Min	Max	Mean	Min	Max	Mean	Min	Max	Min	Max	Mean
04/11/02	1.3	5.7	8.2	6.9	18.8	21.6	20.1	7.6	7.9	266	324	289
05/21/02	1	6.3	7.8	7.2	22.9	24.4	23.6	7.8	8.1	296	303	298
06/19/02	0.6	5.8	9.7	7.8	28.6	30.5	29.5	8	8.7	229	235	232
07/18/02	0.45	6.1	10.4	8.1	28.4	30.6	29.4	7.9	8.7	226	237	231
08/21/02	1	5.1	9.4	7.2	29.6	31.2	30.3	7.9	8.7	254	260	257
09/25/02	0.75	4.9	8.7	7.2	24.1	25.4	24.7	7.8	8.4	272	278	275
04/01/03	1	10.1	12.6	11	15.3	17.4	16.2	8.1	8.5	214	232	220
05/07/03	1	5.9	8.9	6.7	25.5	28	26	7.4	8	262	277	267
06/12/03	1	6.1	9.6	7.4	27	28.6	27.7	8.1	8.7	299	314	305
07/10/03	1	5.1	8.7	6.6	28.9	30.9	29.7	7.8	8.4	296	302	298
08/06/03	0.5	3.7	11.6	7.2	29.4	32.3	30.6	8	8.9	296	319	308
09/11/03	1	4.8	7.9	6	27.6	29.2	28.2	8.1	8.5	321	325	322
Overall		3.7	12.6	7.4	18.8	32.3	26.3	7.4	8.9	214	325	275

Table 5. 24-hour physicochemical parameters for Station 17588, Upper Lake (2002-2003).

		Dissolved oxygen (mg/L)			Temperature (ºC)			pH		Specific conductivity (µS/cm)		
Date	Depth (m)	Min	Max	Mean	Min	Max	Mean	Min	Max	Min	Max	Mean
04/11/02	0.6	7.3	9.9	8.3	19.9	23.1	21	7.8	8.3	294	335	314
05/21/02	0.6	7.4	8.8	8.1	22.2	24.1	23.1	8.1	8.3	314	317	316
06/19/02	0.3	5.2	9.8	7.5	28.1	30.6	29.3	8	8.8	234	240	237
07/18/02	0.3	7.1	11.2	8.3	28.2	30.1	28.9	8.2	8.9	242	252	246

		Dissolved oxygen (mg/L)			Temperature (ºC)			pH		Specific conductivity (µS/cm)		
Date	Depth (m)	Min	Max	Mean	Min	Max	Mean	Min	Max	Min	Max	Mean
08/21/02	0.3	4.8	9.4	6.8	29.1	31.8	30.3	8.1	8.7	271	281	274
09/25/02	0.3	5.9	9.4	7.8	22.4	24.5	23.5	8	8.3	293	297	295
04/01/03	0.3	9.3	10.7	9.8	14.3	18.7	16.1	8.3	8.5	255	279	263
05/07/03	0.3	6.8	9.4	7.8	26	28.8	26.5	8.1	8.5	311	324	317
06/12/03	0.3	5.5	9	7.3	26.4	29.2	27.9	8.1	8.6	345	358	351
07/10/03	0.3	5.6	8.3	7	28	30.6	29.4	8.2	8.6	312	325	319
08/07/03	0.5	5.5	10.3	7.4	28.4	32.3	30.4	8.2	8.8	329	338	334
09/11/03	0.5	4.1	8.7	6.2	26.7	29.4	27.7	8.2	8.8	332	348	337
Overall		4.1	10.7	7.7	14.3	32.3	26.1	7.8	8.9	234	358	300

Physicochemical Profiles

Profiles were taken at the time of 24-hour deployment and upon retrieval of sondes. Profiles were taken at the Dam and Mid-Lake sites only (Table 6 - Table 9). The Upper site was too shallow to collect profiles.

The profile data from each sonde deployment were entered into the TCEQ SWQM database and are also retained in the TCEQ Region 9 Office. Data indicate that water depths are normally near 3 m at the Dam and Mid-Lake sites and 1 m at the Upper Lake site. The reservoir water column is easily mixed by wind action and profiles have not shown any thermal stratification with a defined epilimnion and hypolimnion. However, calm winds and hot days can cause a temperature gradient in the water column with decreasing oxygen concentrations from top to bottom. This condition will indicate greater than a 0.5 ºC temperature change where the dissolved oxygen at the bottom is less than the minimum standard of 3.0 mg/L. However, dissolved oxygen concentrations measured below the mixed surface layer are not considered violations of the Texas Surface Water Quality Standards (TCEQ 2000). When the weather is hot with a light wind present, the temperature of the entire water column can be mixed but the dissolved oxygen concentration may decline from the surface to the bottom. Dissolved oxygen concentrations measured during these situations often range from 4.0 mg/L to 3.0 mg/L at 2 m depth. Measurements within 0.3 m from the bottom can yield dissolved oxygen concentrations less than 3.0 mg/L and still be within the mixed surface layer (see Dam profile on 9/10/2003). These “near bottom” readings can be influenced by the sediment and should not be considered violations of the dissolved oxygen criteria.

Table 6. Physicochemical profile data for Station 17586, Dam (2002).

	Depth (m)	Temp. (ºC)	pH	DO (mg/L)	Specific conductivity (µS/cm)
Date:4/8/02	0.3	18.6	7.8	8.1	232
Time:1330	1	17.4	7.7	8.0	230
	2	16.8	7.7	7.9	231
	3	16.6	7.6	7.5	232
	3.7	16.6	7.6	7.7	234
Date:4/10/02	0.3	19.6	7.6	8.0	234
Time: 1315	1	18.6	7.6	7.8	234
	2	18.0	7.6	7.2	234
	3	17.7	7.5	6.2	234
	3.7	17.4	7.5	5.7	235
Bottom	4				
Date: 5/20/02	0.3	22.8	8.8	6.9	274

	Depth (m)	Temp. (ºC)	pH	DO (mg/L)	Specific conductivity (µS/cm)
Time: 1250	1	22.6	8.8	6.8	274
	2	22.4	8.8	6.6	274
	3	22.2	8.8	5.8	276
	3.5	22.1	8.7	5.7	274
Date: 5/22/02	0.3	22.8	8.0	6.3	278
Time: 1050	1	22.7	8.0	6.2	279
	2	22.7	8.0	6.2	278
	3	22.7	8.0	6.2	278
Date: 6/18/02	0.3	29.7	8.5	9.7	225
Time:1317	1	28.7	8.3	8.3	226
	2	28.0	7.8	5.8	227
	3	27.5	7.4	2.6	229
Date: 6/20/02	0.3	28.8	7.9	6.6	229
Time: 1055	1	28.6	7.8	5.8	229
	2	28.1	7.6	4.1	230
	3	27.8	7.4	1.7	232
	3.5	27.6	7.2	0.7	233
Bottom	3.7				
Date: 7/17/02	0.3	28.6	7.8	6.9	220
Time: 1139	1	28.6	7.7	6.7	221
	2	28.5	7.7	6.0	221
	3	28.4	7.6	5.3	221
Date: 7/18/02	0.3	29.4	8.0	8.0	218
Time: 1258	1	29.1	8.0	7.9	218
	2	28.5	7.8	5.8	219
	3	28.3	7.6	3.6	222
Date: 8/20/02	0.3	29.2	8.1	6.8	245
Time: 1115	1	29.1	8.1	6.8	245
	2	29.1	8.0	6.1	246
	2.5	29.0	7.9	5.1	247
Bottom	2.7				
Date:8/21/02	0.3	29.7	8.2	7.3	246
Time: 1313	1	29.5	8.2	6.9	246
	2	29.4	8.0	6.2	246
	2.5	29.3	8.0	5.3	246
Bottom	3				
Date: 9/26/02	0.3	24.4	8.2	8.3	264
Time: 1455	1	24.4	8.2	8.2	264
	2	24.3	8.1	7.8	264
Bottom	2.3				

Table 7. Physicochemical profile data for Station 17586, Dam (2003).

Date:3/31/03	Depth (m)	Temp. (ºC)	pH	DO (mg/L)	Specific conductivity (µS/cm)
Time: 1405	0.3	16.3	8.0	11.2	194
	1	16.1	8.0	11.1	195
	2	16.0	8.0	10.6	196
	3	15.2	7.8	9.1	196
Bottom	3.6				
Date:4/2/03	0.3	17.6	8.4	11.1	196
Time:1422	1	17.4	8.4	11.0	196
	2	17.5	8.4	10.8	196
	2.7	17.4	8.4	10.6	196

Date:3/31/03	Depth (m)	Temp. (ºC)	pH	DO (mg/L)	Specific conductivity (µS/cm)
Bottom	3				
Date: 5/06/03	0.3	24.9	7.6	6.1	236
Time: 1410	1	24.9	7.6	6.0	236
	2	24.4	7.6	4.8	236
	3	23.8	7.5	2.0	238
Date: 5/08/03	0.3	25.5	7.5	6.0	241
Time: 1020	1	25.5	7.6	5.9	241
	2	25.2	7.5	5.6	241
	3	25.0	7.5	4.8	241
Date: 6/11/03	0.3	26.6	7.7	6.4	260
Time:1020	1	26.6	7.7	6.3	260
	2	26.4	7.6	5.5	260
	3	26.3	7.5	4.0	262
Date: 6/12/03	0.3	27.0	7.6	6.3	262
Time: 1215	1	27.0	7.6	6.3	263
	2	27.9	7.6	6.2	263
	3	26.7	7.5	5.7	263
Date: 7/9/03	0.3	29.6	7.7	6.3	277
Time: 1330	1	29.5	7.7	6.0	277
	2	28.9	7.7	4.5	276
	2.6	28.9	7.6	4.4	278
Bottom	2.9				
Date: 7/10/03	0.3	30.0	8.0	7.5	276
Time: 1330	1	29.7	8.0	7.0	276
	2	29.1	7.8	4.9	277
	2.6	28.8	7.7	4.1	277
Date: 8/05/03	0.3	29.9	8.3	7.1	296
Time: 1300	1	29.7	8.2	6.6	297
	2	29.6	8.1	6.4	297
	3	29.3	8.0	5.6	297
Bottom	3.2				
Date:8/07/03	0.3	31.6	8.7	10.3	294
Time: 1300	1	29.9	8.2	6.4	298
	2	29.6	7.7	3.1	301
	3	29.4	7.5	1.5	302
Bottom	3.2				
Date: 9/10/03	0.3	27.5	8.1	5.8	310
Time: 1208	1	27.3	8.0	5.0	311
	2	27.1	7.9	3.8	311
	3	27.0	7.6	1.1	313
Date: 9/11/03	0.3	27.8	8.1	6.5	311
Time: 1315	1	27.6	8.0	5.7	312
	2	27.3	7.9	4.8	312
	3	27.3	7.9	4.7	312

Table 8. Physicochemical profile data for Station 17587, Mid-Lake (2002).

	Depth (m)	Temp. (ºC)	pH	DO (mg/L)	Specific conductivity (µS/cm)
Date: 4/10/02	0.3	22.0	7.9	8.7	269
Time: 1420	1	20.6	7.9	8.2	271
	2	18.8	7.7	7.0	299
	3	18.4	7.7	6.1	321

	Depth (m)	Temp. (ºC)	pH	DO (mg/L)	Specific conductivity (µS/cm)
Date:4/12/02	0.3	21.5	7.8	6.7	284
Time:1110	1	21.2	7.8	6.7	283
	2	21.1	7.8	6.5	283
	3	20.9	7.8	6.0	289
Bottom	3.3	19.0	7.8	3.2	315
Date: 5/20/02	0.3	22.7	8.3	6.5	298
1220	1	22.6	8.3	6.4	299
	2	22.2	8.2	5.6	301
	2.9	21.8	8.2	4.5	311
Bottom:	3.2				
Date: 5/22/02	0.3	23.2	8.0	6.9	296
Time: 1015	1	23.2	8.0	6.7	297
	2	23.2	8.0	6.6	296
	2.9	23.2	8.0	6.6	296
Date: 6/18/02	0.3	29.9	8.5	9.0	231
Time:1450	1	29.7	8.6	8.9	231
	2	29.1	8.3	7.8	232
	3	27.6	7.7	4.7	236
Date: 6/20/02	0.3	29.4	8.1	6.6	235
Time: 1140	1	29.2	8.0	6.1	235
	2	29.0	7.7	4.6	238
	3	28.9	7.6	3.7	240
Date: 7/17/02	0.3	28.9	8.0	7.6	232
Time: 1220	1	28.4	7.8	6.6	233
	2	27.9	7.7	4.8	244
	3	27.9	7.6	4.3	245
Date: 7/18/02	0.3	29.7	8.4	9.3	231
Time: 1325	1	29.3	8.3	8.4	231
	2	28.7	8.0	6.4	234
	3	27.9	7.7	2.0	247
Date: 8/20/02	0.3	30.0	8.3	7.2	259
Time: 1150	1	29.7	8.2	6.7	259
	2	29.5	8.1	6.1	259
	2.5	29.4	7.9	4.6	261
Bottom	2.9	29.4	7.7	2.3	265
Date: 8/21/02	0.3	31.0	8.6	9.4	256
Time: 1330	1	30.4	8.1	8	258
	2	30.0	7.9	4.6	263
	2.5	29.5	7.7	4.0	266
Bottom	2.8				
Date: 9/26/02	0.3	25.1	8.2	8.0	274
Time: 1520	1	25.1	8.2	7.8	274
	2	24.7	8.1	7.4	274

Table 9. Physicochemical profile data for Station 17587, Mid-Lake (2003).

	Depth (m)	Temp. (ºC)	pH	DO (mg/L)	Specific conductivity (µS/cm)
Date:3/31/03	0.3	17.4	8.6	12.6	216
Time: 1610	1	17.2	8.6	12.7	216

	Depth (m)	Temp. (ºC)	pH	DO (mg/L)	Specific conductivity (μS/cm)
	2	15.4	8.5	11.1	237
	3	14.9	8.2	9.8	251
Bottom	3.3				
Date:4/2/03	0.3	18.2	8.7	12.5	219
Time:1510	1	18.1	8.7	12.3	222
	2	17.9	8.6	12	225
	3	17.3	8.4	10.7	236
Bottom	3.3				
Date: 5/06/03	0.3	25.5	7.8	7.1	271
Time: 1505	1	25.4	7.8	7.0	272
	2	25.2	7.8	6.2	274
	3	25.0	7.7	4.9	289
Date: 5/08/03	0.3	26.6	8.1	7.6	273
Time: 1145	1	26.5	8.0	7.4	274
	2	26.5	8.0	7.2	274
	3	26.5	7.8	6.9	274
Date: 6/11/03	0.3	26.9	8.0	6.7	305
Time:1050	1	26.8	8.0	6.6	303
	2	26.7	7.9	5.7	303
	3	26.6	7.8	4.8	303
Date: 6/12/03	0.3	27.3	8.2	6.6	307
Time: 1250	1	27.3	8.1	6.3	308
	2	27.2	8.0	5.7	311
	3	27.0	7.8	4.7	310
Date: 7/9/03	0.3	30.5	8.3	8.2	298
Time: 1400	1	30.3	8.2	7.2	298
	2	29.0	7.9	3.9	308
	3	28.8	7.8	3.2	313
Date: 7/10/03	0.3	31.3	8.4	9.2	297
Time: 1420	1	29.7	8.2	6.7	301
	2	28.9	7.9	3.8	302
	3	28.9	7.8	3.6	300
Date: 8/05/03	0.3	30.9	8.6	8.2	312
Time: 1340	1	29.6	8.1	5.6	314
	2	29.3	7.9	3.9	314
	2.8	29.2	7.7	2.8	315
Date:8/07/03	0.3	32.7	8.8	10.4	301
Time: 1330	1	30.4	8.1	6.0	320
	2	29.6	7.6	1.0	323
Bottom	2.8				
Date: 9/10/03	0.3	28.8	8.4	6.7	279
Time: 1208	1	28.6	8.4	6.3	322
	2	28.0	8.0	3.7	328
Date:9/11/03	0.3	28.8	8.5	8.2	319
Time: 1433	1	28.0	8.2	5.9	323
	2	27.6	7.9	3.8	328

Biological Parameters

Fish Assemblages

Considering all sampling gear, a total of 30 species of fish were collected (Table 10 - Table 21). This total includes one tadpole madtom (*Noturus gyrinus)* collected in a benthic macroinvertebrate sample. Freshwater shrimp (*Palaemonetes* sp.) were collected along with fish in the seine samples. Electrofishing and seining were each effective in producing high numbers of fishes. Threadfin shad (*Dorosoma petenense*) was the most abundant species collected. Of the 10 species of centrarchids collected, bluegill (*Lepomis macrochirus*) was the most abundant. Five species of cyprinids were collected, with the pugnose minnow (*Opsopoeodus emiliae*) being dominant. The slough darter (*Etheostoma gracile*) and the bigscale logperch (*Percina macrolepida*) were the only two members of the family Percidae that were collected. The smallmouth buffalo (*Ictiobus bubalus*) and river carpsucker (*Carpiodes carpio*) were the only representatives of the Catostomidae family collected. Catfish were not abundant in the collections. Of those collected, channel catfish (*Ictalurus punctatus*) were highest in number, with only two blue catfish (*Ictalurus furcatus*) and two yellow bullhead catfish (*Ameiurus natalis*).

Table 10. Electrofishing results for Stations 17586, 17587, and 17588 (Sep 2002).
Total number of individuals by station with length and weight ranges. Sampling effort was 900 seconds at each sampling area.

	Dam	Mid-Lake	Upper Lake	Total	Length range (mm)		Weight range (g)	
	17586	17587	17588		minimum	maximum	minimum	maximum
Ameiurus natalis (yellow bullhead)								
Aplodinotus grunniens (freshwater drum)		3	7	10	146	340	22	590
Carpiodes carpio (river carpsucker)								
Cyprinella lutrensis (red shiner)								
Cyprinus carpio (common carp)	1			1	505	505	1780	1780
Dorosoma cepedianum (gizzard shad)	399	60	84	543	70	227	8	129
Dorosoma petenense (threadfin shad)	44	58	131	233	50	200		
Etheostoma gracile (slough darter)								
Gambusia affinis (western mosquitofish)								
Ictalurus furcatus (blue catfish)								
Ictalurus punctatus (channel catfish)	7	1	5	13	58	570	26	1900
Ictiobus bubalus (smallmouth buffalo)	1		1	2	420	460	1220	1798
Lepisosteus oculatus (spotted gar)		3	7	10	480	760		
Lepomis cyanellus (green sunfish)	1			1	168	168	110	110
Lepomis gulosus (warmouth)		3		3	53	53	6	7
Lepomis humilis (orangespotted sunfish)		1	2	3	55	72	2	6
Lepomis macrochirus (bluegill)	59	47	87	193	54	134	3	52
Lepomis marginatus (dollar sunfish)								
Lepomis megalotis (longear sunfish)	9	16	9	34	59	107	3	24
Lepomis microlophus (redear sunfish)		1		1	67	67	3	3
Menidia beryllina (inland silverside)			1	1				
Micropterus salmoides (largemouth bass)	13	21	8	42	115	423	14	990
Morone chrysops (white bass)	2	1	1	4	140	145	20	33
Notemigonus crysoleucas (golden shiner)								
Noturus gyrinus (tadpole madtom)								
Opsopoeodus emiliae (pugnose minnow)		27	4	31	37	52		
Percina macrolepida (bigscale logperch)		1		1				
Pimephales vigilax (bullhead minnow)	1	1		2	37	37		
Pomoxis annularis (white crappie)	32	5	32	69	80	270	2	330
Pomoxis nigromaculatus (black crappie)								
Total	569	249	379	1197				

Table 11. Electrofishing results for Stations 17586, 17587, and 17588 (Apr 2003).
Total number of individuals by station with length and weight ranges. Sampling effort was 900 seconds at each sampling area.

	Dam	Mid-Lake	Upper Lake	Total	Length range (mm)		Weight range (g)	
	17586	17587	17588		minimum	maximum	minimum	maximum
Ameiurus natalis (yellow bullhead)	1			1	230	230	160	160
Aplodinotus grunniens (freshwater drum)			6	6	320	460	362	1360
Carpiodes carpio (river carpsucker)								
Cyprinella lutrensis (red shiner)								
Cyprinus carpio (common carp)	1	1	1	3	550	629	1802	3422
Dorosoma cepedianum (gizzard shad)	15	29	36	80	103	400	14	604
Dorosoma petenense (threadfin shad)	9	24	49	82	80	110		
Etheostoma gracile (slough darter)								
Gambusia affinis (western mosquitofish)								
Ictalurus furcatus (blue catfish)								
Ictalurus punctatus (channel catfish)	9		1	10	210	68	420	808
Ictiobus bubalus (smallmouth buffalo)	3		9	12	300	505	572	2002
Lepisosteus oculatus (spotted gar)		1	5	6	294	715	70	1644
Lepomis cyanellus (green sunfish)	1			1	80	80	8	8
Lepomis gulosus (warmouth)	6	4	2	12	58	137	2	48
Lepomis humilis (orangespotted sunfish)								
Lepomis macrochirus (bluegill)	37	45	47	129	57	140	2	58
Lepomis marginatus (dollar sunfish)								
Lepomis megalotis (longear sunfish)	28	4	11	43	70	220	6	62
Lepomis microlophus (redear sunfish)								
Menidia beryllina (inland silverside)			1	1				
Micropterus salmoides (largemouth bass)	13	28	7	48	77	500	6	1802
Morone chrysops (white bass)		1	2	3	110	170	14	54
Notemigonus crysoleucas (golden shiner)	1			1	85	85		
Noturus gyrinus (tadpole madtom)								
Opsopoeodus emiliae (pugnose minnow)	22	14	15	51	50	67		
Percina macrolepida (bigscale logperch)								
Pimephales vigilax (bullhead minnow)								
Pomoxis annularis (white crappie)	19	26	5	50	100	300	15	460
Pomoxis nigromaculatus (black crappie)								
Total	165	177	197	539				

Table 12. Electrofishing results for Stations 17586, 17587, and 17588 (Sep 2003).
Total number of individuals by station with length and weight ranges. Sampling effort was 900 seconds at each sampling area.

	Dam	Mid-Lake	Upper Lake	Total	Length range (mm)		Weight range (g)	
	17586	17587	17588		minimum	maximum	minimum	maximum
Ameiurus natalis (yellow bullhead)			1	1	187	187	35	35
Aplodinotus grunniens (freshwater drum)			1	1	293	293	305	305
Carpiodes carpio (river carpsucker)								
Cyprinella lutrensis (red shiner)								
Cyprinus carpio (common carp)								
Dorosoma cepedianum (gizzard shad)	160	106	75	341	85	290	10	180
Dorosoma petenense (threadfin shad)	165	261	200	626	55	75		
Etheostoma gracile (slough darter)								
Gambusia affinis (western mosquitofish)								
Ictalurus furcatus (blue catfish)								
Ictalurus punctatus (channel catfish)	3	3		6	208	429	65	660
Ictiobus bubalus (smallmouth buffalo)	10	4	3	17	355	580	830	3680
Lepisosteus oculatus (spotted gar)	2	1		3				
Lepomis cyanellus (green sunfish)								
Lepomis gulosus (warmouth)								
Lepomis humilis (orangespotted sunfish)								
Lepomis macrochirus (bluegill)	20	7	14	41	50	120	10	45
Lepomis marginatus (dollar sunfish)								
Lepomis megalotis (longear sunfish)	3	2	5	10	80	120	5	50
Lepomis microlophus (redear sunfish)								
Menidia beryllina (inland silverside)								
Micropterus salmoides (largemouth bass)	20	10	2	32	75	361		735
Morone chrysops (white bass)								
Notemigonus crysoleucas (golden shiner)								
Noturus gyrinus (tadpole madtom)								
Opsopoeodus emiliae (pugnose minnow)	2	3	1	6	40	50		
Percina macrolepida (bigscale logperch)	1			1	78	78		
Pimephales vigilax (bullhead minnow)	1	1		2	58	67		
Pomoxis annularis (white crappie)	15	6	6	27	185	285	95	420
Pomoxis nigromaculatus (black crappie)								
Total	402	404	308	1114				

Table 13. Gill net results for Stations 17586, 17587, and 17588 (Sep 2002).
Total number of individuals by station with length and weight ranges. Sampling effort was one 38 m variable mesh net for one net-night.

	Dam	Mid-Lake	Upper Lake	Total	Length range (mm)		Weight range (g)	
	17586	17587	17588		minimum	maximum	minimum	maximum
Ameiurus natalis (yellow bullhead)								
Aplodinotus grunniens (freshwater drum)	1		2	3	310	346	353	418
Carpiodes carpio (river carpsucker)	1			1				
Cyprinella lutrensis (red shiner)								
Cyprinus carpio (common carp)								
Dorosoma cepedianum (gizzard shad)	3	10	18	31				
Dorosoma petenense (threadfin shad)								
Etheostoma gracile (slough darter)								
Gambusia affinis (western mosquitofish)								
Ictalurus furcatus (blue catfish)								
Ictalurus punctatus (channel catfish)	5	7	5	17	290	630	196	2730
Ictiobus bubalus (smallmouth buffalo)	15	13	6	34	370	490	760	1690
Lepisosteus oculatus (spotted gar)	1	6	5	12	380	910	200	
Lepomis cyanellus (green sunfish)								
Lepomis gulosus (warmouth)								
Lepomis humilis (orangespotted sunfish)								
Lepomis macrochirus (bluegill)								
Lepomis marginatus (dollar sunfish)								
Lepomis megalotis (longear sunfish)								
Lepomis microlophus (redear sunfish)								
Menidia beryllina (inland silverside)								
Micropterus salmoides (largemouth bass)		3		3	240	400	170	830
Morone chrysops (white bass)	2	1	1	4	360	370	428	652
Notemigonus crysoleucas (golden shiner)								
Noturus gyrinus (tadpole madtom)								
Opsopoeodus emiliae (pugnose minnow)								
Percina macrolepida (bigscale logperch)								
Pimephales vigilax (bullhead minnow)								
Pomoxis annularis (white crappie)	5	13	6	24	145	300	40	400
Pomoxis nigromaculatus (black crappie)								
Total	33	53	43	129				

Table 14. Gill net results for Stations 17586, 17587, and 17588 (Apr 2003).
Total number of individuals by station with length and weight ranges. Sampling effort was one 38 m variable mesh net for one net night.

	Dam	Mid-Lake	Upper Lake	Total	Length range (mm)		Weight range (g)	
	17586	17587	17588		minimum	maximum	minimum	maximum
Ameiurus natalis (yellow bullhead)								
Aplodinotus grunniens (freshwater drum)			1	1	385	385	632	632
Carpiodes carpio (river carpsucker)								
Cyprinella lutrensis (red shiner)								
Cyprinus carpio (common carp)	2		2	4	484	605	1536	3400
Dorosoma cepedianum (gizzard shad)	8	13	12	33	268	410	218	770
Dorosoma petenense (threadfin shad)								
Etheostoma gracile (slough darter)								
Gambusia affinis (western mosquitofish)								
Ictalurus furcatus (blue catfish)		1		1				
Ictalurus punctatus (channel catfish)	2	5	2	9	570	570	2506	2506
Ictiobus bubalus (smallmouth buffalo)	6	9	7	22	400	600	1186	3576
Lepisosteus oculatus (spotted gar)	2	1	1	4	485	610	458	992
Lepomis cyanellus (green sunfish)								
Lepomis gulosus (warmouth)								
Lepomis humilis (orangespotted sunfish)								
Lepomis macrochirus (bluegill)		1		1	120	120	48	48
Lepomis marginatus (dollar sunfish)								
Lepomis megalotis (longear sunfish)								
Lepomis microlophus (redear sunfish)								
Menidia beryllina (inland silverside)								
Micropterus salmoides (largemouth bass)	3		2	5	285	334	288	480
Morone chrysops (white bass)		1		1	250	250	226	226
Notemigonus crysoleucas (golden shiner)								
Noturus gyrinus (tadpole madtom)								
Opsopoeodus emiliae (pugnose minnow)								
Percina macrolepida (bigscale logperch)								
Pimephales vigilax (bullhead minnow)								
Pomoxis annularis (white crappie)	10	4	3	17	225	332	178	702
Pomoxis nigromaculatus (black crappie)								
Total	33	35	30	98				

Table 15. Gill net results for Stations 17586, 17587, and 17588 (Sep 2003).
Total number of individuals by station with length and weight ranges. Sampling effort was one 38 m variable mesh net for one net night.

	Dam	Mid-Lake	Upper Lake	Total	Length range (mm)		Weight range (g)	
	17586	17587	17588		minimum	maximum	minimum	maximum
Ameiurus natalis (yellow bullhead)								
Aplodinotus grunniens (freshwater drum)	1			1	527	527	2015	2015
Carpiodes carpio (river carpsucker)								
Cyprinella lutrensis (red shiner)								
Cyprinus carpio (common carp)								
Dorosoma cepedianum (gizzard shad)		18	7	25	252	378	150	645
Dorosoma petenense (threadfin shad)								
Etheostoma gracile (slough darter)								
Gambusia affinis (western mosquitofish)								
Ictalurus furcatus (blue catfish)		1		1	630	630	2435	2435
Ictalurus punctatus (channel catfish)		2		2	402	514	690	1160
Ictiobus bubalus (smallmouth buffalo)	21	23	10	54	238	607	200	3645
Lepisosteus oculatus (spotted gar)		1	1	2	450	688	380	1490
Lepomis cyanellus (green sunfish)								
Lepomis gulosus (warmouth)		1		1	185	185	140	140
Lepomis humilis (orangespotted sunfish)								
Lepomis macrochirus (bluegill)								
Lepomis marginatus (dollar sunfish)								
Lepomis megalotis (longear sunfish)								
Lepomis microlophus (redear sunfish)								
Menidia beryllina (inland silverside)								
Micropterus salmoides (largemouth bass)		1		1	296	296	320	320
Morone chrysops (white bass)	5	21	7	33	287	398	295	650
Notemigonus crysoleucas (golden shiner)								
Noturus gyrinus (tadpole madtom)								
Opsopoeodus emiliae (pugnose minnow)								
Percina macrolepida (bigscale logperch)								
Pimephales vigilax (bullhead minnow)								
Pomoxis annularis (white crappie)	3	21	1	25	217	295	160	410
Pomoxis nigromaculatus (black crappie)								
Total	30	89	26	145				

Table 16. Seine results for Stations 17586, 17587, and 17588 (Sep 2002).
Total number of individuals by station with length ranges. No weight data is available for seine samples.

	Dam	Mid-Lake	Upper Lake	Total	Length range (mm)		Weight range (g)	
	17586	17587	17588		minimum	maximum	minimum	maximum
Ameiurus natalis (yellow bullhead)								
Aplodinotus grunniens (freshwater drum)								
Carpiodes carpio (river carpsucker)								
Cyprinella lutrensis (red shiner)	1	1	4	6				
Cyprinus carpio (common carp)								
Dorosoma cepedianum (gizzard shad)	41		1	42	45	110		
Dorosoma petenense (threadfin shad)	133	72	35	240	45	85		
Etheostoma gracile (slough darter)			1	1				
Gambusia affinis (western mosquitofish)	2	3	34	39	15	40		
Ictalurus furcatus (blue catfish)								
Ictalurus punctatus (channel catfish)		1		1	90	90		
Ictiobus bubalus (smallmouth buffalo)								
Lepisosteus oculatus (spotted gar)								
Lepomis cyanellus (green sunfish)								
Lepomis gulosus (warmouth)								
Lepomis humilis (orangespotted sunfish)								
Lepomis macrochirus (bluegill)	11	10	73	94	15	90		
Lepomis marginatus (dollar sunfish)								
Lepomis megalotis (longear sunfish)		12	13	25	30	70		
Lepomis microlophus (redear sunfish)								
Menidia beryllina (inland silverside)			89	89	30	65		
Micropterus salmoides (largemouth bass)	4	5	2	11	60	130		
Morone chrysops (white bass)								
Notemigonus crysoleucas (golden shiner)								
Noturus gyrinus (tadpole madtom)								
Opsopoeodus emiliae (pugnose minnow)	8	1	138	147	20	60		
Percina macrolepida (bigscale logperch)		6		6	80	80		
Pimephales vigilax (bullhead minnow)		1	79	80	30	60		
Pomoxis annularis (white crappie)								
Pomoxis nigromaculatus (black crappie)								
Total	200	112	469	781				
Freshwater shrimp			395					
Total Seine Haul Distance (m)	23 / 46	28	29 / 14					
Seine Type	straight/bag	straight	straight/bag					

Table 17. Seine results for Stations 17586, 17587, and 17588 (Apr 2003).
Total number of individuals by station with length ranges. Weight data is only available for the largest large mouth bass and white crappie collected.

	Dam 17586	Mid-Lake 17587	Upper Lake 17588	Total	Length range (mm)		Weight range (g)	
					minimum	maximum	minimum	maximum
Ameiurus natalis (yellow bullhead)								
Aplodinotus grunniens (freshwater drum)								
Carpiodes carpio (river carpsucker)								
Cyprinella lutrensis (red shiner)								
Cyprinus carpio (common carp)								
Dorosoma cepedianum (gizzard shad)		9	8	17	80	205		
Dorosoma petenense (threadfin shad)	24	15	18	57	62	105		
Etheostoma gracile (slough darter)								
Gambusia affinis (western mosquitofish)	8		93	101	22	45		
Ictalurus furcatus (blue catfish)								
Ictalurus punctatus (channel catfish)								
Ictiobus bubalus (smallmouth buffalo)								
Lepisosteus oculatus (spotted gar)								
Lepomis cyanellus (green sunfish)								
Lepomis gulosus (warmouth)								
Lepomis humilis (orangespotted sunfish)			2	2	50	55		
Lepomis macrochirus (bluegill)	7	22	20	49	35	119		
Lepomis marginatus (dollar sunfish)	1			1	80	80		
Lepomis megalotis (longear sunfish)			5	5	88	105		
Lepomis microlophus (redear sunfish)								
Menidia beryllina (inland silverside)	3	2	32	37	56	80		
Micropterus salmoides (largemouth bass)	4	3	2	9	82	428		1152
Morone chrysops (white bass)								
Notemigonus crysoleucas (golden shiner)								
Noturus gyrinus (tadpole madtom)								
Opsopoeodus emiliae (pugnose minnow)	24	8	10	42	38	68		
Percina macrolepida (bigscale logperch)								
Pimephales vigilax (bullhead minnow)		1		1	60	60		
Pomoxis annularis (white crappie)	1		2	3	290	330	410	704
Pomoxis nigromaculatus (black crappie)								
Total	72	60	192	324				
Freshwater shrimp		12	28	40	33	38		
Total Seine Haul Distance (m)	46/46	46/46	46/46					
Seine Type	straight/bag	straight/bag	straight/bag					

Table 18. Seine results for Stations 17586, 17587, and 17588 (Sep 2003).
Total number of individuals by station with length ranges. Weight data is only available for the largest largemouth bass collected.

	Dam	Mid-Lake	Upper Lake	Total	Length range (mm)		Weight range (g)	
	17586	17587	17588		minimum	maximum	minimum	maximum
Ameiurus natalis (yellow bullhead)								
Aplodinotus grunniens (freshwater drum)								
Carpiodes carpio (river carpsucker)								
Cyprinella lutrensis (red shiner)		2	4	6	34	47		
Cyprinus carpio (common carp)								
Dorosoma cepedianum (gizzard shad)		9	11	20	89	170		
Dorosoma petenense (threadfin shad)	157	917	116	1190	38	83		
Etheostoma gracile (slough darter)								
Gambusia affinis (western mosquitofish)	31	16	186	233	17	31		
Ictalurus furcatus (blue catfish)								
Ictalurus punctatus (channel catfish)			1	1	43	43		
Ictiobus bubalus (smallmouth buffalo)								
Lepisosteus oculatus (spotted gar)								
Lepomis cyanellus (green sunfish)								
Lepomis gulosus (warmouth)			7	7	54	64		
Lepomis humilis (orangespotted sunfish)		4	5	9	45	68		
Lepomis macrochirus (bluegill)	10	28	78	116	20	59		
Lepomis marginatus (dollar sunfish)		1	13	14	30	40		
Lepomis megalotis (longear sunfish)	2	18	39	59	28	81		
Lepomis microlophus (redear sunfish)								
Menidia beryllina (inland silverside)	62	62	187	311	30	60		
Micropterus salmoides (largemouth bass)	3	1		4	53	327		480
Morone chrysops (white bass)	1			1	216	216		
Notemigonus crysoleucas (golden shiner)	16	2		18	40	60		
Noturus gyrinus (tadpole madtom)								
Opsopoeodus emiliae (pugnose minnow)	62	57	39	158	25	53		
Percina macrolepida (bigscale logperch)	1		2	3	71	80		
Pimephales vigilax (bullhead minnow)	34	30	3	67	26	56		
Pomoxis annularis (white crappie)								
Pomoxis nigromaculatus (black crappie)								
Total	379	1147	691	2217				
Freshwater shrimp			Abundant					
Total Seine Haul Distance (m)	46/46	46/46	46/46					
Seine Type	straight/bag	straight/bag	straight/bag					

Table 19. Trap net results for Stations 17586, 17587, and 17588 (Sep 2002).
Total number of individuals by station with length and weight ranges. Sampling effort was one net-night at each sampling area.

	Dam	Mid-Lake	Upper Lake	Total	Length range (mm)		Weight range (g)	
	17586	17587	17588		minimum	maximum	minimum	maximum
Ameiurus natalis (yellow bullhead)								
Aplodinotus grunniens (freshwater drum)		2		2	30	32	280	355
Carpiodes carpio (river carpsucker)								
Cyprinella lutrensis (red shiner)								
Cyprinus carpio (common carp)								
Dorosoma cepedianum (gizzard shad)	3		10	13	7	28	4	207
Dorosoma petenense (threadfin shad)	4		7	11	6	14	2	13
Etheostoma gracile (slough darter)								
Gambusia affinis (western mosquitofish)								
Ictalurus furcatus (blue catfish)								
Ictalurus punctatus (channel catfish)								
Ictiobus bubalus (smallmouth buffalo)								
Lepisosteus oculatus (spotted gar)								
Lepomis cyanellus (green sunfish)								
Lepomis gulosus (warmouth)			2	2	20	11	177	30
Lepomis humilis (orangespotted sunfish)								
Lepomis macrochirus (bluegill)	7		2	9	6	14	2	56
Lepomis marginatus (dollar sunfish)								
Lepomis megalotis (longear sunfish)								
Lepomis microlophus (redear sunfish)			1	1	12	12	32	32
Menidia beryllina (inland silverside)								
Micropterus salmoides (largemouth bass)								
Morone chrysops (white bass)			1	1	36	36	428	428
Notemigonus crysoleucas (golden shiner)								
Noturus gyrinus (tadpole madtom)								
Opsopoeodus emiliae (pugnose minnow)								
Percina macrolepida (bigscale logperch)								
Pimephales vigilax (bullhead minnow)								
Pomoxis annularis (white crappie)	32	36	25	93	10	35	10	665
Pomoxis nigromaculatus (black crappie)								
Total	46	38	48	132				

Table 20. Trap net results for Stations 17586, 17587, and 17588 (Apr 2003).
Total number of individuals by station with length and weight ranges. Sampling effort was one net-night at each sampling area.

	Dam	Mid-Lake	Upper Lake	Total	Length range (mm)		Weight range (g)	
	17586	17587	17588		minimum	maximum	minimum	maximum
Ameiurus natalis (yellow bullhead)								
Aplodinotus grunniens (freshwater drum)								
Carpiodes carpio (river carpsucker)								
Cyprinella lutrensis (red shiner)								
Cyprinus carpio (common carp)								
Dorosoma cepedianum (gizzard shad)			1	1	189	189	46	46
Dorosoma petenense (threadfin shad)			1	1	119	119	14	14
Etheostoma gracile (slough darter)								
Gambusia affinis (western mosquitofish)								
Ictalurus furcatus (blue catfish)								
Ictalurus punctatus (channel catfish)								
Ictiobus bubalus (smallmouth buffalo)	1			1	440	440	1368	1368
Lepisosteus oculatus (spotted gar)								
Lepomis cyanellus (green sunfish)								
Lepomis gulosus (warmouth)								
Lepomis humilis (orangespotted sunfish)								
Lepomis macrochirus (bluegill)		3	1	4	105	150	16	20
Lepomis marginatus (dollar sunfish)								
Lepomis megalotis (longear sunfish)								
Lepomis microlophus (redear sunfish)								
Menidia beryllina (inland silverside)								
Micropterus salmoides (largemouth bass)								
Morone chrysops (white bass)	1			1	377	377	724	724
Notemigonus crysoleucas (golden shiner)								
Noturus gyrinus (tadpole madtom)								
Opsopoeodus emiliae (pugnose minnow)								
Percina macrolepida (bigscale logperch)								
Pimephales vigilax (bullhead minnow)								
Pomoxis annularis (white crappie)	18	51	33	102	190	359	80	924
Pomoxis nigromaculatus (black crappie)		3	1	4	230	285	216	402
Total	20	57	37	114				

Table 21. Trap net results for Stations 17586, 17587, and 17588 (Sep 2003).
Total number of individuals by station with length and weight ranges. Sampling effort was one net-night at each sampling area.

	Dam[a]	Mid-Lake	Upper Lake	Total	Length range (mm)		Weight range (g)	
	17586	17587	17588		minimum	maximum	minimum	maximum
Ameiurus natalis (yellow bullhead)								
Aplodinotus grunniens (freshwater drum)			5	5	239	316	150	335
Carpiodes carpio (river carpsucker)								
Cyprinella lutrensis (red shiner)								
Cyprinus carpio (common carp)								
Dorosoma cepedianum (gizzard shad)		4	19	23	160	374	45	470
Dorosoma petenense (threadfin shad)	2	2	24	28	69	113		
Etheostoma gracile (slough darter)								
Gambusia affinis (western mosquitofish)								
Ictalurus furcatus (blue catfish)								
Ictalurus punctatus (channel catfish)		1		1	132	132		
Ictiobus bubalus (smallmouth buffalo)		2		2	378	430	905	1340
Lepisosteus oculatus (spotted gar)								
Lepomis cyanellus (green sunfish)								
Lepomis gulosus (warmouth)			1	1	160	160	95	95
Lepomis humilis (orangespotted sunfish)								
Lepomis macrochirus (bluegill)		11	2	13	75	143		
Lepomis marginatus (dollar sunfish)								
Lepomis megalotis (longear sunfish)								
Lepomis microlophus (redear sunfish)								
Menidia beryllina (inland silverside)								
Micropterus salmoides (largemouth bass)								
Morone chrysops (white bass)								
Notemigonus crysoleucas (golden shiner)								
Noturus gyrinus (tadpole madtom)								
Opsopoeodus emiliae (pugnose minnow)								
Percina macrolepida (bigscale logperch)								
Pimephales vigilax (bullhead minnow)								
Pomoxis annularis (white crappie)		42	40	82	181	312	80	515
Pomoxis nigromaculatus (black crappie)								
Total	2	62	91	155				

a - Net at Dam captured a beaver and likely reduced the effectiveness of the gear.

There are no biological indices developed for Texas reservoirs and similar data are not available from any other reservoirs in Texas. As such, it's not possible to draw any conclusions about whether this type of data will be useful in determining support of an ALU designation.

The Tennessee Valley Authority (TVA) uses five key indicators, which are dissolved oxygen, chlorophyll, sediment quality, benthic macroinvertebrates and fish assemblage, to assess the ecological health in Tennessee River Basin reservoirs (Dycus and Baker 2001). The TVA recognized that their reservoirs were manipulated systems and reference conditions were not available. TVA chose to use available data and best professional judgment to develop indicators. One indicator is the Reservoir Fish Assemblage Index (RFAI); it uses twelve fish community metrics that can be broken down into five general categories: taxa richness and composition, trophic composition, reproductive composition, abundance, and fish health (Hickman and McDonough 1996). The RFAI was designed specifically for the TVA reservoirs and uses metrics commonly used in stream indices for biological integrity. By developing the RFAI, TVA has demonstrated that it is possible to create metrics that take into account the artificial nature of reservoirs.

The general categories and some of the individual metrics included in the RFAI may be useful for assessing the fish assemblage in Lake Mexia. Metrics to consider include number of species, number of sunfish species, number of intolerant species, percent tolerant individuals, percent dominance, number of piscivore species, percent omnivores, percent invertivores, total number of individuals, and percent anomalies. Although not in the RFAI, percent of individuals as non-native species may also be useful. An analysis of the applicability of individual metrics for Lake Mexia was not in the scope of this study.

The artificial nature of reservoirs makes it challenging to make a connection between the metrics that characterize a fish assemblage and the attainment of an ALU. Making a distinction between which metric values or percentages represent a particular fish assemblage condition (poor, fair, or good) can be difficult. For example, fish species such as channel catfish, gizzard shad, green sunfish, warmouth sunfish, and bluegill are classified as tolerant (Linam and Kleinsasser 1998), but are also important species for angling and/or prey for sport fish. Populations of these species are influenced directly or indirectly through management goals that include stocking, angling and predation. As such, it is important that a given metric take into account the impacts associated with a managed fish community.

Comparison with TPWD Inland Fisheries Monitoring Survey Results

An objective of this work is to evaluate whether biological data from the reservoir can be used to assess the ALU. To address this, TPWD Inland Fisheries survey results from Lake Mexia have been compared with data from this bioassessment work. This analysis may contribute to the development of methods for assessing reservoir ALU and help determine how fisheries data could be used. At present the state has not established a way to use biological data to assess the biological integrity of reservoirs. It is recognized that reservoirs are not natural systems and are manipulated in many ways. Meeting fishery management goals may be an important element for determining support of the ALU.

This bioassessment study combined aspects of TCEQ's UAA timing, effort and sampling protocols with TPWD fisheries survey protocols. Each sampling design has a different purpose. The TCEQ UAA sampling is designed to sample all available habitats and combinations of habitats in order to collect a representative sample of the species present in their relative abundances, then to use this data to determine if a water body is meeting its designated ALU. The TPWD fish surveys are intended to provide updated information and make management recommendations to protect and enhance the sport fishery (TPWD 1998). Historically, the TPWD has stocked Lake Mexia with blue catfish, flathead catfish, green/redear sunfish hybrids, largemouth bass, and Florida largemouth bass as shown in Appendix B.

The TPWD Inland Fisheries survey methods produce the number and catch of species per unit effort (CPUE) by gear type for gill nets, trap nets, and electrofishers. Each survey method has a specific objective and target species (TPWD 1998) as shown below.

Electrofishing:

- To obtain data necessary to estimate abundance and population (age and size) structure of all black bass species and recreationally important sunfish species.
- To obtain data necessary to estimate abundance and size structure of important prey species (gizzard shad, threadfin shad, and sunfishes).
- To obtain data necessary to assess the genetic composition of largemouth bass populations.

Gill Netting:

- To obtain data necessary to estimate abundance and population (age and size) structure of blue catfish, channel catfish, flathead catfish, striped bass, white bass, hybrid striped bass, red drum, and walleye.

Trap Netting:

- To obtain data necessary to estimate abundance and population (age and size) structure of white crappie, black crappie, and hybrid crappie.

Differences between the TPWD and TCEQ protocols include the gear types used and the documentation of species collected. The TPWD only records targeted species captured and seining is not used in their surveys. For both the TPWD fisheries surveys and this work electrofishing, gill netting, and trap netting gear were used. However, the level of sampling effort and method of choosing sample sites were different. TPWD uses a randomized method to determine sample sites each time a reservoir survey is conducted. This bioassessment project divided the reservoir into three areas (Upper Lake, Mid-Lake and Dam) then randomly selected fixed sample sites within each area.

The TPWD Lake Mexia 2003 fisheries survey (Baird and Tibbs 2004) recorded ten targeted species of fish captured by electrofishing, gill netting, and trap netting. The September 2003 bioassessment sampling conducted during the same time period as the TPWD 2003 survey recorded 17 species using the same collection methods. The bioassessment sampling added seining to the collection methods and recorded six additional species for a total of 23 species. The collections in September 2002 and April 2003 recorded 21 species and 20 species respectively. The seining effort added three species and four species, to those events, for a total of 24 species for each effort.

Similar species assemblages were collected during each event; however, the September 2002 species list lacked three species that were included in September 2003. In general, each sampling event produced a species list that varied by 2 to 4 species from the other sampling events. All methods and sampling events taken together produced 29 species of fish. A total of 30 species of fish were collected during this study when a tadpole madtom (*Noturus gyrinus*) collected in a benthic macroinvertebrate sample is included. The level of effort and number of species from each sampling event are shown in Table 22 and Table 23.

Table 22. Level of effort by fish collection gear type.

	TPWD	Bioassessment	TPWD	Bioassessment
	# of sampling sites		effort per site	
Electrofishing	12	6	5 minutes	7.5 minutes
Gill netting	5	3	one net-night	
Trap netting	5	3	one net-night	

Table 23. Number of fish species collected from each sampling event.

	Bioassessment			TPWD	
	Sep 2002	Apr 2003	Sep 2003	2003	Bioassessment events combined
Species by electrofishing, trap netting and gill netting	21	20	17	10	
Additional species by seining	3	4	6		
Total species	24	24	23	10	29

The total number of fish by species collected from the three bioassessment sampling events and from the 2003 TPWD survey is enumerated in Table 24. Comparisons of fish species and total numbers collected per method per sampling event are shown in Table 25. Electrofish and seine samples consistently collected more numbers of fish and species than gill net and trap net samples. Each gear type had low variability in species composition between sampling events (Table 25).

Table 24. Fish collected by gear type for each sampling event.

Fish species	Electrofish				Gill net				Seine			Trap net			
	Sep 2002	Apr 2003	Sep 2003	TPWD 2003	Sep 2002	Apr 2003	Sep 2003	TPWD 2003	Sep 2002	Apr 2003	Sep 2003	Sep 2002	Apr 2003	Sep 2003	TPWD 2003
Ameiurus natalis (yellow bullhead)		1	1												
Aplodinotus grunniens (freshwater drum)	10	6	1		3	1	1					2		5	
Carpiodes carpio (river carpsucker)					1										
Cyprinella lutrensis (red shiner)									6		6				
Cyprinus carpio (common carp)	1	3				4									
Dorosoma cepedianum (gizzard shad)	543	80	341	505	31	33	25		42	17	20	13	1	23	
Dorosoma petenense (threadfin shad)	233	82	626	2007					240	57	1190	11	1	28	
Etheostoma gracile (slough darter)									1						
Gambusia affinis (western mosquitofish)									39	101	233				
Ictalurus furcatus (blue catfish)						1	1								
Ictalurus punctatus (channel catfish)	13	10	6		17	9	2	33	1		1			1	
Ictiobus bubalus (smallmouth buffalo)	2	12	17		34	22	54						1	2	
Lepisosteus oculatus (spotted gar)	10	6	3		12	4	2								
Lepomis cyanellus (green sunfish)	1	1													
Lepomis gulosus (warmouth)	3	12		1			1				7	2		1	
Lepomis humilis (orangespotted sunfish)	3									2	9				
Lepomis macrochirus (bluegill)	193	129	41	86		1			94	49	116	9	4	13	
Lepomis marginatus (dollar sunfish)										1	14				
Lepomis megalotis (longear sunfish)	34	43	10	10					25	5	59				
Lepomis microlophus (redear sunfish)	1			4								1			
Menidia beryllina (inland silverside)	1	1							89	37	311				
Micropterus salmoides (largemouth bass)	42	48	32	62	3	5	1		11	9	4				
Morone chrysops (white bass)	4	3			4	1	33	13			1	1	1		
Notemigonus crysoleucas (golden shiner)		1									18				
**Noturus gyrinus* (tadpole madtom)															
Opsopoeodus emiliae (pugnose minnow)	31	51	6						147	42	158				
Percina macrolepida (bigscale logperch)	1		1						6		3				
Pimephales vigilax (bullhead minnow)	2		2						80	1	67				
Pomoxis annularis (white crappie)	69	50	27		24	17	25			3		93	102	82	182
Pomoxis nigromaculatus (black crappie)													4		
Total	1197	539	1114	2675	129	98	145	46	781	324	2217	132	114	155	182

*Tadpole madtom was collected while sampling for benthic macroinvertebrates.

Table 25. Fish summary statistics by gear type for each sampling event.

Gill net	Sep 2002	Apr 2003	Sep 2003	TPWD 2003
No. of species	9	11	10	2
Total number of fish	129	98	145	46
CPUE, fish/net-night	43	33	48	9
No. of species not collected by other methods for same event	1	1	1	0
No. of species not collected by same method at each of the 3 bioassessment events	1	2	1	0
Electrofish				
No. of species	20	18	14	6
Total number of fish	1197	539	1114	2674
CPUE, fish/hour	1596	718	1485	2674
No. of species not collected by other methods at same event	3	4	1	0
No. of species not collected by same method at each of the 3 bioassessment events	2	1	0	0
Seine				
No. of species	13	12	17	NA
Total number of fish	781	323	2217	NA
CPUE, fish/30 m	170	36	246	NA
No. of species not collected by other methods for same event	3	4	6	NA
No. of species not collected by same method at each of the 3 bioassessment events	1	1	3	NA
Trap net				
No. of species	8	7	8	1
Total number of fish	132	114	155	182
CPUE, fish/net-night	44	38	52	36
No. of species not collected by any other method at same event	0	1	0	0
No. of species not collected by same method at each of the 3 bioassessment events	1	1	1	0

It appears that the TPWD fish survey data alone is not adequate for determining whether a reservoir is meeting its designated ALU. The surveys are intended to provide updated information on the fishery and make management recommendations to protect and enhance the sport fishery. If ecological indices or metrics prove to be useful in assessing reservoirs it will be important to use methods that can capture the entire fish community. Electrofishing and seining were the most effective sampling methods and were the only gears that collected species classified as intolerant to anthropogenic effects. The TPWD survey level of effort for electrofishing with the addition of seining may be adequate if all species and individuals collected are recorded.

Although the TPWD survey protocols are not intended to be used to assess the ALU, they do provide information about predator/prey relationships, individual catch rates for prey and predator species, and growth rates. The TPWD Lake Mexia 2003 fishery survey report (Figure 2) indicates the reservoir supports a healthy prey base and largemouth bass and white crappie populations provide excellent angling opportunities. Management strategies include stocking blue catfish if adequate recruitment is not documented in 2008.

Stocking history at Mexia Reservoir, Texas. Size categories are: Fry (FRY), Fingerling (FGL), and Adult (ADL).

Species	Year	Number	Size
Blue catfish	1975	30,000	FGL
	1995	140,000	FGL
	1996	140,000	FGL
	Species total	310,000	
Flathead catfish	1969	3,806	FGL
	Species total	3,806	
Green X Redear hybrid	1980	1,000	FGL
	Species total	1,000	
Largemouth bass	1996	43	ADL
	Species total	43	
Florida largemouth bass	1974	75,120	FGL
	1976	70,000	FGL
	1977	140,340	FGL
	1995	142,384	FGL
	1998	140,668	FGL
	Species total	568,512	

Figure 2. Stocking history at Lake Mexia (from Baird and Tibbs 2004).

Benthic Macroinvertebrates

The benthic macroinvertebrate assemblages are shown in

Table 29 - Table 31. The Ekman dredge samples produced low numbers of organisms (16–120) and taxa (5–9), composed mostly of chironomids, oligochaetes**,** and hirudinids in that order of relative abundance. None of the samples contained the desired 135 organisms. The number of Ephemeroptera taxa (0 to 1) was low and no Trichoptera taxa were collected from the sediment. Two out of the nine samples included *Hexagenia* sp. which is considered a long-lived species. The presence of long-lived taxa is indicative of conditions which allow long-term survival (Dycus 2001). Freshwater mussels and aquatic snails are also considered long-lived taxa and were collected in five of the nine samples. Species richness and percent functional feeding groups for each sample are shown in Figure 3. Species richness had a narrow range with no clear distinction between sampling areas. The functional feeding groups generally followed the same order from most abundant to least abundant: collector-gatherers, predators, filtering collectors, shedders and scrapers. Shedders and scrapers were a small percentage of each sample.

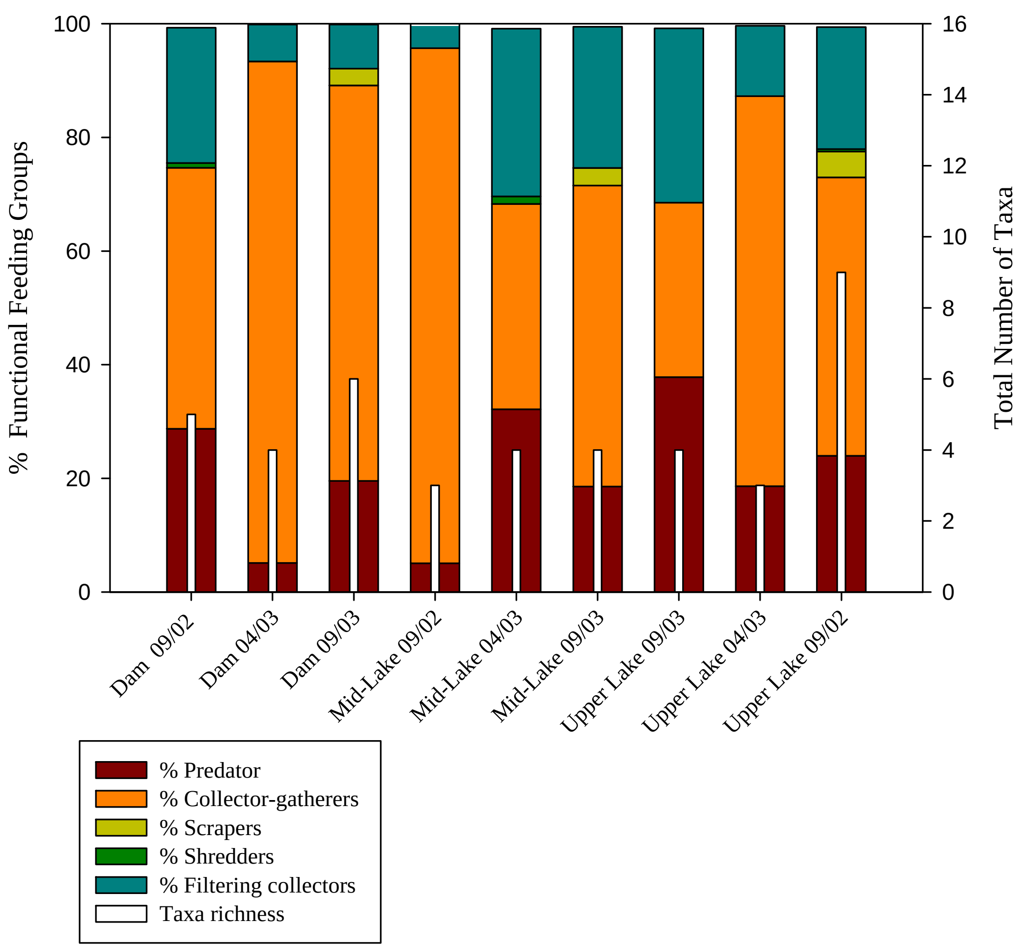

Figure 3. Lake Mexia benthic macroinvertebrate dredge sample data.

The macroinvertebrate samples collected by washing bundles of shoreline aquatic vegetation produced six orders of insects with approximately 12 families represented. Amphipods, hirudinids, oligochaetes, pelecypods, and gastropods were also collected. Amphipods were the dominant organism by number in some of the samples. Trichoptera taxa numbers were low, found in five of the ten samples. Ephemeroptera taxa were present in each sample. Species richness and percent functional feeding groups for each sample are shown in Figure 4. Species richness was higher in the vegetation samples with a wider range (9 to 16) than the sediment samples. There is no clear distinction between sampling areas. The functional feeding groups were more evenly distributed between collector-gatherers, predators, filtering collectors, shredders and scrapers. In September, 2002 there were two samples from the Dam area. These two samples showed comparable variability in functional feeding groups as samples collected at other areas and at other times.

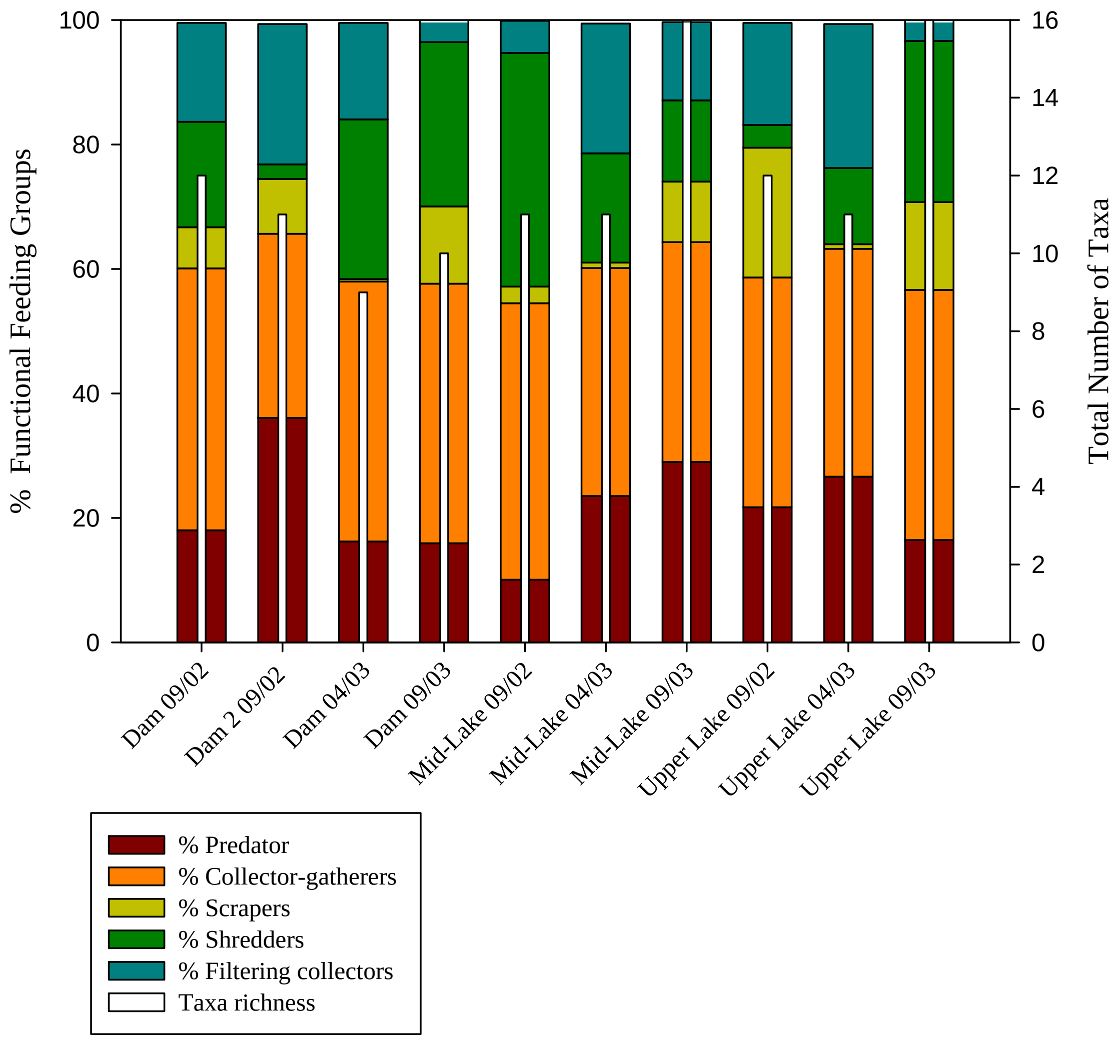

Figure 4. Lake Mexia benthic macroinvertebrate vegetation sample data.

It is difficult to interpret the benthic macroinvertebrate data without having reference sites or additional data to better understand the variability among the samples.

The Oklahoma Conservation Commission found that benthic macroinvertebrate metrics can accurately indicate the biotic health of shallow reservoirs (Wagner 1996). The Oklahoma project evaluated seven ecological metrics using benthic macroinvertebrate data collected from 15 small reservoirs (19 to 1,157 ha (47 to 2,860 acres)) throughout the state's ecoregions. The study found that the metric scores and the chlorophyll *a* trophic state indices were correlated in shallower reservoirs which were not strongly stratified by temperature, suggesting that the benthic macroinvertebrate metrics used (Table 26) reflect the trophic state of shallow reservoirs.

Table 26. Rapid bioassessment metrics applied to small Oklahoma reservoir benthic macroinvertebrate samples (Wagner 1996).

Metric	Description
Percentage of samples with long lived taxa present	Separates low quality reservoirs from high quality reservoirs by indicating the percent of the reservoir bottom with no toxicants & suitable D.O. to support benthic macroinvertebrates over long periods of time.
Average taxa richness per sample (family level)	Determines reservoir quality by indicating the diversity of the benthic macroinvertebrate community.
Percentage of samples with sensitive taxa present	Identifies high quality reservoirs by indicating the percent of the reservoir bottom having sediment & water capable of supporting sensitive taxa.
Percentage of samples with only tubificids and/or chironomids present	Identifies low quality reservoirs by indicating the percent of the reservoir bottom that is only capable of supporting very tolerant benthic macroinvertebrates.
Percentage of total organisms composed of tubificids and chironomids	Separates low and mid range reservoir quality by indicating the percent of total organisms made up of very tolerant organisms.
Percentage of total organisms sensitive	Identifies high quality reservoirs.
Percentage of samples with no benthic macroinvertebrates present	Identifies low quality reservoirs by indicating the percent of reservoir bottom unable to support benthic macroinvertebrates.

The Oklahoma project only looked at benthic macroinvertebrates from dredge samples because they were seeking an estimate of reservoir health at the sediment-water interface. The study excluded macroinvertebrates from the analysis that were considered "less benthic," such as amphipods and some coleopteran, dipteran, and odonate taxa.

Due to sampling design differences between this study and the Oklahoma project the metrics above can be applied with limited confidence to the macroinvertebrate dredge samples from Lake Mexia. The Oklahoma project used various benthic macroinvertebrate sampling scenarios, none of which were composite samples as were used in this study. The Oklahoma sampling scenarios are provided in Table 27 for comparison with this study's sampling effort.

The Lake Mexia benthic macroinvertebrate metric score and chlorophyll *a* TSI value correspond well to the shallow reservoirs that are categorized as eutrophic in the Oklahoma analysis (Table 28). This suggests that benthic macroinvertebrate data can be used to assess water quality impacts to the ALU of reservoirs in Texas. In Table 28 an individual metric score of one represents the lowest quality and a score of three represents the highest quality.

The vegetation samples produced more taxa than the sediment samples and may be useful in evaluating shoreline habitat loss from development rather than a water quality concern. More data will be needed from additional reservoirs in Texas to investigate this further.

Table 27. Comparison of Oklahoma and Texas benthic macroinvertebrate sampling protocols.

Studies	Collection methods	Total # of samples
Oklahoma reservoirs[a]	10 samples from each of three transects (lacustrine, transition, riverine)	30
	10 samples from each of two transects (lacustrine, transition, riverine)	20
	Three deepest samples from each of three transects (lacustrine, transition, riverine)	9
	10 samples from the lacustrine transect	10
	Five samples from each of three transects (lacustrine, transition, riverine)	15
Lake Mexia[b]	Three composite samples from three sampling areas (Dam, Mid-Lake, Upper Lake)	9

a Each sample was a single ponar dredge grab evenly spaced across each transect.

b Composite samples were three to six Ekman dredge grabs collected from the mid channel and near shoreline.

Table 28. Benthic macroinvertebrate metric values and scores for Lake Mexia and shallow reservoirs in Oklahoma. V indicates value and S indicates score.

	Lake Mexia		Oklahoma reservoirs																			
			Comanche		Cushing		Frederick		McAlester		Pauls Valley		Rocky		Skipout		Taylor		Chickasha		Claremore	
Metrics	V	S	V	S	V	S	V	S	V	S	V	S	V	S	V	S	V	S	V	S	V	S
Percent samples with long lived taxa	66%	3	57%	2	37%	2	4%	1	40 %	2	97%	3	43%	2	0%	1	0%	1	0%	1	30%	1
Average taxa richness per sample (family level)	4	3	3	2	2	2	2	1	3	2	3	3	3	2	2	2	2	1	1	1	3	2
Percent samples with sensitive taxa	55%	2	73%	3	67%	2	68%	2	93 %	3	97%	3	57%	2	13%	1	13%	1	0%	1	30%	1
Percent sample with only tubificids and/or chironomids	22%	3	17%	3	27%	3	29%	3	7%	3	3%	3	43%	2	50%	2	73%	1	80%	1	37%	2
Percent total organisms tubificids and chironomids	90%	1	19%	3	8%	3	3%	3	21 %	3	23%	3	28%	3	64%	2	90%	1	18%	3	18%	3
Percent total organisms sensitive	3%	1	35%	3	47%	3	46%	3	54 %	3	44%	3	11%	2	2%	1	0.4%	1	0%	1	2%	1
Percent samples with no macroinvertebrates	0%	3	0%	3	67%	1	0%	3	0%	3	0%	3	0%	3	3%	2	10%	1	20%	1	0%	3
Total metric score	16		19		16		16		19		21		16		11		7		9		13	
TSI chlorophyll a	54		51		52		51		45		44		62		61		67		62		61	
Trophic state	Eutrophic		Eutrophic		Eutrophic		Eutrophic		Mesotrophic		Mesotrophic		Hyper - eutrophic		Hyper - eutrophic		Hyper - eutrophic		Hyper - eutrophic		Hyper - eutrophic	

Table 29. Lake Mexia macroinvertebrate data (Sep 2002).

Class	Order	Family	Genus / Species	Dam 17586 Dredge	Dameast Vegetation	Damwest Vegetation	Mid-Lake 17587 Dredge	Midwest Vegetation	Upper Lake 17588 Dredge	Uppereast Vegetation
Gastropoda										
		Physidae			1					
Pelecypoda					1				1	
Nematoda									1	
Oligochaeta				12			102		28	1
		Naididae			7					
Hirudinea						7		1	1	
Amphipoda				1				153		
		Talitridae								
			Hyalella azteca		60	5			1	3
Decapoda										
		Palaemonidae/Atyidae		1						
		Cambaridae			1					
Insecta										
	Ephemeroptera									
		Caenidae								
			Caenis sp.		23	15		6	11	58
		Baetidae				1		1		
	Odonata									
		Coenagrionidae			2	5		2		3
			Argia sp.							1
			Enallagma/Coenagrion			2				
			Acanthagrion sp.							
		Corduliidae				3				
			Epitheca sp.							1
		Gomphidae								
			Gomphus sp.						1	
		Belostomatidae						1		
		Naucoridae								
			Pelocoris sp.					4		
	Trichoptera									
		Leptoceridae				1				4
		Polycentropodidae								2

Class	Order	Family	Genus / Species	Dam 17586 Dredge	Dameast Vegetation	Damwest Vegetation	Mid-Lake 17587 Dredge	Midwest Vegetation	Upper Lake 17588 Dredge	Uppereast Vegetation
		Limnephilidae			2					
		Hydroptilidae				5		2		
	Coleoptera									
		Gyrinidae								
			Dineutus sp.		2	3		1		3
		Elmidae								1
		Hydrophilidae						1		2
		Dytiscidae			1					
	Diptera									
		Chironomidae		44	88	101	15	32	75	72
		Tabanidae								
			Chrysops sp.		1					
		Chaoboridae								
			Chaoborus sp.	3			1		1	
		Sample Size		61	189	148	118	204	120	151
		No. of Species		5	12	11	3	11	9	12

Table 30. Lake Mexia macroinvertebrate data (Apr 2003).

Class	Order	Family	Genus / Species	Dam 17586 Dredge	Dameast Vegetation	Mid-Lake 17587 Dredge	Midwest Vegetation	Upper Lake 17588 Dredge	Upperwest Vegetation
Gastropoda									
		Physidae					4		1
Pelecypoda				1			3		1
Oligochaeta				58		1		9	3
		Tubificidae							
			Branchiura sp.			1			
Hirudinea							3	1	
Amphipoda					610	1	76		47
Decapoda									
		Palaemonidae/Atyidae			2				
Isopoda					13				
Insecta									
	Plecoptera								
		Perlodidae							1
	Ephemeroptera								
		Caenidae							
			Caenis sp.		9		2		3
		Ephemeridae							
			Hexagenia sp.	1					
	Odonata								
		Coenagrionidae					3		
			Argia sp.		1	1			3
			Enallagma/Coenagrion		3				2
		Libellulidae							
			Erythemis sp.		1		1		
			Pachydiplax sp.				1		
		Naucoridae							
			Pelocoris sp.		3				
	Trichoptera								1
		Leptoceridae					2		
	Coleoptera						1		
		Gyrinidae							

Class	Order	Family	Genus / Species	Dam 17586 Dredge	Dameast Vegetation	Mid-Lake 17587 Dredge	Midwest Vegetation	Upper Lake 17588 Dredge	Upperwest Vegetation
			Dineutus sp.						1
		Hydrophilidae							
			Berosus sp.						1
	Diptera								
		Chironomidae		11	570	34	135	6	137
		Stratiomyidae							
			Hedriodiscus				1		
		Ceratopogonidae							
			Palpomyia sp.		1				
		Sample Size		71	1213	38	232	16	201
		No. of Species		4	10	5	12	3	12

Table 31. Lake Mexia macroinvertebrate data (Sep 2003).

Class	Order	Family	Genus / Species	Dam 17586 Dredge	Dameast Vegetation	Mid-Lake 17587 Dredge	Midwest Vegetation	Upper Lake 17588 Dredge	Upperwest Vegetation
Gastropoda					1				1
		Physidae							
Pelecypoda				1	3	1	1	2	6
Oligochaeta				21		5			
Hirudinea				2	2		2		4
Amphipoda					85		35		116
Decapoda									
		Palaemonidae/Atyidae					1		
Insecta									
	Ephemeroptera								
		Caenidae							
			Caenis sp.	2	40	1	25		29
		Ephemeridae							
			Hexagenia sp.					2	
	Odonata								
		Coenagrionidae							
			Argia sp.		8				2
			Enallagma/Coenagrion		8		3		6
			Acanthagrion sp.				1		
		Corduliidae							
			Epitheca sp.				3		
		Gomphidae							
			Octogomphus sp.				1		
		Libellulidae							
			Pachydiplax sp.				4		
	Hemiptera								
		Belostomatidae							
			Belostoma sp.						2
		Naucoridae							

Class	Order	Family	Genus / Species	Dam 17586 Dredge	Dameast Vegetation	Mid-Lake 17587 Dredge	Midwest Vegetation	Upper Lake 17588 Dredge	Upperwest Vegetation
			Pelocoris sp.		4		3		6
	Lepidoptera								
		Noctuidae							1
	Coleoptera								32
		Elmidae							
			Dubiraphia sp.				1		1
		Hydrophilidae							3
			Berosus sp.				2		2
		Dytiscidae							4
			Celina sp.		1		3		7
		Scirtidae							
			Cyphon sp.						4
	Diptera								
		Chironomidae		5	8	9	48	59	5
		Tabanidae					1		
		Chaoboridae							
			Chaoborus sp.	3				7	
		Stratiomyidae							
			Odontomyia sp.		2				
		Sample Size		34	162	16	134	70	231
		No. of Species		6	11	4	16	4	18

Zooplankton

Zooplankton assemblages are shown in Table 32 and Table 33. For each sample, rotifers were the most abundant class, followed by copepods, and cladocerans. Due to the small sample size it is difficult to interpret the data.

As part of the USEPA National Lake Assessment, TCEQ sampled about 40 Texas lakes and reservoirs in 2007 (USEPA 2006). The national assessment used a probabilistic design to select water bodies throughout the nation that are larger than ten surface acres. The sampling included sediment cores for diatoms, shoreline habitat and macrophyte survey points, and benthic macroinvertebrate and planktonic collections. The results from the study will be used to assess the ecological health of lakes and reservoirs nationally and may provide insight on appropriate bioassessment methods for reservoirs in general and specifically on the use of zooplankton data. The final report is in preparation.

Table 32. Zooplankton collection (Sep 2002).

	Dam		Mid-Lake		Upper Lake	
Station	17586		17587		17588	
Date	Sep 27, 2002		Sep 27, 2002		Sep 27, 2002	
Time	1345		1215		1145	
V1 ml	150		130		150	
V2 ml	1		1		1	
	N	# / m^3	N	# / m^3	N	# / m^3
Rotifers						
Polyarthra sp.	2	3,851	3	5,006	14	26,957
Brachionus sp.1	18	34,659	55	91,782	34	65,467
Brachionus sp.2	23	44,286	43	71,757	54	103,977
Filinia sp.	2	3,851				
Conochilus sp.					4	7,702
Unknown rotifer	1	1,925	1	1,669	2	3,851
Copepods						
Nauplii	21	40,435	18	30,038	4	7,702
Cyclops sp.	1	1,925	4	6,675	3	5,776
Cladocerans						
Daphnia sp.	3	5,776	2	3,338	1	1,925
Ceriodaphnia sp.	1	1,925				
Bosmina sp.					1	1,925
Algae						
Spirulina sp.					1	1,925
Pediastrum sp.					3	5,776

Net opening = 11.5 cm

Net tows: 3 by 2.5 m vertical tows at Dam and Mid-Lake. 3 by 2.5 m horizontal tows at

Upper Lake.
$\# / m^3 = (N \times V1) / (V2 \times V3)$
N = # counted
V1 =Volume of concentrated sample
V2 =Volume counted
V3 = Volume of grab sample = (Tow Length)(Net Mouth Area)= 77,902 cm^3

Table 33. Zooplankton collection (Apr 2003).

	Dam		Mid-Lake		Upper Lake	
Station	17586		17587		17588	
Date	Apr 1, 2003		Apr 1, 2003		Apr 1, 2003	
Time	1345		1315		1145	
V1 ml	100		100		110	
V2 ml	1		1		1	
	N	# / m^3	N	# / m^3	N	# / m^3
Rotifers						
Polyarthra sp.	10	12,821	8	10,256	8	11,282
Brachionus sp.1	37	47,436	57	73,077	46	64,872
Filinia sp.	2	2,564			2	2,821
Conochilus sp.						
Unknown rotifer	4		12	15,385	12	16,923
Copepods						
Nauplii	21	26,923	8	10,256	6	8,462
Cyclops sp.			4	5,128		
Cladocerans						
Daphnia sp.	4					
Bosmina sp.	2					
Unknown			2	2,564		
Algae						
Pediastrum sp.	2	2564	4	5,128	2	2,821

Net opening = 11.5 cm
Net tows: 3 by 2.5 m vertical tows at Dam and Mid-Lake. 3 by 2.5 m horizontal tow at Upper Lake.
$\# / m^3 = (N \times V1) / (V2 \times V3)$
N = # counted
V1 =Volume of concentrated sample
V2 =Volume counted
V3 = Volume of grab sample = (Tow Length)(Net Mouth Area)

Shoreline Habitat and Aquatic Macrophytes

A shoreline distance of 300 m was visually assessed at two sites within each sampling area. Measurements were scored using the Lakeshore Habitat Measurements and Metrics form, Figure 7-5 from the EPA *Lake and Reservoir Bioassessment and Biocriteria: Technical Guidance Document* (EPA 1998). Table 34 - Table 36 show Lakeshore Habitat Measurement summary charts for each of the three sampling events. The charts, along with their comments, are best used to simply describe the shoreline. Table 37 shows the TPWD Inland Fisheries Assessment Procedures' (TPWD 1998) Habitat Assessment Table data collected in April 2003.

The data collected using the EPA shoreline procedures provided general information about the condition of the shoreline including riparian vegetation, bank measurements and human influences. Unfortunately the EPA approach to assessing human influence uses only presence or absence, which does not allow assessment of the severity of a given type of human influence. The presence/absence analysis indicates that the reservoir is surrounded by a mixture of shoreline use types including single family homes on large lots, campgrounds, natural areas, and a small amount of rangeland. A more thorough investigation of the shoreline habitat and watershed is needed to determine how it influences the water quality and aquatic life.

The TPWD Inland Fisheries habitat assessment focused on shoreline attributes that provide habitat for fish and percentages of native and non-native aquatic vegetation. The assessment indicated that the aquatic macrophyte community is dominated by native emergent vegetation and that invasive aquatic vegetation is not a concern. In some cases, Inland Fisheries management staff routinely survey macrophytes to produce an area coverage calculation and detailed location information about each macrophyte type present in a reservoir. These surveys are typically done in reservoirs where macrophytes are found in abundance, being reestablished, part of a management goal, or if there is a concern about an invasive species. None of these situations applies to Lake Mexia and a detailed macrophyte survey was not performed.

The aquatic macrophyte data from this project is shown in Table 38 - Table 55**.** The reservoir was mostly devoid of rooted submergent and floating leaved macrophytes such as hydrilla, milfoil, lilies, *etc.*, except for water lotus thinly scattered near the upper station. Aquatic vegetation was primarily composed of rooted emergent aquatic plants along the shoreline. The dominant species populating the shorelines were cutgrass, bulrush, reed, water willow, cattails, smartweed, and sesbania. A small patch of water hyacinth was observed during the September 2002 survey near the dam. That was the only instance of an invasive species observed throughout the study.

Table 34. Shoreline habitat data (Sep 2002).

	1	2	3	4	5	6	7	8
Riparian vegetation[a]								
Canopy (% cover)	2	2		2	2	4	3	
Understory (% cover)	1	2		0	1	1	4	
Ground cover (% cover)	3	4		1	1	1	4	
Barren (% cover)	1	0		1	0	1	2	
Bank measurement[a]								
Rocky (%)	1	0		0	1	3	0	
Soil (%)	0	4		2	1	1	1	
Vegetated (%)	2	4		4		3	4	
Other (%)	4							
Bank erosion score[b]	0					0	0.5	
Human influence measurements[c]								
Buildings	0.5	1			1	1	0	
In-lake structure	1	0			1	1	0	
Roads, railroads	0	0			0.5	0.5	0	
Agriculture	0	0			0	0	1	
Lawn	1	0			1	1	0	
Dump or landfill	0	0			0	0	0	

Locations: 1-Dameast, 2-Damnorth, 3-Damwest, 4-Mideast, 5-Midwest, 6-Uppersouth, 7-Upperwest, 8-Uppereast. See Figure 1 for transect locations. Site number columns left blank in table are sites where data was not collected.

a - 0=absent, 1=sparse (<10%), 2=moderate (10-40%), 3=heavy (40-75%), 4=very heavy (>75%)
b - 0=none, 4=severe
c - 0=absent, 1=present within transect , 0.5= adjacent or behind transect

Site descriptions:
1 - 100 m. vegetation, 50 m not concrete
2 - Across cove, along a peninsula. 6 m trees. Entire stretch has common reed fronted by water willow.
3 - Stretch is lined with reed. Trees small, sparse. Water willow in front of the reed
4 - Along the campground. Water willow entire stretch. 10% bull rushes in patches. Some cattail. Oaks, willows, cedar, locust. Eroded cut bank if reservoir was full.
5 - Large lots for homes. Wooded lawns, three piers. Trees are elm, oak, yaupon, cedar.
6 - Riprap and/or natural boulder along waterline. 60 m concrete retaining wall. Seven intact or broken piers. Seven to eight lots with homes and mobile homes. Grassed lawns with trees. Trees are red oak, hackberry, redbud, juniper, elm. Road 90m behind homes.
7 - Wooded with thick under brush and misc. ground cover. Cattle. Cattails tops eaten off. In woods are ragweed, green briar, vines, hackberry, and cedar. Water willow weed covers 100% of transect area. Smartweed behind it, along normal water line. Cattails in front of water willow.
8 - Water lotus. Shore heavily trodden by cattle. 50% cattails. Large trees. Dead cedars in water.

Table 35. Shoreline habitat data (Apr 2003).

	1	2	3	4	5	6	7	8
Riparian vegetation[a]								
Canopy (%) cover	2		3	2	2	2	4	
Understory (%) cover	1		1	1	1	1	3	
Ground cover (%) cover	3		3	3	3	2	4	
Barren (%) cover	0		0	1	0	2	0	
Bank measurement[a]								
Rocky (%)	3		0	0	0	2	0	
Soil (%)	2		1	2	1	1	0	
Vegetated (%)	2		4	2	3	2	4	
Other (%)	4					2		
Bank erosion score[b]	0		0	2	1	1	0	
Human influence measurements[c]								
Buildings	1		1	1	1	1	0	
In-lake structure	1		0	0	1	1	0	
Roads, railroads	0		0	0	0	0	0	
Agriculture	0		0	0	0	0	0	
Lawn	1		0	1	1	1	0	
Dump or landfill	0		0	0	0	0	0	

Locations: 1-Dameast, 2-Damnorth, 3-Damwest, 4-Mideast, 5-Midwest, 6-Uppersouth, 7-Upperwest, 8-Uppereast. See Figure 1 for transect locations. Site number columns left blank in table are sites where data was not collected.

a - 0=absent, 1=sparse (<10%), 2=moderate (10-40%), 3=heavy (40-75%), 4=very heavy (>75%)
b - 0=none, 4=severe
c - 0=absent, 1=present within transect , 0.5= adjacent or behind transect

Site descriptions: The absence of site descriptions indicates no new information from previous survey.
5- House, two piers, grassed lawns.
7- A shallow flat along a peninsula. Lots of trees, understory. No slope, no erosion.

Table 36. Shoreline habitat data (Sep 2003).

	1	2	3	4	5	6	7	8
Riparian vegetation[a]								
Canopy (%) cover	2		3	1	1	4	3	
Understory (%) cover	1		4	2	2	2	3	
Ground cover (%) cover	1		4	4	4	3	4	
Barren (%) cover	4		0	1	0	2	0	
Bank measurement[a]								
Rocky (%)	1		0	0	0	3	0	
Soil (%)	0		0	1	0	1	0	
Vegetated (%)	1		4	4	4	2	4	
Other (%)					0	0		
Bank erosion score[b]	1		1	1	1	1	1	
Human influence measurements[c]								
Buildings	1		0.5	1	1	1	0	
In-lake structure	1		0	0	1	1	0	
Roads, railroads	0.5		0	1	0.5	0.5	0	
Agriculture	0		0	0	0	0	1	
Lawn	1		0	1	1	1	0	
Dump or landfill	0		0	0	0	0	0	

Locations: 1-Dameast, 2-Damnorth, 3-Damwest, 4-Mideast, 5-Midwest, 6-Uppersouth, 7-Upperwest, 8-Uppereast. See Figure 1 for transect locations. Site number columns left blank in table are sites where data was not collected.

a - 0=absent, 1=sparse (<10%), 2=moderate (10-40%), 3=heavy (40-75%), 4=very heavy (>75%)
b - 0=none, 4=severe
c - 0=absent, 1=present within transect , 0.5= adjacent or behind transect

Site descriptions: The absence of site descriptions indicates no new information from previous survey.
1- 85% concrete shoreline. 10% riprap.
3- Along a peninsula. 100% of transect has emergent vegetation.
4- Along the campground.

Table 37. TPWD Inland Fisheries Habitat Assessment (Apr 2003).

Habitat type	Site 1	Site 3	Site 4	Site 5	Site 6	Site 7
Shoreline habitat (%)						
Bulkhead	0	0	0	0	0	0
Boulder	0	0	0	0	0	0
Cut bank	0	0	0	0	0	0
Concrete	45	0	0	0	40	0
Dead trees, stumps	1	5	10	20	0	20
Eroded bank	1	0	30	2	0	0
Flooded dead terrestrial vegetation	0	0	2	0	0	0
Flooded live terrestrial vegetation	0	0	2	2	0	10
Overhanging brush	3	0	0	2	0	10
Indescript or featureless	0	0	0	0	0	0
Rock bluff	0	0	0	0	0	0
Rip rap	50	0	0	5	0	0
Rocky or gravel shoreline	0	0	0	0	30	0
Vegetation (%)						
Alligator weed	0	0	0	0	0	0
Hydrilla	0	0	0	0	0	0
Native emergent vegetation	100	95	100	95	0	100
Native floating vegetation	0	5	0	5	0	0
Native submergent vegetation	0	0	0	0	0	0
Eurasian water milfoil	0	0	0	0	0	0
Water hyacinth	0	0	0	0	0	0
Water lettuce	0	0	0	0	0	0
Habitat type (#)						
Boat docks, piers, marinas	3	0	0	2	0	0
Dead trees, stumps	sparse	5	10	10	0	2

Site descriptions (see Figure 1 for site locations):

1- Dameast - Emergent vegetation covers 40% of shoreline, of three types, reeds, cattail, and water willow.

3- Damwest - Shoreline is fringing wetland, mostly reeds, also cattail, water willow outer bed mixed with - *Lemna*, *Azolla*, *Ludwigia*.

4- Mideast - Almost all of shoreline vegetated with three types identified elsewhere, all native emergent vegetation.

5- Midwest - Vegetation alternating cattail clumps, some rush, beds of water willow, w/ some floating *Azolla* and duckweed and other short emergent vegetation. More woody debris than other transects.

6- Uppersouth - Shoreline alternating concrete, native rock, and a stretch of vegetative shoreline. 20% vegetated shoreline with grass, trees. 30% native rock.

7- Upperwest – Mostly water willow, cattail, and smartweed.

Table 38. Aquatic macrophyte data at Dameast station (Sep 2002).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Bulrush	10	0 to 3	0-1	Bottom is thin layer of sediment over hard sand
Water willow	65	0 to 3	0 to 0.3	
Buttonbush	5	0 to 0	0 to 0	
Reed	20	0 to 3	0 to 0.3	

Lawns, several homes, with 2 docks. 85% of transect has concrete retaining wall, 20% covered with vegetation, most sprayed with weed killer. Some rock/boulder riprap along wall. 15% of transect is rock/boulder riprap covered by dense vegetation. No vegetation recovered by raking.

Table 39. Aquatic macrophyte data at Damwest station (Sep 2002).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Common reed	100	-5 to 0	0	From waterline in 5 m
Water willow	50	0 to 7	0 to 0.4	
Cattail	5			
Water hyacinth	1			In cove

Entire transect lined with common reed in front of densely wooded area, plus one house. Approximately 50% of transect has water willow in front of cane. There is a small cove at house. Water is down one foot at outer edge of cane. Substrate is sand. No vegetation recovered by raking.

Table 40. Aquatic macrophyte data at Mideast station (Sep 2002).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Water willow	100	0 to 4	0 to 0.3	
Smartweed	65	0	0	On land behind water willow
Buttonbush	<5			On shore, water level is down
Cattail	5			
Rush	10			On shore, water level is down
Pampas grass				

Silty substrate. Steeper sloping banks than Upper Lake, with patchy eroded areas. Camping shelters on shore.

Table 41. Aquatic macrophyte data at Midwest station (Sep 2002).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Water willow	100	0 to 5	0.5	
Knotweed				Along the normal lake level zone
Buttonbush				
Cattail		0 to 3	0 to 0.2	

Silty sand substrate. Knotweed along normal lake level zone.

Table 42. Aquatic macrophyte data at Upperwest station (Sep 2002).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Water willow	100	0 to 4	0.1	
Smartweed	100			Inshore from the water willow
Cattail	7	0	0.1	
Broadleaf	<5			Scattered

Flat slope banks. Signs of cattle grazing.

Table 43. Aquatic macrophyte data at Uppersouth station (Sep 2002).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Cattail	10	0 to 5	0 to 0.3	
Water willow	30	0 to 3	0 to 0.2	
Knotweed				On shore
Buttonbush	<5			On shore

Homes and lawns within the transect. Substrate has rock out to 6 m, then silty sand. Rock is mixture of natural sandstone and riprap.

Table 44. Aquatic macrophyte data at Dameast station (Apr 2003).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Bulrush/ Cattail mix	20	<1 to 8	0 to 1	Substrate is riprap with overlying sediment
Water willow	65	<1 to 10	<1 to 0.8	Barely emerged, possibly killed and making come-back

Transect begins at pier. Emergent cattail bed for 50 m. Then begins concrete bulkhead and improved lawns. Three additional docks in transect. 60 m of died-back water willow.

Table 45. Aquatic macrophyte data at Damwest station (Apr 2003).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Phragmites bed with some cattail		<1 to 12	<1 to 0.6	Substrate of silt, muck
Water willow with *Azolla*, L*udwigia*, L*epinia*	100	10 to 18	0.6 to 0.8	Makes up the outer fringe of vegetation

Shore is mostly fringing wetland composed of *Phragmites* with some cattail. This bed extends out 12 m from shore with some *Ludwigia* sp., duckweed and *Azolla* sp. mixed in.

Table 46. Aquatic macrophyte data at Mideast station (Apr 2003).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Emergent vegetation				Primarily water willow with some *Ludwigia*, unidentified broad leaf plant and lanceolate leaf plant
Cattail	10	0 to 7	<1 to 3	Silt and muck around cattails
Reed	23	0 to 5		10 m then 60 m reed patches

Shoreline is patchy distribution of different vegetation types of cattail, rushes, water willow. Screened cabin camping area. Grass understory, trees.

Table 47. Aquatic macrophyte data at Midwest station (Apr 2003).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Short emergents, primarily water willow.	70	<1 to 3	<1 to 0.9	Mix of water willow, *Ludwigia*, button bush, some rush (alternate leaves)
Bed of reed/cattail mixed	5	<1 to 4	<1 to 0.7	Some *Azolla*, knotweed, and debris towards bank.
Cattail	50	<1 to 5	<1 to 0.7	Cattail patches alternating with water willow, short emergents

Lawns to water edge, adjacent houses. Pier in water. Water willow beds and tall emergents (cattails, rushes). Some trees in water. Some rocks on bottom.

Table 48. Aquatic macrophyte data at Uppersouth station (Apr 2003).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Water willow	30	<1 to 3	to 0.6	Very sparse along highly modified shore, lots of riprap
Cattail	10	<1 to 8	to 0.6	Few scattered clumps

This shoreline is adjacent to several residences and is highly modified. Concrete edge with lawn up to shoreline, as well as piers with poles in water (metal and wood). Some trees as well. Vegetation sparse and not diverse. Almost all water willow/cattail.

Table 49. Aquatic macrophyte data at Uppereast station (Apr 2003).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Mix of short-form emergents	100	0 to 3	0 to 0.2	
Cattail	20	1 to 5	0.3 to 0.6	

This shoreline is one edge of long narrow peninsula. It is a shallow flooded area dominated by short emergent plants, mostly knotweed or lanceolate shaped leaved plants. Some various short rushes and broad leaf plants collected. There is an offshore ring of cattails. Silt and muck substrate.

Table 50. Aquatic macrophyte data at Dameast station (Sep 2003).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Cutgrass	10	<1 to 5	<1 to 1	Most abundant plant at this transect. Sandy silt substrate
Bulrush	<5%	<1 to 5	<1 to 1	Sandy silt substrate
Water willow	10 %	<1 to 5	<1 to 1	Second most abundant, but density is sparse over transect
Buttonbush	<5%	<1 to <1	<1	Close to shoreline

Concrete or lawns to waters edge; piers, rip-rap. 80% concrete retaining wall, 20% vegetated. 300 m transect.

Table 51. Aquatic macrophyte data at Damwest station (Sep 2003).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Phragmites spp.	100	<1 to 4		Substrate detritus on silty sand
Cutgrass	<5	<1 to 2	<1 to 3	3rd most abundant, mixed in with water willow
Cattail	<5	1 to 2	<1 to 1	Sparse
Water willow	80	3 to 10	<1 to 2	2nd band outside of the *Phragmites* and much sparser
Sesbania (legume)				On shore facultative wetland

Shoreline relatively undeveloped, one house on shore, shoreline 100 % vegetated. 300 m transect.

Table 52. Aquatic macrophyte data at Mideast station (Sep 2003).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Cattail	45	<1 to 5	<1 to 1	In thick groups. Sandy silt substrate.
Water willow	90	1 to 20	<1 to 2	Makes up the outer fringe Less thick but along entire length of transect
Cutgrass	10	<1 to 2	<1 to 2	
Buttonbush	<5	<1 to 4	<1	
Bulrush	30	<1 to 2	<1 to 1	
Sesbania	<5	<1 to <1	<1	
Knotweed				Located inward from water willow

Campground with wooded lawn. Shoreline with fringing vegetation, 100% vegetated.

Table 53. Aquatic macrophyte data at Midwest station (Sep 2003).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Cutgrass	75	<1 to 5	<1 to 2	Substrate silt, muck and detritus
Water willow	100	4 to 5	<1 to 2	Most abundant plant

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Unknown purple flowering plant (not water hyacinth)	<5	<1 to 1	<1 to 1	
Knotweed	<5	<1 to 1	<1 to 1	
Bulrush	5	<1 to 2	<1 to 2	
Buttonbush	5	<1	<1	

Fringing wetland plants with houses and lawns inland. Shoreline is 100% vegetated.

Table 54. Aquatic macrophyte data at Uppersouth station (Sep 2003).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Cattail	<5	<1 to 3	<1 to 2	4th most abundant plant
Water willow	20	1 to 5	<1 to 2	Most abundant
Buttonbush	<5	<1	<1	3rd most abundant plant
Cutgrass	10	<1 to 3	<1 to 2	2nd most abundant plant

Shoreline has houses and docks but has some shoreline vegetation. Lawns not extending to water's edge. Middle of transect has concrete along edge. 2/3 is vegetated, 1/3 is concreted.

Table 55. Aquatic macrophyte data at Uppereast station (Sep 2003).

Vegetation	Percent extension along transect	Distance from shore begin/end (m)	To max. depth (m)	Comments
Water willow	100	<1 to 5	<1 to 1	Most abundant plant Much detritus in substrate
Knotweed	50	<1 to 1	<1	3rd most abundant with a continuous band
Sagittari spp. (arrowhead) or *Platyphyla*	<5	<1 to 1	<1 to 1	Rare
Cutgrass	70	<1 to 5	<1 to 1	Outer fringe, outside of water willow
Sesbania	5	1 to 2	<1 to 1	Silt and muck substrate
Unknown purple leaf plant	<5	<1 to 1	<1 to 1	

Undeveloped shoreline peninsula, some cattle. Transect is 100% vegetated.

Conclusions

The results indicate the reservoir meets the dissolved oxygen criteria for high ALU and that no change to the criteria is needed. Lake Mexia was removed from the 303(d) list based on the dissolved oxygen data collected for this project.

Biological indices have not been developed to assess ALU in Texas reservoirs nor are comparable data available from similar reservoirs to make any comparisons regarding support of the ALU designation. At a superficial level, the fish assemblage data, as well as a 2003 TPWD fishery survey of Lake Mexia, do not suggest impairment from depressed dissolved oxygen. The study found 30 species of fish, including two species classified as intolerant to anthropogenic effects. The TPWD fishery survey indicates the reservoir supports a healthy prey base and largemouth bass and white crappie populations provide excellent angling opportunities. The TVA successfully used ecological fish metrics to assess its reservoirs. Many of the TVA Reservoir Fish Assemblage Index metrics may be applicable to Lake Mexia or other Texas reservoirs.

The benthic macroinvertebrate data varied depending on the substrate sampled. Samples associated with vegetation had higher species richness than the sediment samples. There is not enough information regarding benthic macroinvertebrates in Texas reservoirs to make a determination of whether Lake Mexia is supporting a healthy benthic community. The state of Oklahoma studied 15 small reservoirs throughout the state and found that the 10 shallow reservoirs in the study showed an excellent correlation between benthic macroinvertebrate metric scores and reservoir trophic status (TSI). The benthic macroinvertebrate metrics were applied to the Lake Mexia benthic data. The Lake Mexia benthic macroinvertebrate metric score and chlorophyll *a* TSI value correspond well to the shallow reservoirs that are categorized as eutrophic in the Oklahoma analysis. This is a good indicator that benthic macroinvertebrate data can be used to assess the ALU of a reservoir. Sampling benthics from aquatic vegetation may be useful in evaluating shoreline habitat loss from development. More benthic and shoreline habitat data will be needed from additional reservoirs in Texas to investigate this further.

The zooplankton sampling was a small portion of the total sampling effort. Due to the small sample size, and lack of biological indices or comparable data from similar reservoirs, no determination was made on whether zooplankton could be used to assess the ALU. The pending final report for the USEPA National Lake Assessment from 2007 may provide insight on the usefulness of planktonic data when assessing an ALU.

The shoreline habitat surveys characterized shoreline uses and available aquatic habitat. However, the approach to assessing human influence on the shoreline was based on presence/absence and did not assess the severity of a given human influence type. The aquatic macrophyte community was dominated by native emergent vegetation. Very little invasive vegetation was observed. A more thorough investigation of the shoreline habitat and watershed is needed to determine how it influences the water quality and aquatic life.

Another objective of the study was to evaluate whether biological data from the reservoir has utility in assessing the ALU. This proved to be difficult, as this was the first study in Texas to collect biological data in a reservoir for the purpose of assessing aquatic life use attainment. There are no biological indices developed for Texas reservoirs and similar data are not available from any other reservoirs in Texas. As such, it's not possible to draw any strong conclusions about whether this type of data will be useful in determining support of an ALU designation. The study also evaluated whether the existing biological data from TPWD Inland Fisheries surveys can be used to assess the ALU. At present, it appears that TPWD survey data alone is not adequate for determining whether a reservoir is meeting its designated ALU. If ecological indices or metrics prove to be useful in assessing reservoirs, the TPWD survey level of effort for electrofishing with the addition of seining may be adequate if all species and individuals collected are recorded. Other natural resource agencies outside of Texas have found success in using biological data to assess reservoirs. The metrics used by other states may have some applicability in Texas.

The study did indicate that a combination of water quality and biological data can be evaluated by natural resource agencies to determine how well a reservoir supports aquatic life. Several approaches to developing methods for assessing ALU attainment in reservoirs are available. One way would be to collect biological data as was done for this study from a variety of reservoirs across the state. This would allow natural resources agencies to develop assessment tools similar to those for streams in Texas and reservoirs in other states. An approach such as the 2007 USEPA National Lake Assessment could also be appropriate. The results from the study will be used to assess the ecological health of lakes and reservoirs nationally and may provide insight on appropriate bioassessment methods for reservoirs in Texas. Another approach would be to use existing fisheries survey data. This would focus assessments on present goals for each public reservoir in Texas, *i.e.*, "fishable" and serve as a step towards a comprehensive tool for assessing the overall ecosystem health of a reservoir. Irrespective of the approach selected, it is clear that biological data can be used in conjunction with water quality data and watershed characteristics to assess the health of reservoirs.

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