

LAKE GRANBURY CHARACTERIZATION STUDY

Final Report



SUBMITTED TO:
ENERCON SERVICES, INC.
400 Valley Road, Suite 301
MT. Arlington, NJ 07856-2316

PREPARED BY:
BIO-WEST, INC.
1812 Central Commerce Court
Round Rock, Texas 78664
Ph: 512.990.3954
Fax: 512.990.5153

March 2008

INTRODUCTION

Lake Granbury is located in Hood County, Texas, adjacent to the city of Granbury. The lake is approximately 35.5 miles long, and was created in 1969 when DeCordova Bend Dam was built on the Brazos River. As a result, 103 miles of shoreline were created along this 8,310 acre lake. The dam is operated by the Brazos River Authority for power plant cooling, flood control, water supply, and recreation (Baird and Tibbs 2005). Lake Granbury has a maximum depth of 23 meters (75 feet). Water level in the lake is maintained by an open spillway and the retention time is estimated at 260 days (Baird and Tibbs 2005). Fish stocking by the Texas Parks and Wildlife Department (TPWD) began in 1969 with the stocking of largemouth bass (*Micropterus salmoides*), fingerlings and channel catfish (*Ictalurus punctatus*). Stocking has continued in this lake with the addition of striped bass (*Morone saxatilis*) and blue catfish (*Ictalurus furcatus*). Other game fishes in the lake include white bass (*Morone chrysops*), hybrid striped bass (*Morone saxatilis* X *Morone chrysops*), crappie (*Pomoxis* sp.), and several species of sunfish (*Lepomis* sp.).

In May 2007, BIO-WEST initiated a four-season ecological study to characterize the aquatic vegetation, fish, benthic, and plankton communities, and general water quality within Lake Granbury and the Brazos River. A list of the dates for each seasonal sampling event is provided in Table 1. This report summarizes the findings from all data collected during this seasonal characterization conducted in 2007 - 2008.

Table 1. Seasonal sampling events conducted in Lake Granbury and the Brazos River.

Season	Sampling Date
Spring	May 9 – 10 (2007)
Summer	September 3 – 5 (2007)
Fall	November 12 – 14 (2007)
Winter	January 7 – 8 (2008)

METHODS

Study Site

Five sampling sites around Lake Granbury were chosen for this study, based on information provided by Enercon Services professionals. The lake sites are all within 2.6 kilometers (km) of the dam and located on the southern shore because any potential future intake or discharge structures will likely be located in this area. Four of the sites are located in Lake Granbury and one site is located in the Brazos River downstream of DeCordova Bend Dam (Figure 1). Site locations were recorded on a handheld Garmin GPS unit, and fixed station photographs were taken with a digital camera at each site.

Site LG-1 is the furthest upstream site, and is located adjacent to a boat ramp. It encompasses an area from the shore to approximately 12.5 meters (m) away from the shore, where the water depth ranges from 11 m to 17 m. The bank is dominated by vegetation and is not reinforced, although the site is not far from developed shoreline with bulkheading. The lake bottom substrate is predominantly firm clay/bedrock, and submerged trees are scattered throughout the area. Site LG-2 is located in the midst of several boat docks along developed shoreline reinforced with bulkheading. The site is located from 10 m to 30 m from the shore, with water depths ranging between 7 m and 9 m. Substrate is firm

clay/bedrock with submerged trees present in the area. Site LG-3 is the only pelagic site and is located 110 m to 120 m from shore. Substrates here range from deep silt to bedrock and cobble. Depths within the site range from 13 m to 15 m, and it is also found adjacent to a boat ramp. Site LG-4 is nearest to the dam (330 m away) and is located from shore to 11 m out. Depths range from 5 m to 7 m, and the shoreline is undeveloped, but it is immediately downstream of several boathouses. The lake bottom substrate is bedrock and cobble, and submerged trees are infrequently encountered along the bottom.

The fifth site (BR-1) is located in the Brazos River, 2.9 km downstream of DeCordova Bend Dam. Since this is a river site, approximately 75 m (longitudinally) of stream length were assessed during each sampling event to adequately characterize the assortment of aquatic habitats in the area. Wetted widths of the river at this site are variable and range from 33 m to 115 m, depending on flow conditions. The aquatic habitats include side channels, backwaters, pools, runs, and riffles. Development along the banks is relatively low in this area compared to areas further downstream, although one house is prominent on the southern bank. The riparian vegetation community here is highly diverse with several tree, shrub, and grass species dominating the banks. The river bottom substrates at this site range from silt (backwaters) to gravel, cobble, and bedrock in the main channel.

Aquatic and Terrestrial Vegetation

Since aquatic vegetation was sparse at all sites (excluding planktonic algae), dominant terrestrial vegetation were also identified at all sites (excluding site LG-3) for all sampling periods. This included identifying vegetation found on the bank adjacent to the lake sites. All vegetation was identified to species.

Fish Community

The fish community was sampled at all sites on Lake Granbury and the Brazos River during all four sampling periods during 2007 - 2008. At each lake site, a 38.1 meter (125-ft) long experimental gill net with mesh sizes ranging from 2.5 to 7.6 centimeters (1.0-3.0 inches) was set and allowed to sit over night (13 – 16 hours). Several times submerged trees became entangled in the gill nets, and when this occurred (and no fish were caught) the nets were reset the following night. Several types of seines (bag, straight, etc.) and a backpack electrofisher were used to collect fish in the river site (BR1). Once captured, each fish was measured for total length (millimeter) and weight (gram) and released at the site of capture.

Benthic Community

Benthic invertebrate communities were sampled utilizing several methods with the intent to assess the taxa found within different habitats. At all lake sites, a three-grab composite Ponar sample was collected from the lake bottom substrate. At the Brazos River site, D-frame nets were employed along the bank edges and within the channel to collect organisms for identification. This net was more effective in sampling the riffle, backwater, and undercut banks that are present at this site. All samples were immediately stored in a 95% ethanol solution and identification of invertebrates was performed in the laboratory. All insect taxa were enumerated and identified to genus. Non-insect taxa (annelids, amphipods, etc.) were identified to the lowest possible taxon.

Plankton Community

Plankton communities were sampled using a vertically towed Watermark® simple plankton net with 80-micron mesh. A single-tow sample was collected at each site, as well as a duplicate sample at two

of the five sites for quality assurance measures. All samples were collected during daylight hours from 10:00 – 14:00 to minimize the effect of diurnal movements of zooplankton on the sampling design. For the summer sample, extra samples were taken at each site for analysis to identify populations of golden algae (*Prymnesium parvum*) in the lake. Samples were preserved in Lugol's solution and transported to the laboratory for identification and enumeration.

Water Quality

Data on surface water temperature (Celsius), pH, conductivity (microsiemens/cm), dissolved oxygen (DO, mg/L), and turbidity (NTU) were collected at the surface of each site using a handheld YSI multiparameter probe. Hardness (mg/L as Ca), alkalinity (mg/L), and total dissolved solids (TDS, mg/L) were determined in the laboratory from 500 mL surface water grab samples collected at each site. In addition, several surface water parameters (temperature, pH, conductivity, DO) were collected at three locations (DS, mid, US) within the Brazos River site. A water column profile of temperature and DO was measured at all four lake sampling sites, and one additional site, to assess changes in these parameters as they relate to depth. This additional site (DO Profile, Figure 1) was located in a pelagic region (18 m in depth) of Lake Granbury to assess DO and temperatures in deeper portions of the lake. Due to the influence of water temperature on biological and ecological responses in a reservoir, a spatial surface profile of temperature was also collected across 77 points (~26/season) at the lower end of Lake Granbury (near the study sites) for 2007 (this component was not included in the January 2008 sampling).

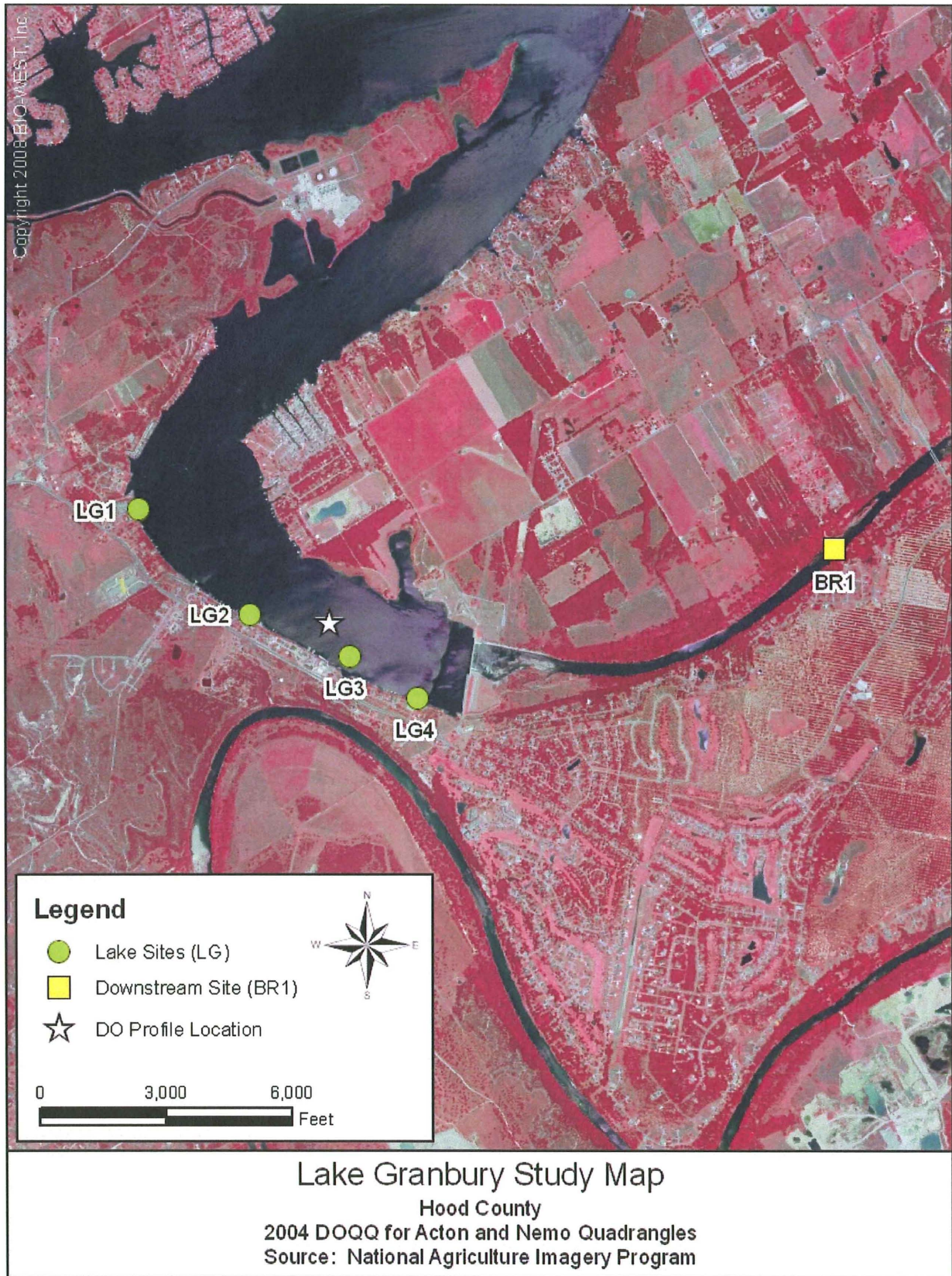


Figure 1. Location of five study sites and DO profile site on Lake Granbury and the Brazos River.

RESULTS

Vegetation Communities

Lake Granbury is an impoundment along the Brazos River, situated within an urbanized area. As a result, most of the shoreline around the lake is developed, with houses, landscaping, docks, and bulkheads lining the perimeter. Portions of the lake also have submerged trees and tree trunks, which are especially apparent along the shorelines. Site LG2 is located between two boathouses along a well-developed section of the southern shoreline. As a result, the only terrestrial vegetation that is present here are landscaped plants. Additionally, site LG3 is located in a deep water area and planktonic algae were the only natural vegetation at this site. Therefore, only the vegetation communities located at sites LG1, LG4, and BR1 are described further in this report (Table 2). The only native emergent aquatic plant species reported present in the reservoir are cattail (*Typha* sp.) and bulrush (*Scirpus* sp., Baird and Tibbs 2005). No floating aquatic plants were observed during the study period at any of the lake sites.

The dominant tree species along the banks of Lake Granbury were Ashe's juniper (*Juniperus ashei*) and green ash (*Fraxinus pennsylvanica*) during all seasons. The only emergent plant present at both the LG1 and LG4 lake sites was common reed (*Phragmites australis*), which dominated during all seasons except in the spring. During the summertime, Rooseveltweed (*Baccharis neglecta*) and buttonbush (*Cephalanthus occidentalis*) became dominant along the shoreline of LG1. Coralberry (*Symphoricarpos orbiculatus*) appeared at site LG4 in November 2007. These plants are also commonly found along other undeveloped shorelines at the lake.

The land-use along the Brazos River downstream of DeCordova Bend Dam is characterized by stretches of development (houses), and relatively untouched riparian corridors. A road bisects site BR1 along the northern shore, and a house is located on the southern shore. As a result, most of the vegetation species described in this report are from the river right (north) shoreline. American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), and eastern cottonwood (*Populus deltoides*) are the dominant tree species located in the riparian zone along the river banks at this site. The greatest diversity and abundance of dominant plant species occurred during the summer and fall seasons. Switchgrass (*Panicum virgatum*) and Bermuda grass (*Cynodon dactylon*) were the dominant grasses at the site. Pennsylvania smartweed (*Polygonum pensylvanicum*), rough cocklebur (*Xanthium strumarium*), and grape (*Vitis* sp.) were dominant herbaceous plants during the fall season. Aquatic filamentous algae were common within the channel during the fall season, likely due to a lack of flushing events and hot weather preceding the sampling effort. Much of the herbaceous ground cover was dormant during the winter sampling effort, and dominant plants at this time included overstory species (trees) common at the site. Meadow garlic (*Allium canadense*) was first observed in spring as the growing season commenced.

Due to the shallower depths and episodic flow events along the Brazos River site, BR1 had a more diverse plant community, both aquatic and terrestrial, than the lake sites exhibited. The emergent vegetation along the shore at the lake sites was limited to a few meters in width due to the steep slopes into the lake, and floating aquatic vegetation was not observed at these sites during the study period. Although the banks of the shoreline around the Lake Granbury sites do not support a very diverse population of native plants, continued monitoring of areas around the potential intake structures is recommended to identify any noxious plants, both aquatic and terrestrial that may become established as a result of potential introductions.

Table 2. Aquatic and terrestrial vegetation dominant at each site during all sampling efforts.

Site [†]	Common Name	Scientific Name	Classification	Winter	Spring	Summer	Fall
BR1	American elm	<i>Ulmus americana</i>	Riparian	X	X	X	X
	Green ash	<i>Fraxinus pennsylvanica</i>	Riparian	X	X	X	X
	Eastern cottonwood	<i>Populus deltoides</i>	Riparian	X	X	X	X
	Poison ivy	<i>Toxicodendron radicans</i>	Riparian	X	X	X	X
	Bermuda grass	<i>Cynodon dactylon</i>	Riparian			X	X
	Pennsylvania smartweed	<i>Polygonum pennsylvanicum</i>	Riparian				X
	Switchgrass	<i>Panicum virgatum</i>	Riparian		X	X	X
	Grape	<i>Vitis</i> sp.	Riparian				X
	Rough cockleburr	<i>Xanthium strumarium</i>	Riparian				X
	Indian woodoats	<i>Chasmanthium latifolium</i>	Riparian			X	
	Meadow garlic	<i>Allium canadense</i>	Riparian		X		
	Cuman ragweed	<i>Ambrosia psilostachya</i>	Riparian				X
	Filamentous algae	<i>Spirogyra</i> , <i>Anabaena</i> spp., etc.	Floating				X
	LG1	Ashe's juniper	<i>Juniperus ashei</i> Buchh.	Riparian	X	X	X
Buttonbush		<i>Cephalanthus occidentalis</i>	Riparian			X	
Rooseveltweed		<i>Baccharis neglecta</i>	Riparian			X	
Common reed		<i>Phragmites australis</i>	Emergent	X		X	X
LG4	Ashe's juniper	<i>Juniperus ashei</i> Buchh.	Riparian	X	X	X	X
	Green ash	<i>Fraxinus pennsylvanica</i>	Riparian	X	X	X	X
	Coralberry	<i>Symphoricarpos orbiculatus</i>	Riparian				X
	Common reed	<i>Phragmites australis</i>	Emergent	X		X	X

[†]Sites LG2 and LG3 are not included in this table due to the lack of natural vegetation.

Fish Community

A total of 1,097 individuals representing 22 fish species were captured in the Brazos River and Lake Granbury in 2007 - 2008 (Tables 3 & 4). The most common fish captured at the Brazos River site was the inland silverside (*Menidia beryllina*, 536 individuals). This species is a common riverine fish in Texas, and were most abundant during the summer sampling event in shallow backwaters that were easily sampled. Red shiners (*Cyprinella lutrensis*) and blacktail shiners (*Cyprinella venusta*) were also relatively abundant at this site and are ubiquitous in water bodies across Texas. Juvenile channel catfish (*Ictalurus punctatus*) were common in riffle habitat in the summer when these fish grew large enough to recruit to our sampling equipment (backpack electrofisher). Adults of this species are commonly found in Lake Granbury. Sunfish were especially common in the river during the fall and winter sampling efforts. Longear sunfish (*Lepomis megalotis*) and green sunfish (*Lepomis cyanellus*) were the most common ones encountered. White bass were relatively common in this reach, while largemouth bass were infrequently encountered.

Seasonal changes in fish populations and diversity are apparent at the Brazos River site. In spring, fewer fishes (93) and number of species (7) were collected compared to summer. It is likely that these depressed numbers are a result of river flow during the spring sampling effort. When this site was sampled flows were 2,220 cfs (Figure 2), which made sampling difficult in the main channel. In addition, the riffle was deep underwater (and we were not able to sample it), and there were no backwater habitats present. The only areas we could sample effectively were a side channel and some edge habitat. High flows continued into summer (resulting in delaying the summer effort), but by September they were low enough for effective sampling. Also, juvenile fish born in the spring were large enough to recruit to sampling equipment. For these reasons, more fish were caught in summer than any other seasons. Fewer fish were present in fall, likely a result of movement out of the study reach. By winter, total numbers of fish at the Brazos River site were reduced to 56.

Table 3. Fish species collected at the Brazos River site during 2007 - 2008.

Common Name	Scientific Name	Number Collected			
		Spring	Summer	Fall	Winter
Site BR1					
Freshwater drum	<i>Aplodinotus grunniens</i>		4	1	
Red shiner	<i>Cyprinella lutrensis</i>	75	80	2	6
Blacktail shiner	<i>Cyprinella venusta</i>	9	6	3	3
Common carp	<i>Cyprinus carpio</i>		1		
Gizzard shad	<i>Dorosoma cepedianum</i>	1	1	1	
Orangethroat darter	<i>Etheostoma spectabile</i>			1	3
Gambusia	<i>Gambusia</i> sp.	3	7	1	
Blue catfish	<i>Ictalurus furcatus</i>		1		
Channel catfish	<i>Ictalurus punctatus</i>		49	4	1
Green sunfish	<i>Lepomis cyanellus</i>			28	8
Bluegill	<i>Lepomis macrochirus</i>		1	12	3
Longear sunfish	<i>Lepomis megalotis</i>		5	16	22
Redear sunfish	<i>Lepomis microlophus</i>			1	
Inland silverside	<i>Menidia beryllina</i>	1	529	5	1
Largemouth bass	<i>Micropterus salmoides</i>			2	2
White bass	<i>Morone chrysops</i>	3	4	16	3
Dusky darter	<i>Percina sciera</i>				3
Bullhead minnow	<i>Pimephales vigilax</i>	1	7		
Flathead catfish	<i>Pylodictis olivaris</i>		3	1	1
Total		93	694	93	56

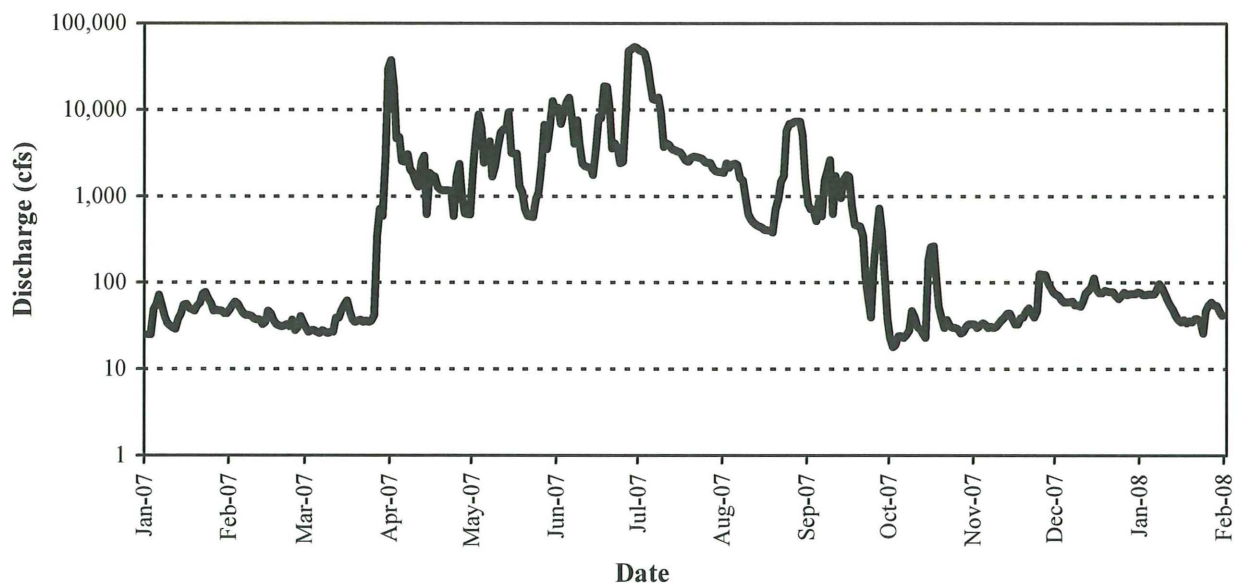


Figure 2. Springflow in the Brazos River at USGS gage 08091000 (Glen Rose) during the study period (USGS 2007).

Very few fishes were caught at the Lake Granbury sites during this study period (161 individuals, Table 4). It should be noted, however, that fish were not sampled during the spring sampling effort. The most common fish captured in the lake was gizzard shad (*Dorosoma cepedianum*). Channel catfish, common carp (*Cyprinus carpio*), and white bass were also relatively common. Smallmouth buffalo (*Ictiobus bubalo*), freshwater drum (*Aplodinotus grunniens*), and white crappie (*Pomoxis annularis*) were fishes that were unique to the lake sites. Site LG1 had the fewest fish caught in the lake. Although habitat seems ample for most fishes (undeveloped shoreline, submerged trees), problems arising from submerged trees fouling the nets (they were reset during two sampling efforts) and a steep dropoff into the lake (net not set on the substrate evenly) likely made sampling less effective here. The most productive site in terms of abundance (total number of individuals) and fish diversity was LG4. This site also has undeveloped shoreline, but there are no dropoffs.

Many of the fishes captured at these sites are reflective of what has been stocked in Lake Granbury in recent years (Baird and Tibbs 2005). Although, fishes stocked at higher densities (striped and largemouth bass) are very uncommon at these sites. Other sections of the lake have more habitat available (undeveloped shorelines, emergent vegetation). Continued monitoring by the TPWD indicates that prey fish (gizzard and threadfin shad) are very common in the reservoir (Baird and Tibbs 2005). Unfortunately, this agency does not sample within the study reach of this study. All of their collections take place over 4.5 km upstream of site LG1. Other sections of the lake have more habitat available (undeveloped shorelines, emergent vegetation), and the developed southern shoreline with accompanying boat docks are likely reasons why so few fishes were collected here. As a result, the TPWD findings may not be indicative of the fish populations located within the study reach. Therefore, if an outflow and inflow pipe were to be constructed in this area, constant monitoring in this reach is needed to understand the effects on the resident fish population. In addition, any water flowing out of Squaw Creek Reservoir would likely have different water chemistry (especially temperature), and could significantly change fish populations downstream (Brazos River). As with any changes to habitat, constant monitoring of the lake before and after any disturbance is needed to fully understand the effects on the biota.

Table 4. Fish species collected in Lake Granbury during 2007 - 2008.

Site	Common Name	Scientific Name	Number Collected		
			Summer	Fall	Winter
LG1	Common carp	<i>Cyprinus carpio</i>	2		
	Gizzard shad	<i>Dorosoma cepedianum</i>	1	5	1
LG2	Common carp	<i>Cyprinus carpio</i>	6	1	2
	Gizzard shad	<i>Dorosoma cepedianum</i>	3	1	
	Channel catfish	<i>Ictalurus punctatus</i>	2		31
	Smallmouth buffalo	<i>Ictiobus bubalo</i>			1
	Largemouth bass	<i>Micropterus salmoides</i>			1
	White bass	<i>Morone chrysops</i>			4
	Striped bass	<i>Morone saxatilis</i>	1		
	White crappie	<i>Pomoxis annularis</i>	1		3
LG3	Common carp	<i>Cyprinus carpio</i>	1	1	
	Gizzard shad	<i>Dorosoma cepedianum</i>	2	4	10
	Blue catfish	<i>Ictalurus furcatus</i>		1	
	Smallmouth buffalo	<i>Ictiobus bubalo</i>			1
LG4	Freshwater drum	<i>Aplodinotus grunniens</i>			1
	Common carp	<i>Cyprinus carpio</i>	12	2	9
	Gizzard shad	<i>Dorosoma cepedianum</i>	14	8	7
	Channel catfish	<i>Ictalurus punctatus</i>		1	
	Blue catfish	<i>Ictalurus furcatus</i>		1	
	Smallmouth buffalo	<i>Ictiobus bubalo</i>	2	3	1
	Bluegill	<i>Lepomis macrochirus</i>		1	
	White bass	<i>Morone chrysops</i>	2	3	4
	Largemouth bass	<i>Micropterus salmoides</i>		1	
	White crappie	<i>Pomoxis annularis</i>		2	1
Total			49	35	77

Plankton Community

Nauplii (larval calanoids and cyclopoids) were the most numerous group of zooplankton in each season (Table 5). With cyclopoids far outnumbering calanoids (1,398 and 454, respectively), it is likely that most of the nauplii in Lake Granbury are cyclopoids. Similar numbers of nauplii in each season are reflective of year round reproduction by adults. Rotifers were the next most numerous group collected in the reservoir. These animals' numbers peaked in summer and winter, which may be

reflective of recent reproduction. Cladocerans from the Bosminidae (neo-natal crayfish) family were most numerous in fall in Lake Granbury (only 32 collected at site BR1) reflecting recent reproduction in this family. This group is infrequently encountered because most are collected only when the net scrapes along the bottom of the lake. Another cladoceran family, Daphniidae (water fleas), was very common in spring in the lake and the Brazos River. At the Brazos River site, one *Daphnia lumholtzi*, an exotic species from Africa, Australia, and India was captured in spring. Though this species has been reported in Texas, it has not been found in Hood County. Detrimental impacts of this species are not yet fully understood. Conchostraca (clam shrimps) were uncommon in all seasons at all sites with most individuals present in fall (17).

Golden algae were first suspected to cause major blooms (and associated fish kills) in Texas in 1981. These harmful algae have been found in Lake Granbury, and are the suspected cause of fish kills in the lake in 2007. Since 2001, it is reported that golden algae have killed at least 5 million fishes (TPWD 2007). In September, one sample was taken at site LG1 to determine if they were present in the lake. They were not present in the sample from this site. Although golden algae have been found in large numbers in the lake, it is hypothesized that when temperatures are higher in the lake (summer months) green algae are dominant and keep the harmful golden algae in check (Tiffany Morgan, Brazos River Authority, pers. comm.). When water temperatures decrease (winter months) golden algae increase in number because green algae are not cold tolerant. At a sampling site near DeCordova Bend Dam, golden algae numbers peaked at the end of March/early April in 2007 (Roelke et al. 2007). The bloom was ended when a high-flow event flushed the lake in April. Fish kills linked to golden algae blooms have been substantial and have occurred every year from 2001 to 2006 (TPWD 2007). If water is to be transported from Lake Granbury to Squaw Creek Reservoir (where golden algae numbers are likely low), then careful monitoring of algal blooms is necessary. Water exported from Lake Granbury must only be exported when golden algae numbers are low to prevent the spread of this harmful organism. If these algae are introduced to Squaw Creek Reservoir, the fish population could be decimated rapidly.

Table 5. Total number of plankton types observed at each site in 2007 – 2008.

Plankton Taxa	Number of Individuals Collected			
	Spring	Summer	Fall	Winter
Cyclopoida	592	239	493	74
Calanoida	67	40	229	118
Nauplii	1175	1124	931	1009
Rotifera	201	761	407	902
Bosminidae	84	8	667	269
Daphniidae	561	25	18	1
Conchostraca	0	1	17	0

Benthic Community

Over 5,000 invertebrates representing at least 57 genera of invertebrates were collected from Lake Granbury and the Brazos River in 2007 – 2008 (Appendix A). The most diverse family was Chironomidae (midges) with at least 17 genera collected. *Parachironomus* was the most common genera of the chironomids. This family can be indicative of poor water quality, and it was one of the most common organisms collected in Lake Granbury. Substrates in the lake range from silt to bedrock and are not very conducive to high invertebrate species diversity. The most numerous family collected was Simuliidae (black flies) with over 2,100 individuals identified, most of which were from site BR1 in the fall. Also in fall, 3 pyralids (Pyralid moths) were collected in the Brazos River; these insects are rarely encountered in their aquatic larval forms. One mud crab (*Rhithropanopeus* sp.) was collected at the Brazos River site during the summer sampling effort. These crabs are typically found in estuarine systems, but were first reported in Palo Pinto County in 1998, and were later discovered in Lake Granbury (Hood County) and Squaw Creek Reservoir. It is not understood how these organisms are able to live in these fresh water impoundments.

Caddisflies were relatively common and diverse at the downstream site where four different genera were collected. Ephemeroptera (mayflies) were also found in the Brazos River. With Plecopterans (stoneflies), these three orders are often used as indicators of the health of a system. The lack of stoneflies indicates a lower diversity, but these organisms are often found in cooler waters. However, the diversity of caddisflies and mayflies in the river indicate a relatively healthy system. More species were found at site BR1 because of the variety of habitats present (Table 6). With the exception of spring (when flows limited available habitat), this site contained a good diversity of habitats including large woody debris, boulders, riffles, backwaters, undercut banks, and submerged vegetation. Flow conditions in spring made effective invertebrate sampling difficult at site BR1 where most invertebrates were collected in 2007 – 2008. Therefore, these low numbers underestimate the population and diversity present at this site. Invertebrates were most common in fall likely due to recent reproduction and egg hatching within the water column in the Brazos River. They were most common in the winter within Lake Granbury due to several types of midges (Chironomidae, Chaoboridae) present within the substrate of the lake. Only 3 invertebrates were collected at site LG4 during the study period because of very hard substrates (bedrock) present at this site. Site LG3 had the greatest number of organisms in the lake because the substrate here is silty and more amenable to invertebrates and invertebrate collection.

Table 6. Invertebrate taxa collected at each site during each season in 2007 – 2008.

Season	Site					Total
	BR1	LG1	LG2	LG3	LG4	
Spring	42	0	36	12	0	90
Summer	1123	4	24	147	1	1299
Fall	2946	21	27	59	0	3053
Winter	266	212	17	70	2	567

Water Quality

Water quality parameters collected from surface water at all sites and seasons can be found in Appendix A. Conductivity was similar among sites each season, but site BR1 tended to have higher readings in each season (except winter). It was similar between spring and summer, but was lowest in fall, and increased again in winter. Conductivity is higher in the river because ions that had settled in Lake Granbury pour over the open spillway of the dam and increase the conductance in the river. Similarly, TDS was highest at the river site in all seasons (except fall). TDS was highest in spring because of precipitation events filling the lake and spilling into the river. Often, precipitation and increased load from tributaries will increase TDS during the year. Continued rainfall into summer kept these levels high into September. By fall and winter, fewer precipitation events decreased the amount of dissolved ions contributing to the system thereby reducing conductivity and TDS levels. pH was similar among sites (7.9 – 10.2), and showed little seasonal variation except for winter. Overall, the water in Lake Granbury and the Brazos River are more basic, and fall in the normal range for most freshwater lakes (Kalff 2002). In winter, however, mean pH across all sites was 9.6 compared to 8.5 in the spring (the next highest seasonal average). Alkalinity is the measure of the acid neutralizing capability of a water body. Alkalinity was similar among all sites and seasons, but did show an increasing trend from 2007 to 2008 (mean mg/L: spring - 97; summer - 120; fall - 128; winter - 142). High alkalinities (like these) increase the ability of a reservoir to buffer the water, and are likely why the pH is relatively stable.

Turbidity was highly variable among sites and seasons, and did not show any clear trends. In spring, it was highest at sites LG1 and BR1 (7.7 and 4.9 NTU, respectively), while extremely low at LG2 and LG3 (<1.0 NTU at each). While turbidity is expected to be higher at the river site (water from the spillway hits substrate along the river bottom adding sediment to the river), it is unclear why it is variable within the lake. In fall, turbidity increased as you go upstream, but no clear explanation can be deduced for this phenomenon. In winter, this trend is reversed so turbidity is highest at site BR1. Increased mixing of the water due to similar densities in winter may have increased dissolved sediment at the river site. Except for winter, hardness was highest at the Brazos River site in all seasons (Appendix A). On average, hardness decreased across all sites from spring 2007 to winter 2008 (mean mg/L: spring - 280; summer - 251; fall - 226; winter - 174).

Water temperatures varied with the season, and in the reservoir also varied with depth (Appendix A, Figure 3). Reflecting seasonal changes, temperatures were highest in summer and lowest in winter. Mean surface water temperatures were highest in the Brazos River because DeCordova Bend Dam has an open spillway, therefore, surface water (the warmest part of the water column) spills over the dam into the river. The lowest mean water temperatures were at sites LG1 and LG2 possibly because these are closest to shore and more shaded than the other sites. Although, surface water temperatures varied widely, temperatures changed little with an increase in depth (Figure 3). A thermocline was only apparent in the spring and summer efforts at greater depths. A weak thermocline indicates similar water densities and a well-mixed reservoir that turns over often (retention time estimated at 260 days, Baird and Tibbs 2005). Since the Brazos River is a large river, water flows relatively quickly through Lake Granbury creating a well-mixed basin. In fall and winter, no thermocline could be detected, and temperatures varied little with depth (fall: 17.9 - 18.6 °C; winter: 8.4 - 9.5 °C).

Dissolved oxygen (DO) was highest in winter at all sites when water temperatures were lowest (Appendix A). DO was highest at the Brazos River site in each season except spring. With water spilling over the dam, atmospheric mixing increases the amount of soluble oxygen in the water resulting in higher DO levels in the river. DO was highest in the lake at site LG1 (mean = 10.2 mg/L). This site is located at a bend in the lake, and the thalweg (deepest part) of the lake passes near the site. Most of the water flowing in the lake flows along the thalweg, and this movement likely contributed to

an increase in DO at this site. Dissolved oxygen decreased with depth in all seasons except winter (Figure 4). In aquatic environments, light penetration and photosynthetic activity both decrease with depth, and respiration and decomposition by bacteria and other organisms increase oxygen demand in the lower water column. These processes result in a marked decline in DO at greater depths. DO decreased to 0 mg/L at depths greater than 14 m in spring and summer. DO in fall showed a steady decline as depth increased, but did not drop below 2.0 mg/L even at greater depths. As the temperature profile showed, this lake is well-mixed in winter. As a result, DO levels actually increased with an increase in depth in January 2008.

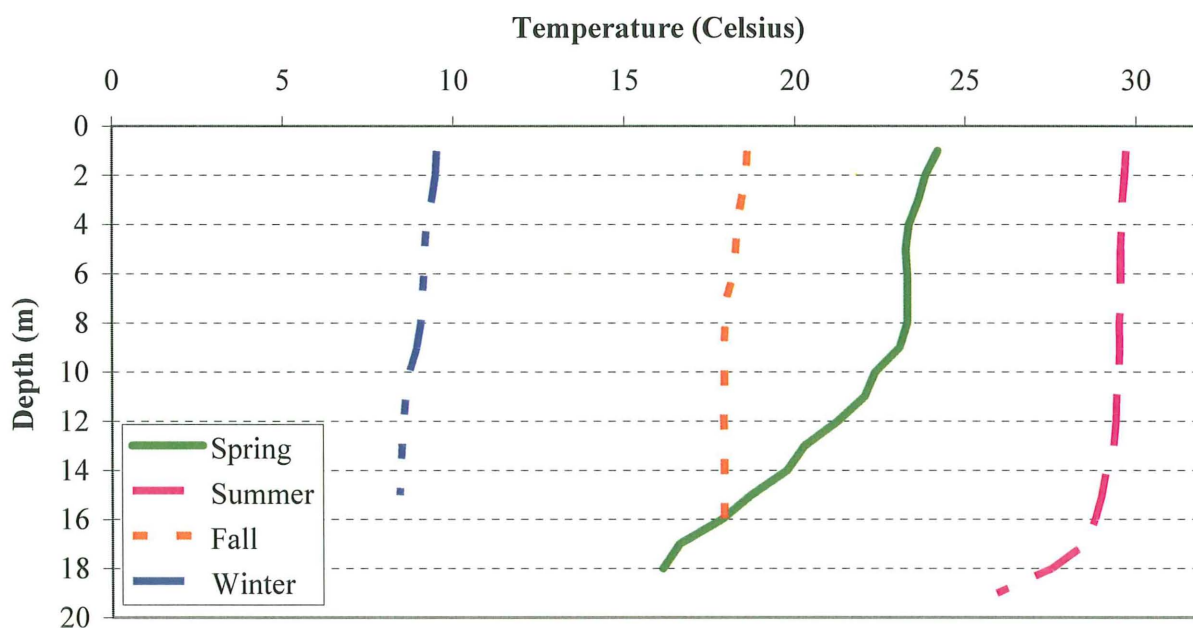


Figure 3. Water temperatures (C) as they relate to depth at the DO Profile site during each season.

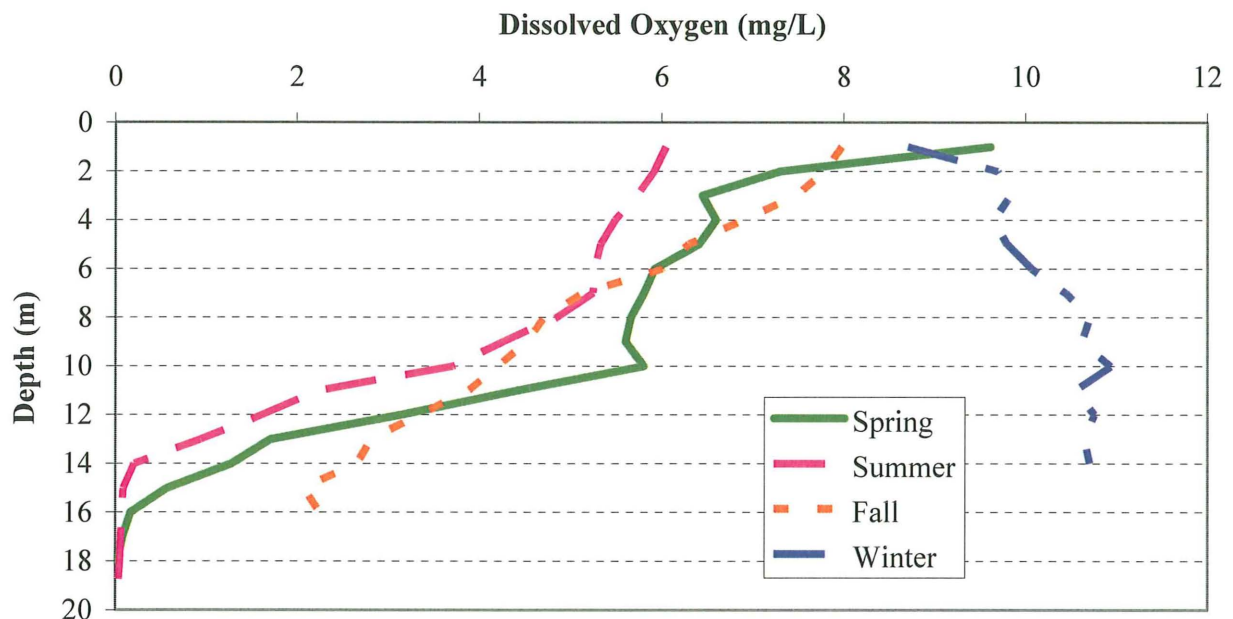


Figure 4. Dissolved oxygen (mg/L) as it relates to depth at the DO Profile site during each season.

SUMMARY OF FINDINGS

This report presents the findings from data collected from four seasonal sampling efforts on Lake Granbury and the Brazos River in 2007 - 2008. Aquatic and terrestrial vegetation are uncommon in the lower section of Lake Granbury because the shorelines are steep and have been developed. Ashe's juniper and common reed were the only common plants observed at each site. There was no seasonal variation in the overstory at the Brazos River site with American elm, green ash, and eastern cottonwood dominating. Filamentous algae were common at this site in fall because flows were low due to few precipitation events in the watershed in the preceding months. The fish community was more abundant and diverse at the Brazos River site compared to the lake sites. More habitats (riffles, runs, etc.) within the river site allow a greater diversity of fishes to live in a smaller area. Red shiners, inland silversides, and juvenile channel catfish were the most common fishes in the river. Most fishes were caught in summer when low flows allowed for a more complete sampling of all habitats present. Far fewer fishes were caught at the Lake Granbury sites during all seasons. Developed shoreline and little structure (compared to other areas of the lake) where the sampling sites are located contributed to this low number. Gizzard shad and common carp were captured at each of the four sites in the lake. Channel catfish were the most common game fish captured while white and largemouth bass were uncommon at these sites. These fish have been stocked in the reservoir, but are likely in other areas of the lake where habitats are more conducive to growth and survival. Most fishes caught in the lake were captured at site LG4.

Zooplankton in the lake and river varied by season, and nauplii were the most common planktonic organism collected. At site BR1, a daphniid was captured that had not previously been reported from this area of Texas, though it is not known if this species is considered harmful. No golden algae were found in a single plankton sample in summer, but blooms have been regularly reported in the reservoir

since 2001. Since then over 5 million fishes have been killed, and blooms tend to occur in the late winter and early spring. If water is to be exported to Squaw Creek Reservoir (where it was not found), then careful consideration is warranted when golden algae blooms occur in Lake Granbury so this harmful organism is not introduced to another water body. A major bloom could rapidly decimate the fish population in Squaw Creek Reservoir. Benthic invertebrates were most common in fall and most diverse at site BR1. The large number of habitats present at this site encourages colonization by a wide variety of invertebrates. Simuliids and chironomids were the most common organisms collected in this study. One mud crab was captured at this site, but any negative impacts of this introduced species are yet to be reported. A low diversity of invertebrates collected in Lake Granbury is likely due to homogenous substrates (bedrock, silts) dominating the floor of the lake. In addition, low invertebrate species diversity maybe an indicator of poor water quality. Conductivity and total dissolved solids were higher in the Brazos River than at other sites. Alkalinity at the study sites was relatively high increasing the ability of the reservoir to buffer water, which was reflected in the similar pH values across sites and seasons. Water temperatures in the lake varied seasonally, but changed little with depth. Dissolved oxygen was highest in winter, and changed little with an increase in depth. In summer and spring when the lake was thermally stratified, DO levels decreased to zero at greater depths. Because Lake Granbury was formed by damming the Brazos River, the water in the reservoir is well mixed. As a result, thermal and oxygen stratification of the water column is not as pronounced as in other reservoirs.

With the potential for water in Lake Granbury to be diverted into Squaw Creek Reservoir and later discharged into the Brazos River basin, continued monitoring of the health of aquatic communities in these water bodies is highly recommended. Harmful golden algae levels in Lake Granbury should be monitored closely so that they are not flushed into Squaw Creek Reservoir, resulting in potential widespread fish kills. Also due to the potential of heated water to be discharged into the Brazos River (downstream of Lake Granbury), a monitoring plan developed specifically for biological and environmental conditions in this watershed would benefit the future maintenance of a healthy aquatic community, and the quick response to potential environmental threats (golden algae, invasive species, etc.) could mitigate any effects the water may cause in this system.

REFERENCES

- Baird, M. S., J. Tibbs. 2005. Statewide Freshwater Fisheries Monitoring and Management Program. 2005 Survey Report, Granbury Reservoir. Texas Parks and Wildlife Department. 30 pp.
- Roelke, D. L., B. W. Brooks, J. P. Grover. 2007. Water Quality Program for Lake Granbury Texas. 4th Quarter Report. 20 pp.
- Texas Parks and Wildlife Department (TPWD). 2007. Golden Algae in Texas. Factsheet. 1 pp.
- U.S. Geological Survey (USGS). 01/2007. Provisional data for Texas. Location: <http://tx.waterdata.usgs.gov/niwis/help/provisional>.

Appendix A
Additional Data

Benthic invertebrates collected at all sites during the 2007 spring sampling effort.

Family	Genus	Site					Total
		LG1	LG2	LG3	LG4	BR1	
Caenidae	<i>Caenis</i>					1	1
Hydropsychidae	<i>Hydropsyche</i>					2	2
Tricorythidae	<i>Trichorixa</i>					1	1
Leptoceridae	<i>Oecetis</i>					1	1
Ceratopogonidae	<i>Culicoides</i>					1	1
Chaoboridae	<i>Chaoborus</i>					2	2
Chironomidae	<i>Ablabesmyia</i>		1				1
Chironomidae	<i>Chironomus</i>		1	8			9
Chironomidae	<i>Cryptochironomus</i>		3				3
Chironomidae	<i>Parachironomus</i>					32	32
Chironomidae	<i>Paracladopelma</i>		1	4			5
Chironomidae	<i>Procladius</i>		30				30
Chironomidae	<i>Pseudochironomus</i>					2	2

Benthic invertebrates collected at all sites during the 2007 summer sampling effort.

Family	Genus	Site					Total
		LG1	LG2	LG3	LG4	BR1	
Baetidae	<i>Callibaetis</i>					5	5
Baetidae	<i>Camelobaetidius</i>					25	25
Baetidae	<i>Fallceon</i>					113	113
Caenidae	<i>Caenis</i>					78	78
Leptohiphidae	<i>Tricorythodes</i>					71	71
Leptophlebiidae	<i>Neochoroterpes</i>					31	31
Heptogeniidae	<i>Stenonema</i>					3	3
Coenagrionidae	<i>Enallagma</i>					1	1
Coenagrionidae	<i>Argia</i>					3	3
Philopotamidae	<i>Chimarra</i>					9	9
Hydropsychidae	<i>Cheumatopsyche</i>					446	446
Hydropsychidae	<i>Hydropsyche</i>					27	27
Hydroptilidae	<i>Orthotrichia</i>					1	1
Leptoceridae	<i>Nectopsyche</i>					1	1
Leptoceridae	<i>Oecetis</i>					1	1
Gerridae	<i>Trepobates</i>					1	1
Elmidae	<i>Dubiraphia</i>					2	2
Elmidae	<i>Stenelmis</i>					15	15
Gyrinidae	<i>Gyretes</i>					4	4
Hydrophilidae	<i>Berosus</i>					3	3
Simuliidae	<i>Simulium</i>					12	12
Ceratopogonidae	<i>Probezzia</i>					1	1
Chaoboridae	<i>Chaoborus</i>		4	146			150
Chironomidae	<i>Ablabesmyia</i>					5	5
Chironomidae	<i>Chironomus</i>	1				3	4
Chironomidae	<i>Parachironomus</i>	1				228	229
Chironomidae	<i>Paracladopelma</i>						0
Chironomidae	<i>Polypedilum</i>	2				29	31
Chironomidae	<i>Procladius</i>					3	3
Chironomidae	<i>Tanytus</i>		19				19
Psychodidae	<i>Culicoides</i>					1	1
Daphniidae	sp.			1			1
Anellida	sp.		1		1		2
Xanthidae	<i>Rhithropanopeus</i>					1	1

Benthic invertebrates collected at all sites during the 2007 fall sampling effort.

Family	Genus	Site					Total
		LG1	LG2	LG3	LG4	BR1	
Baetidae	<i>Caenis</i>					4	4
Baetidae	<i>Camelobaetidius</i>					1	1
Baetidae	<i>Centroptilum</i>					1	1
Baetidae	<i>Fallceon</i>					253	253
Leptophlebiidae	<i>Neochoroterpes</i>					36	36
Leptophlebiidae	<i>Traverella</i>					1	1
Heptogeniidae	<i>Stenacron</i>					12	12
Tricorythidae	<i>Tricorythodes</i>					13	13
Coenagrionidae	<i>Argia</i>					1	1
Philopotamidae	<i>Chimarra</i>					9	9
Hydropsychidae	<i>Cheumatopsyche</i>					573	573
Hydropsychidae	<i>Hydropsyche</i>					1	1
Leptoceridae	<i>Oecetis</i>					5	5
Polycentropodidae	<i>Cyrnellus</i>	3					3
Elmidae	<i>Stenelmis</i>					6	6
Corydalidae	<i>Corydalus</i>					1	1
Simuliidae	<i>Simulium</i>					2000	2000
Chaoboridae	<i>Chaoborus</i>	3	11	54			68
Chironomidae	<i>Ablabesmyia</i>					1	1
Chironomidae	<i>Beardius</i>					1	1
Chironomidae	<i>Chironomus</i>	11	8	5		8	32
Chironomidae	<i>Cryptochironomus</i>					1	1
Chironomidae	<i>Glyptotendipes</i>		3				3
Chironomidae	<i>Hydrobaenus</i>	1					1
Chironomidae	<i>Polypedilum</i>	3	5			11	19
Chironomidae	<i>Procladius</i>					4	4
Pyrilidae	<i>Petrophila</i>					2	2
Pyrilidae	<i>Crambus</i>					1	1

Benthic invertebrates collected at all sites during the 2008 winter sampling effort.

Family	Genus	Site					Total
		LG1	LG2	LG3	LG4	BR1	
Ephemeraidae	<i>Hexagenia</i>		1				1
Baetidae	<i>Fallceon</i>					3	3
Leptophlebiidae	<i>Neochoroterpes</i>					40	40
Heptogeniidae	<i>Stenacron</i>					5	5
Tricorythidae	<i>Tricorythodes</i>					2	2
Coenagrionidae	<i>Argia</i>					4	4
Hydropsychidae	<i>Cheumatopsyche</i>					86	86
Leptoceridae	<i>Oecetis</i>					2	2
Polycentropodidae	<i>Cynellus</i>				1		1
Elmidae	<i>Stenelmis</i>					3	3
Simuliidae	<i>Simulium</i>					100	100
Chaoboridae	<i>Chaoborus</i>	195		48			243
Chironomidae	<i>Chironomus</i>	8	10	11			29
Chironomidae	<i>Coelotanypus</i>			1			1
Chironomidae	<i>Cryptochironomus</i>		2			1	3
Chironomidae	<i>Dicrotendipes</i>					5	5
Chironomidae	<i>Larsia</i>					1	1
Chironomidae	<i>Parachironomus</i>	8	2	10		4	24
Chironomidae	<i>Procladius</i>	1					1
Chironomidae	<i>Rheocricotopus</i>					4	4
Chironomidae	Sp.		2				2
Chironomidae	<i>Tanytarsus</i>					3	3
Physidae	Sp.					2	2
Ancylidae	Sp.				1	1	2

Water chemistry parameters of surface water at sampling sites in 2007 - 2008.

Sampling Period	Site				
	BR1	LG1	LG2	LG3	LG4
Temperature (C)					
Spring	22.2	27.6	26.3	26.7	27.2
Summer	29.9	30.6	30.4	29.6	29.6
Fall	30.0	20.0	19.3	18.9	19.1
Winter	14.5	10.0	10.5	9.6	9.5
Dissolved Oxygen (mg/L)					
Spring	9.7	15.5	11.5	12.1	11.3
Summer	8.5	6.9	6.7	5.6	5.9
Fall	7.7	6.2	6.2	5.6	5.2
Winter	15.2	12.2	14.2	14.6	14.6
pH					
Spring	8.0	9.0	8.7	8.5	8.4
Summer	8.3	8.4	8.3	8.3	8.2
Fall	8.4	8.1	8.1	8.0	7.9
Winter	10.2	9.5	9.1	9.4	9.6
Conductivity (µs/cm)					
Spring	191	159	159	159	160
Summer	185	156	158	158	162
Fall	126	122	122	122	122
Winter	136	139	139	139	139
Turbidity (NTU)					
Spring	4.9	7.7	<1.0	4.1	<1.0
Summer ^a	-	-	-	-	-
Fall	4.2	7.0	7.7	10.5	10.5
Winter	10.6	9.5	9.7	8.9	8.7
Hardness (mg/L)					
Spring	296	247	323	269	264
Summer	271	240	242	250	251
Fall	235	225	225	223	223
Winter	68.9	191	186	216	208

***No readings taken due to a malfunctioning probe.**

Water chemistry parameters of surface water at sampling sites in 2007 - 2008.

Sampling Period	Site				
	BR1	LG1	LG2	LG3	LG4
TDS (mg/L)					
Spring	1090	904	884	876	874
Summer	873	798	803	833	812
Fall	631	633	630	636	626
Winter	700	615	608	612	653
Alkalinity (mg/L)					
Spring	100	96	94	98	96
Summer	120	120	130	110	120
Fall	130	130	120	130	130
Winter	140	140	140	140	150